REFLUX CLASSIFICATION OF SOUTH AFRICAN COAL

BY

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EXAMINER'S COPY

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PREFACE

The research contained in this dissertation was completed by the candidate while based in the Discipline of Chemical Engineering, School of Engineering of the College of Agriculture, Engineering and Science, University of KwaZulu-Natal, Howard College, South Africa. Mintek provided financial support.

The contents of this work have not been submitted in any form to another university and, except where the work of others is acknowledged in the text, the results reported are due to investigations by the candidate.

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Signed: Dr. J. Pocock

Date: 05 December 2016

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ABSTRACT

In mineral processing, the value of a particle is inexorably related to its specific gravity (Galvin et al., 2009). As a result, gravity concentration is widely employed in the beneficiation of valuable minerals from the associated waste mineral matter as separation of a feed into two or more fractions is accomplished according to particle density (Napier-Munn and Wills, 2006). Although gravity separation aims to separate particles primarily according to density, the size and shape of the particles also contributes to the separation achieved. Thus, the suppression of the effect of particle size in gravity separation is crucial in the mineral processing industry. There have been numerous developments in the field of gravity separation equipment that are able to selectively, and consistently, fractionate a feed according to density by manipulating hydrodynamic forces in different system configurations.

This study investigated the gravity separation of fine coal samples with a relatively high ash content using a new and innovative technology, the Reflux Classifier. The novel design of the device incorporates a set of inclined plates attached to the top of a conventional fluidised bed. Thus, the device combines the uniform flow conditions of the liquid fluidised bed and the well-established throughput advantage of the lamella settler (Nguyentranlam and Galvin, 2001).

The premise of the research entailed the concentration of small quantities of fine high ash South African coal (particles finer than 1000 µm) according to density through both batch and semi-continuous investigations. A laboratory scale reflux classifier with three distinct inclined sections (70° from the horizontal), consisting of 6, 8, 12 channels with perpendicular channel spacings of 6.50, 4.50 and 2.10 mm respectively was built and commissioned at UKZN. Batch test-work was conducted on each of the 3 configurations using fluidisation flowrates of 3, 6, 9 and 12 l/min.

The investigation proved promising and moderate to high upgrade in the overflow product was achieved in the 8 and 12 channel configurations, with significant improvement at higher flowrates. With an operating fluidisation rate of 9 l/min, the upgrades ranged from 40% to 80% in the -1000 + 75 µm size range for all channel spacings tested. Moreover, in the size range comprising particles finer than 75 µm, for which gravity separation techniques are typically ineffective, a reduction in ash content from 60.71% to 36.81% was attained when

using the narrowest channel spacing (12 channels with 2.10 mm channel spacing), which translated to an upgrade (reduction in ash content compared to the feed) of 39.72%. Furthermore, an upgrade in the product of up to 85% in the coarser size ranges (+600 μm) was realised. Overall, a reduction in feed ash content from roughly 60% to 36.59% was attained at a yield of 50.97% using 12 channels.

These results encouraged semi-continuous tests on this configuration, which generated yields ranging from 57%-69% with a relatively low ash content, typically between 32%-40% (compared to a feed ash of roughly 60%), in the -106 + 75 μm size range. Additionally, consistently high upgrades were seen throughout the entire duration of the run for particles larger than 106 μm, approaching an upgrade of 85% at the coarsest particle size. An overall yield of 57.91% was achieved, with a reduction in overall ash from 56.69% in the feed to 33.11% in the product, which constituted an upgrade of approximately 42%. Particle re-suspension behaviour induced by high aspect ratios, which heavily promotes density driven separation, was also noted in the 12 channel configuration.

ACKNOWLEDGMENTS

Firstly, I want to thank God, for granting me strength and never forsaking me, even when I had given up.

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NOMENCLATURE

Symbol	Description	Units
d	Particle diameter	m
d_{50}	Particle separation size	μm
d_h	Diameter of heavy particle	μm
d_l	Diameter of light particle	μm
F	Throughput advantage	-
g	Gravitational acceleration	m/s^2
L	Length of channels	m
m_f	Mass of displaced fluid medium	kg
m_p	Particle mass	kg
R	Particle drag force	N
Re_t	Reynolds number of d_{50} particle	-
v	Superficial fluidisation velocity	m/s
v'	Superficial fluid velocity through channel	m/s
v_t	Terminal velocity of particle	m/s
v_t'	Terminal velocity of particle in the direction tangential to the surface	m/s
z	Perpendicular channel width	m
η	Segregation efficiency	-
ρ_f	Density of fluid medium	kg/m^3
ρ_p	Density of particle	kg/m^3
ρ_{ph}	Density of heavy particle	kg/m^3
ρ_{pl}	Density of light particle	kg/m^3
ρ_{sl}	Density of slurry	kg/m^3
μ_f	Viscosity of fluid medium	Pa.s
θ	Angle of inclination	Degrees (°)

CHAPTER 1: INTRODUCTION

1.1 Importance of the topic

Mineral beneficiation has a long and diverse history that dates back to the Roman Empire, and a myriad of new techniques and developments have been made since then (Napier-Munn and Wills, 2006). However, simply put, it encompasses various separation processes that aim to concentrate the minerals to the level required for their end-use and enrich the value of the raw material. South Africa is arguably one of the richest countries in the world in terms of mineral resources, and the mining industry has contributed significantly towards the employment sector, infrastructure and economy of the country. The mining process recovers valuable raw materials such as coal, metallic and non-metallic minerals, and further processing is typically required to isolate and concentrate the valuable materials through the process of mineral beneficiation. The ever-increasing demand for mineral resources to sustain the economic development of the country, as well as the continuous and mechanised nature of mining, has led to a drastic reduction in high-grade ore reserves. Consequently, the valuable mineral particles of typical run-of-mine ores are dispersed more finely, and are recovered with a greater proportion of impurities. This has led to a growing trend to exploit lower-grade and finer deposits, and the application of beneficiation processes to feeds composed of fine size fractions has received particular interest (Arnold et al., 2012).

In mineral processing, the value of a particle is generally related to its specific gravity (Galvin et al., 2009). Consequently, gravity concentration is extensively used in the beneficiation of valuable minerals from the associated waste mineral matter as separation of a feed into two or more fractions is accomplished according to particle density (Napier-Munn and Wills, 2006). The separation mechanism exploits the difference in density between valuable particles and the associated waste, as particles of different densities respond differently to gravitational force. Larger particles are affected more markedly; thus, the efficiency of gravity separation tends to be higher when processing coarser size ranges. Although gravity separation aims to separate particles primarily according to density, the size and shape of the particles also contributes to the separation achieved. Thus, the suppression of the influence of particle size in gravity separation is of paramount importance in the mineral processing industry. There have been numerous developments in the field of gravity separation equipment that are able to selectively, and consistently, fractionate a feed according to density by manipulating hydrodynamic forces in different system configurations.

The present study was conducted in collaboration with Mintek, and entailed the gravity separation of fine coal using a new and innovative technology, the Reflux Classifier. Mintek has recently acquired a pilot scale reflux classifier that is being used to evaluate the separation of coal from its associated gangue. However, the pilot-scale unit requires a relatively large quantity of ore for testing, and tests can usually only be conducted at a plant site. Thus, the proposed project involved batch and semi-continuous experimental work in a laboratory scale unit. The premise of the investigation entailed the concentration of small quantities of fine high ash South African coal according to density.

While conventional gravity separators, such as jigs and spirals, suffer inefficient separation and recovery of fine particles, the reflux classifier is capable of separating, according to density, down to a particle size of 75 µm (Galvin et al., 2010b; Napier-Munn and Wills, 2006). This is due to the novel design of the device, which consists of a set of inclined plates attached to the top of a conventional fluidised bed. Thus, the device incorporates the uniform flow conditions of the liquid fluidised bed and the well-established throughput advantage of the lamella settler (Nguyentranlam and Galvin, 2001). The reflux classifier finds extensive use in solid-liquid separations, and has already had considerable success in separating Australian coal mineral matter in both pilot and full-scale applications (Galvin et al., 2002; 2005). In the reflux classifier, the feed is introduced into the vertical fluidised bed zone by way of a feed chute, and is subsequently fluidised by a rising current of water and allowed to expand into the channels. The fluidised bed section achieves separation primarily through hindered settling mechanisms which are directly related to particle size and density. Ordinarily, a fluidised bed separator is somewhat inept at separating fine denser particles and coarse lighter particles that settle with the same velocity. This issue is overcome by the incorporation of the inclined channels, in which the prevailing hydrodynamic forces favours particle transport according to density (Galvin et al., 2009). Additionally, Boycott (1920) observed that particles settle much faster in inclined channels than in vertical channels. Thus, both coarse and fine light particles are conveyed through the channels to the overflow. Large, dense particles readily report to the underflow, while entrained fine, dense particles in the fluid flowing through the channels settle out of the suspension and accumulate on the surface of the inclined channel. A concentrated sediment layer is formed on the channel surface that subsequently slides down to the fluidised zone below. A reflux effect arises as a result of these heavier particles returning to the bulk suspension below, and separation is enhanced due to this inherent recycling of particles (Nguyentranlam and Galvin, 2001). Laskovski et al. (2006) and Galvin et al. (2009) conducted a series of batch elutriation experiments which revealed that separation of a feed according to particle density is enhanced when using closely spaced inclined channels.

1.2 Aims and objectives

The aims of this project entailed the design and fabrication of a laboratory scale reflux classifier which was capable of batch separation tests on small quantities of high ash South African coal. Additionally, the minimum particle size that the unit was capable of efficiently separating was investigated. A semi-continuous set of tests was also undertaken. The unit was designed with three distinct inclined sections, consisting of 6, 8, 12 channels with channel spacings of 6.50, 4.50 and 2.10 mm respectively. Each inclined section could be interchanged and tested independently, thus, the effect of channel spacing on the separation of finer size fractions could be examined.

1.3 Outline of thesis

This thesis begins with a detailed literature review comprising Chapter 2. The role of beneficiation is briefly highlighted in mineral processing and a review of the typical beneficiation processes applied in coal processing is provided. Thereafter, the relevant theory behind particle settling is reviewed. The concept of classification is also discussed, and free and hindered settling mechanisms are reviewed. Particle transport in inclined channels and its effect on settling rates is then discussed, and a detailed review of the relevant theory related to the reflux classifier is provided. Previous studies are also discussed, with particular emphasis on those relating to the suppression of the effects of particle size on gravity separation. The methodological approach and equipment configuration is discussed in Chapter 3. A detailed overview of the laboratory scale unit is given, as well as all ancillary equipment. The results are presented in Chapter 4, and the findings are reviewed and compared with previous studies. Additionally, the significance of the results is discussed. The concluding remarks as well as possible recommendations for the advancement of the research project are listed in Chapters 5 and 6 respectively

CHAPTER 2: LITERATURE REVIEW

2.1 Coal beneficiation

A brief overview of the relevance of gravity concentration in industry and the significance of beneficiation in mineral processing is provided below. A review of the typical coal beneficiation processes is then given, and the principal of operation of the relevant devices are highlighted. The objective of this review is to provide a theoretical background of the coal industry and conventional beneficiation processes, prior to being introduced to the reflux classifier and its applicability in mineral beneficiation.

2.1.1 Gravity separation

Run-of-mine ore comprises both valuable minerals and unwanted materials, commonly known as gangue. Beneficiation entails the concentration of the valuable material by using differences in physical or chemical properties between the valuable material and the gangue to achieve an efficient separation. Comminution is first carried out on the ore to liberate the valuable material from the waste and a suitable method of separation is then applied to concentrate the valuable particles.

Gravity separation techniques exploit the difference in density between the valuable mineral and the gangue. A viscous fluid that resists the particle movement is often incorporated as part of the separation mechanism, and the motion of particles relative to each other in the medium varies in response to gravity. The movement of particles, and consequently, the separation, is dependent on the particle size, shape and density. Thus, larger particles are affected more than smaller particles, and the efficiency of gravity separation consequently increases with an increase in particle size (Napier-Munn and Wills, 2006). The method has garnered extensive usage due to the relatively low operating costs as well as low environmental pollution compared to other methods.

2.1.2 The role of beneficiation in mineral processing

The objective of beneficiation entails fracturing the large lumps of run-of-mine (ROM) ore, and separating the valuable material. This critical step ensures that the valuable material is sufficiently free from the accompanying gangue material to facilitate the ensuing concentration processes. The overall quality of the raw mined material places severe limitations on its commercial use. Moreover, ores vary significantly in chemical and physical structure, thus, the choice of beneficiation technique depends on the ore type, the method of mining, and the end use of the material (Schweinfurth, 2009).

Coal beneficiation, using gravity separation, has been performed for many decades in traditionally water-based operations. The separation of the non-combustible ash component from coal results in a cleaner burning product and improves its calorific value. Furthermore, the cost of transporting the material on the basis of combustible product tonnage is reduced, as well as a notable improvement in the metallurgical coal quality. In present times, typical ROM coals are considerably finer, contains more impurities and have higher moisture contents (Napier-Munn and Wills, 2006). This may be attributed to the continuous, mechanical and indiscriminate nature of mining of lower quality minerals which consequently introduces finer material with more impurities. Significant quantities of water are also used to minimise dust production. Although a general decline in the current quality of ROM coal is being observed, there is an ever increasing requirement for these materials that meets both environmental and commercial standards, further necessitating efficient means of beneficiation.

2.1.3 Coal preparation

A fundamental step in the preparation of coal is the evaluation of the various properties of the raw mined material. Details regarding the composition and physical properties of the coal may be determined by analysis of bore cores, from seam exposures in an operating mine, or by testing a sub-sample of the ROM coal. These preliminary tests provide information that elucidates the chemical constitution of the coal, the particle size distribution of the ROM material, as well as its moisture content. Furthermore, these results may reveal variations in the mined material due to obtaining material from the different areas in the seam, in addition to deviations which may be a result of the associated strata (Vanangamudi et al., 1986).

The method in which the coal is mined, which may be considered the first stage of comminution, will have a significant influence on the particle size distribution of the ROM material. Additional parameters such as the extent of mixing during excavation, transport and delivery are crucial factors in wet conditions as clay may become attached to the coal, which may lead to water clarification issues (Macpherson, 2011).

2.1.4 Brief overview of a typical plant flowsheet

A typical flowsheet for a conventional coal cleaning plant will generally consist of successive unit operations aimed at size classification, cleaning, and dewatering. The collection of unit operations may be referred to as a circuit and is normally duplicated many times over to maintain a high degree of cleaning, as well as to ensure efficient usage operations that are more adept to specific particle size ranges (Arnold et al., 2012).

The cleaning procedure usually begins with the size classification of the feed coal into coarser and finer size fractions through the use of vibrating screens and sizing cyclones respectively. The coarser particles are thereafter processed in a static dense medium separation device, such as a drum, and the finer particles are cleaned using an assortment of dense medium cyclones and spirals. The ultra-fine material, for which typical gravity separation techniques are inefficient, usually undergo further screening to remove particles finer than 40 μm which would otherwise contribute to the formation of slimes. Thereafter, the coal is processed through a flotation circuit. Finally, dewatering is accomplished through the use of screens, thickeners, filters and dryers (Arnold et al., 2012).

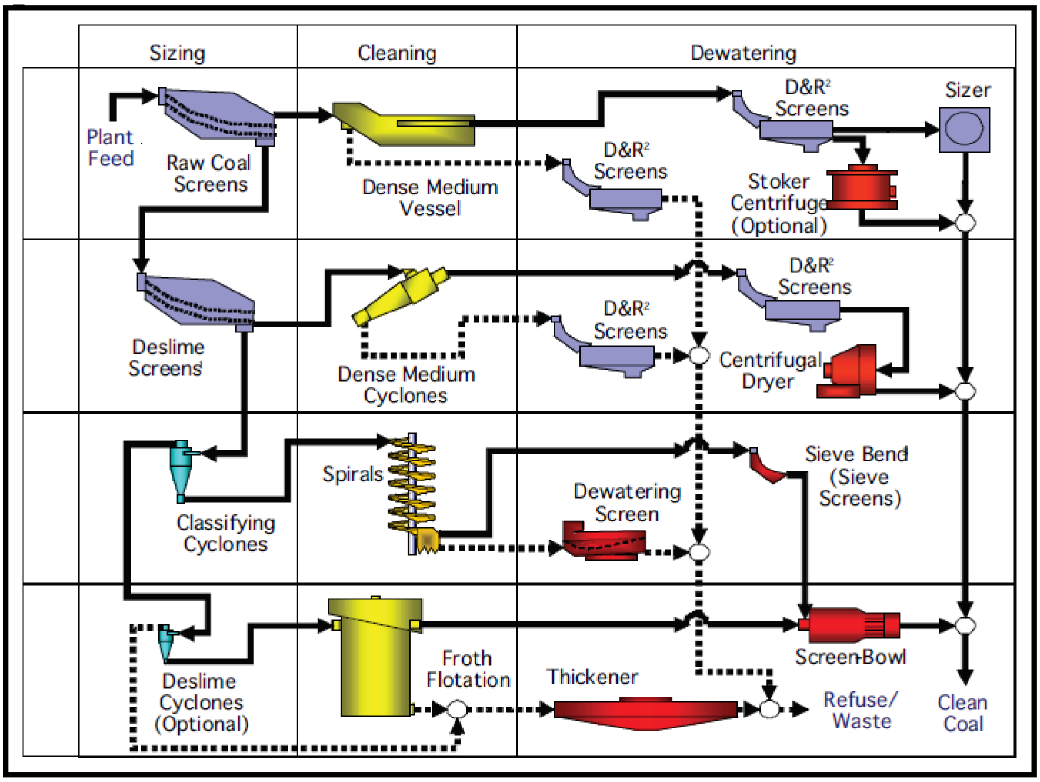

Figure 2.1.1: Schematic flowsheet of a conventional coal cleaning plant (Arnold et al., 2012)

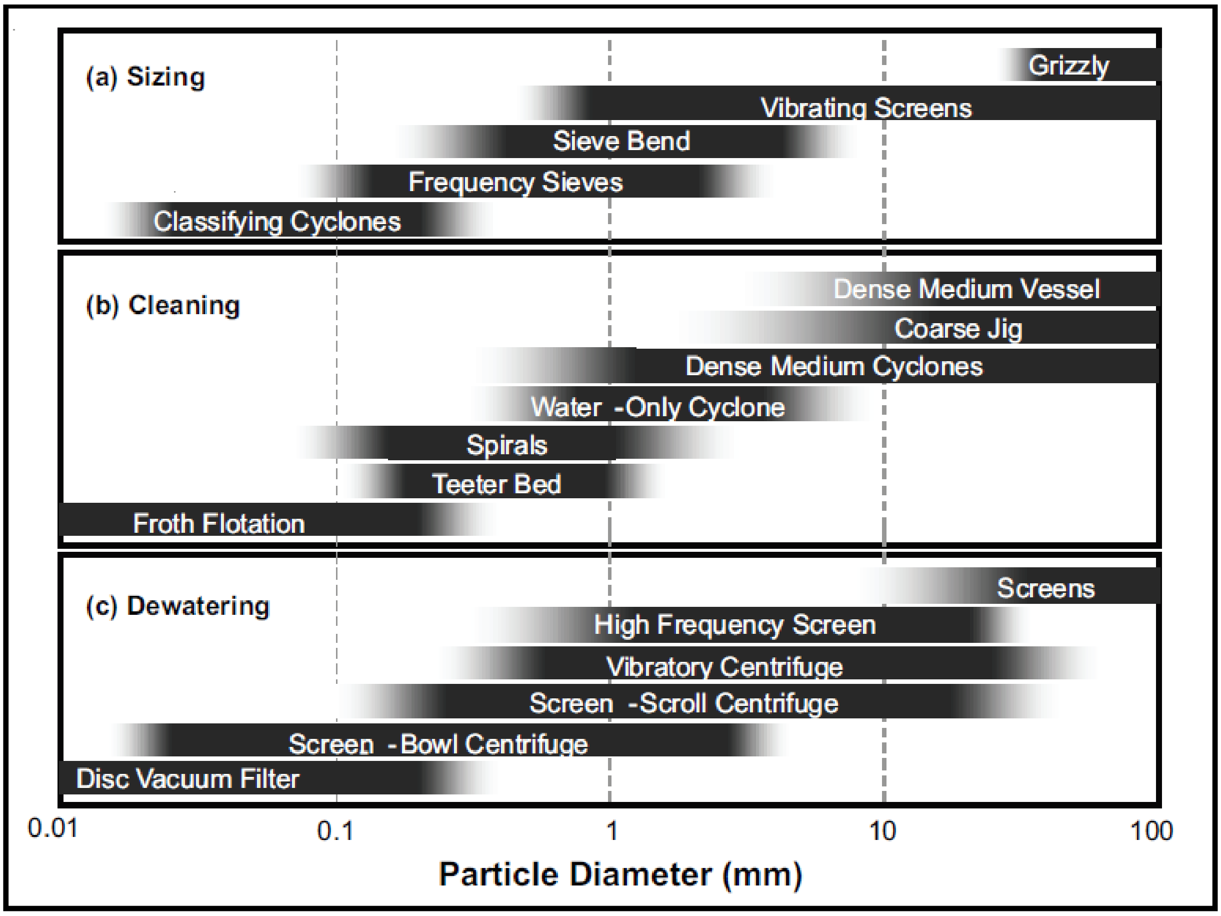

Figure 2.1.2: Typical unit operations and their applicable size range (Arnold et al., 2012)

2.1.5 Physical coal beneficiation

Physical coal beneficiation methods, also referred to as physical coal cleaning (PCC), aim to eliminate ash-forming constituents as well as pyritic sulphur from ROM coal without the use of chemical reagents. The majority of mined coal undergoes physical beneficiation, which may occur under wet or dry conditions, as PCC is more effective at removing high ash coal constituents than chemical coal cleaning (Arnold et al., 2012). There are several physical coal beneficiation techniques that have gained commercial popularity due to their ease of operation and their ability to be applied to varying ranks and sizes of coal; however, innovative processes aimed at cleaning finer coal sizes still remain an avenue of on-going research and development (Schweinfurth, 2009). Physical coal cleaning can be employed to simply remove coarse impurities or, in more sophisticated systems, to effectively remove sulphur and ash as well. Physical cleaning is generally used in commercial coal preparation plants, and the processes involved are designed to specifically exploit the differences in density and surface properties of the coal and its impurities to achieve a desired separation.

Modern coal preparation plants may not necessarily utilise a specific cleaning process, and may opt for different processes applied sequentially or in various combinations (Schweinfurth, 2009).

2.1.6 Wet coal beneficiation

The most commercially prevalent coal beneficiation techniques are wet processes. Water-based separation processes are more robust, with little dependency on the moisture content and size distribution of the feed, which have considerable influence in dry beneficiation processes. Additionally, wet beneficiation processes generally have a higher capacity, are less energy intensive, and are more suitable for the majority of current ROM coals (Macpherson, 2011).

Fundamentally, most wet coal beneficiation processes exploit gravity as a driving force for concentrating usable coal and removing ash-forming impurities and pyritic sulphur constituents in coal. The physical properties of the ROM coal, in particular the size, determine the most applicable technique for the effective reduction of the aforementioned impurities (Napier-Munn and Wills, 2006).

A brief overview of common wet beneficiation techniques are described below:

2.1.6.1 Spirals

Spirals have seen extensive usage in coal cleaning plants due to their economical and simplistic mode of operation, and their proficiency in gravity concentration of coarser particles. Spirals account for 6% of global coal processing, and are generally applied to particles in the -2 + 0.5 mm size range (Gupta and Riazi, 2016). The flow of pulp generally consisting of 30% to 40% solids is subject to centripetal forces (Gupta and Riazi, 2016). The dense material accumulates inwards around the centre of the spiral, and the lighter clean coal gathers around the outside of the spiral, with the middlings situated between the dense and light material (Napier-Munn and Wills, 2006). The distinct products are collected at the bottom of the spiral through the use of separate chutes. In a study conducted by Killmeyer et al. (2001), coal with a top size of 2.38 mm was cleaned in a single spiral from a head ash of approximately 22% to a product with roughly 17% ash. A typical coal cleaning spiral often operates with a capacity of 1-3 t/h, and a battery of spirals are usually employed to achieve the desired capacity. This in itself harbours a problem, in that a slight change in the consistency of the feed, which may easily result due the array of devices involved, can lead to a considerable decrease in efficiency and product recovery (Napier-Munn and Wills, 2006).

2.1.6.2 Froth flotation

Froth flotation has been the historically preferred method when targeting beneficiation of particularly fine coal, usually below 500 μm (Gupta and Riazi, 2016). Unlike the previously discussed gravity separation techniques, in which the density differences are exploited, froth flotation makes use of the distinct surface characteristics of the coal and the associated gangue. The coal particles are made to be hydrophobic through the addition of a selective reagent, and attach to the air bubbles rising through the pulp, leaving behind the hydrophilic gangue material. A reagent, termed the "collector", is used to enhance the attachment of the fine coal to the rising air bubbles, and most often takes the form of a hydrocarbon liquid such as diesel (Napier-Munn and Wills, 2006). Thorough distribution and adsorption of the collector to the surface of the coal is promoted through mechanical mixing. The froth containing the fine recovered coal is skimmed off at the surface followed by filtration. A series of flotation cells are often employed, with the residual pulp after the froth collection being fed to the next cell. The procedure is repeated to ensure a satisfactory residence time for separation, and the residual slurry in the final cell is collected as the tailings. In an experimental campaign conducted by Han (1983), coal particles finer than 30 μm with a head ash content of 30% was cleaned to a product consisting of 12% ash. The suitability of froth flotation to fine particles cements its place as an integral cleaning stage in modern coal preparation plants; however, its relatively high operating costs encourages research into more economical methods of treatment (Gupta and Riazi, 2016).

2.1.6.3 Dense medium separation (DMS) in static baths

Dense medium separation, also known as sink-float separation, is a form of gravity separation that requires particular scrutiny as it is a common method for concentration of minerals with specific gravities ranging from 2 to 4.5. Dense medium separation uses a liquid medium with an intermediate density between that of the valuable minerals and the gangue. The crushed ore is introduced to the fluid medium and the density gradient causes the particles that are heavier than the medium to sink and the lighter particles to float (Napier-Munn and Wills, 2006). The technique results in efficient separation and the cut-point can be easily adjusted by controlling the density of the medium. It can be applied to any ore with a density difference that is large enough to facilitate the separation process.

In dense medium separation of coal using baths, the dense medium is first introduced into the bath, or vessel. The dense medium is typically a mixture of water and fine magnetite. The proportion of water to fine powder may be adjusted to maintain the correct separation density. The feed coal is usually first screened, or de-slimed, to remove very fine particles which could affect the viscosity of the dense medium and consequently, the effectiveness of the separation. The oversize coal is then fed into the vessel. The lighter fraction, which consists of valuable coal, is removed as the floats, whilst the heavier mineral matter is collected as the sinks (Napier-Munn and Wills, 2006).

Due to the popularity of this method, several types of equipment have been fabricated to mechanise this technique and to accommodate perpetually increasing throughput requirements.

2.1.6.3(a) Wemco drum separator

The Wemco drum is a simple and effective device that consists of a rotating drum that is lined internally with ladle-like lifters. The vessel may treat coal between 25-85 mm in diameter with a maximum capacity of 450 tph; however, the maximum feed size primarily depends on the size of the inlet, outlet and lifters. The drum is filled with a predetermined quantity of dense medium slurry, and coal is then fed into the drum. The lifters continuously capture the denser mineral matter as the drum rotates. The lifters discard the heavy particles into a launder located in the middle of the drum, which are then removed from the drum through a sinks chute. The lighter, valuable coal exits the drum with the medium and is passed through a drain and rinse screen to recover the medium. The mineral matter, or sinks, is also rinsed to recover the dense medium.

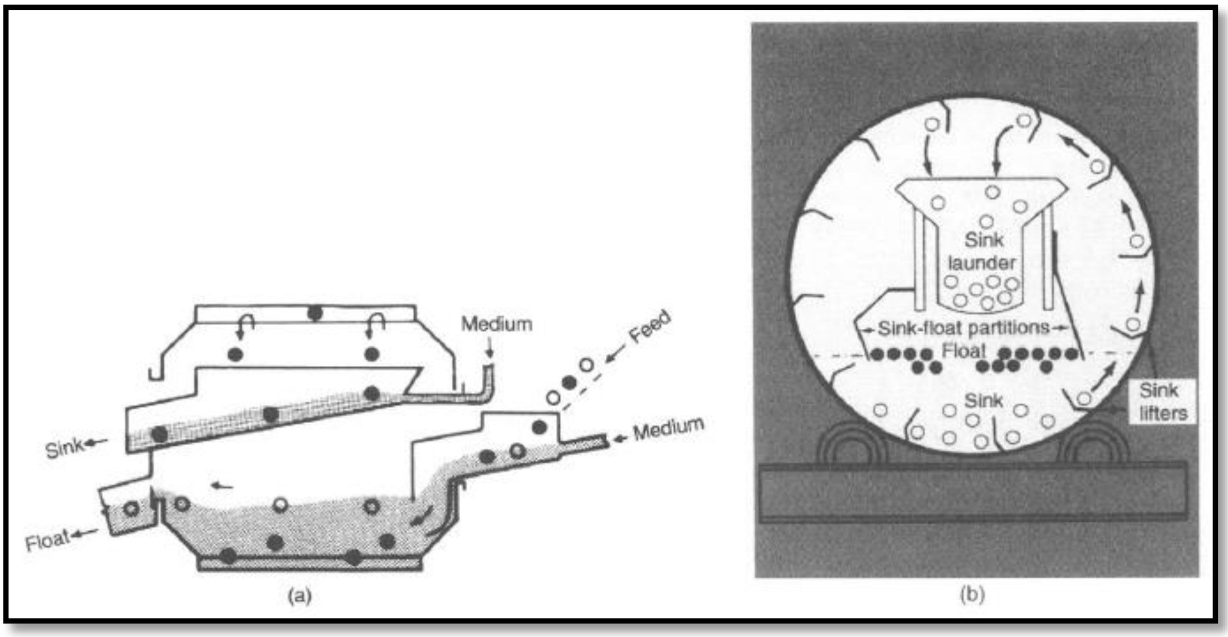

Figure 2.1.2: DMS drum: (a) side view, (b) end view (Napier-Munn and Wills, 2006)

2.1.6.3(b) Drewboy bath separator

The French designed Drewboy bath was extensively utilised for beneficiation in the UK coal industry due to its high floats capacity (Napier-Munn and Wills, 2006). The feed coal is introduced into the vessel at one end and the lighter floats are discharged at the opposite end by means of a star-wheel with a suspended rubber or chain straps. The heavier sinks material is lifted from the base of the vessel by a radially vaned wheel that is mounted parallel to the flow of coal, and at an angle with respect to the bath. The inclined design facilitates the removal of coarse sinks material (Horsfall, 1992). The dense separation medium is fed into the unit at the bottom of the vessel as well as with the feed coal (Napier-Munn and Wills, 2006).

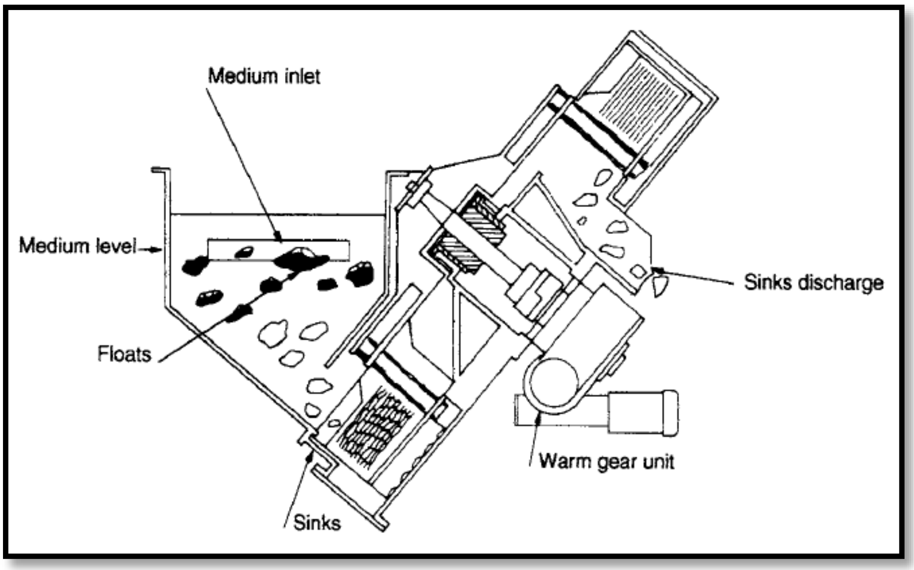

Figure 2.1.3: Drewboy separator (Napier-Munn and Wills, 2006)

2.1.6.3(c) Norwalt washer

The Norwalt washer is a South African development. Coal is fed into the middle of the annular separating vessel, and is driven into the dense medium by means of stirrers attached to a rotating curtain-type wall (Horsfall, 1992). This ensures that the feed coal and medium are thoroughly mixed. The clean coal, that is, the floats, is moved along the surface by the stirrers and is discharged over a weir. The heavy material is moved along the bottom of the vessel by scrapers attached to the stirrer arms, and is discharged through an opening at the bottom of the separator into a wheel or bucket-type elevator.

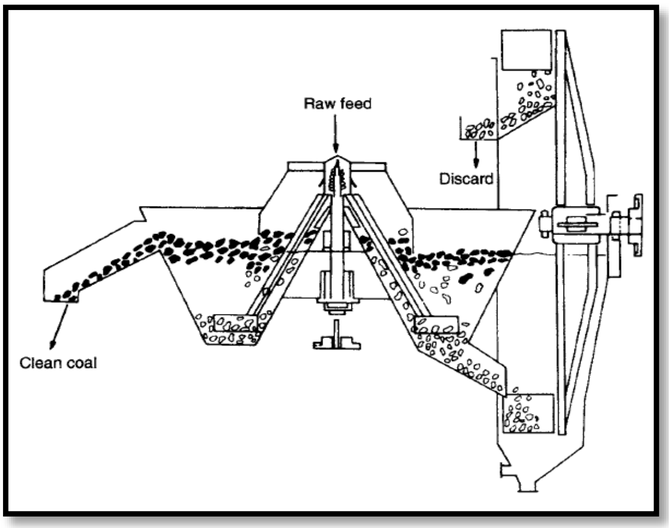

Figure 2.1.4: Norwalt washer (Napier-Munn and Wills, 2006)

2.1.6.4 Centrifugal dense medium separators

The principle mode of separation is similar to that of static baths, albeit with one fundamental modification. In contrast to dense medium separation in static baths, which depends exclusively on the density differences in the gravitational field between coal and the dense medium, centrifugal separators exploit centrifugal force to separate particles of varying densities.

The raw coal fed to these separation devices is usually finer than the feed to the static bath devices (typically less than about 50 mm). It is screened at about 0.5 mm, so as to prevent the contamination of the medium with fine material, or slimes, which may adversely affect the medium viscosity. Extensive research and tests have been undertaken globally to extend the range of particle size over which centrifugal dense medium separation may be successfully applied. This is particularly relevant in the coal industry, as the benefits include the elimination of de-sliming screens and reduced froth flotation of the screen undersize (Koper, 2009).

2.1.6.4(a) Dutch State Mines (D.S.M) cyclone

Undoubtedly, the most commonly used centrifugal dense medium separator is the cyclone, which is similar in operation to the typical hydrocyclone. The original design of the cyclone was developed in the Netherlands by the Dutch State Mines (Koper, 2009). Cyclones were ordinarily used to beneficiate coal in the size range of 0.5-40 mm; however, later developments permitted the treatment of coarser coal between 100 mm to 125 mm.

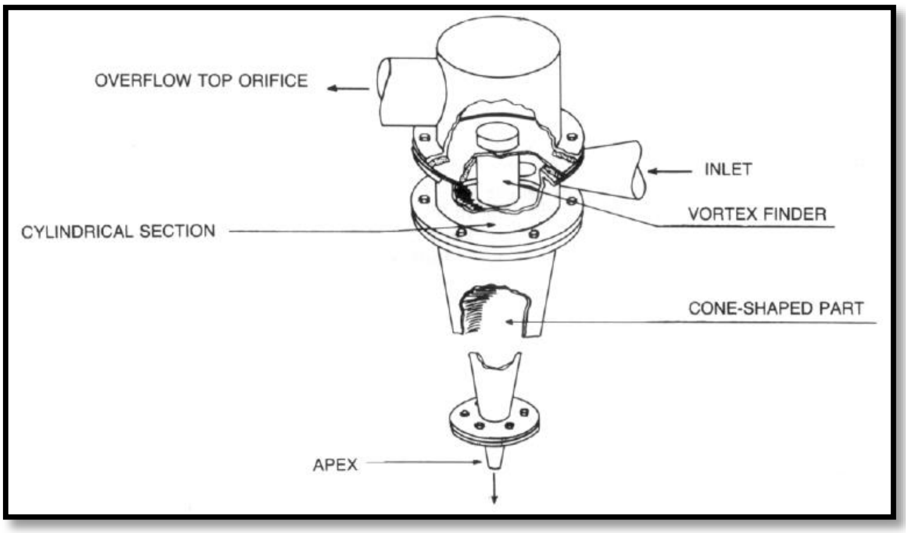

Figure 2.1.5: DSM cyclone (Koper, 2009)

The raw coal is suspended in a medium, which typically consists of magnetite ground to below 45 µm in diameter. The slurry is introduced tangentially to the cyclone through the use of a pump or by gravity; however, gravity feeding requires a taller, and consequently, a more expensive design. Outward centrifugal and inward centripetal forces induce a density dependent separation. The reject material is forced towards the wall of the cyclone and exits through the apex, or spigot. The coal product floats to the flow around the axis and is discharged via the overflow top orifice (Napier-Munn and Wills, 2006).

Beneficiation of coal using dense medium cyclones is extensively employed in South Africa for the size range of 0.5-50 mm. If smaller particles are included in the feed, the chosen solids medium must be suitably fine to maintain medium stability; however, the incorporation of fine coal particles may result in an undesirable medium viscosity.

2.1.6.4(b) Vorsyl separator

The Vorsyl separator is widely used in coal beneficiation, predominantly, for smaller sized coal with a top-size of about 50 mm (Shaw, 1984). The raw coal is first de-slimed before being fed tangentially into the separator together with the separating medium slurry. The lighter coal product is directed into the clean coal outlet by way of the vortex finder, whilst heavier mineral matter, as well as material of equivalent density to that of the medium, is driven towards the vessel wall by centrifugal acceleration. This rejects material, together with the medium, is discharged via the attached throat into a shallow shale chamber. Thereafter, the rejects are passed tangentially into a vortextractor, which dissipates the inlet pressure through the generation of an inward spiral flow to the outlet, ultimately discharging the rejects through a large outlet nozzle (Shaw, 1984).

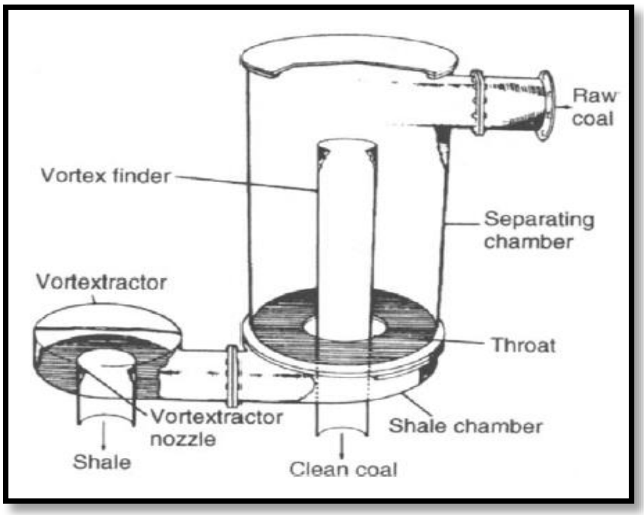

Figure 2.1.6: Vorsyl separator (Napier-Munn and Wills, 2006)

2.1.6.4(c) LARCODEMS separator

The Large Coal Dense Medium Separator, or LARCODEMS, was designed to process large quantities of coal below 100 mm in diameter (Shah, 1987). The device is cylindrical in shape and is inclined at 30° with respect to the horizontal. Dense medium slurry at the desired separation density is fed under pressure, by means of a pump or static head, into the inlet at the lower end of the unit. Raw coal, typically in the size range of 0.5-100 mm, is introduced into the separator through a feed chute located at the top end. The feed flows in a counter-current manner with respect to the medium and, similarly to the Vorsyl separator, a vortextractor is utilised to remove the rejects. However, the vortextractor of the LARCODEMS is slightly off-centre, which provides improved control of the medium exit rate. The ratio of the medium flow between the rejects and the product outlet can be varied to obtain a desired yield with a negligible effect on the separation efficiency (Napier-Munn and Wills, 2006).

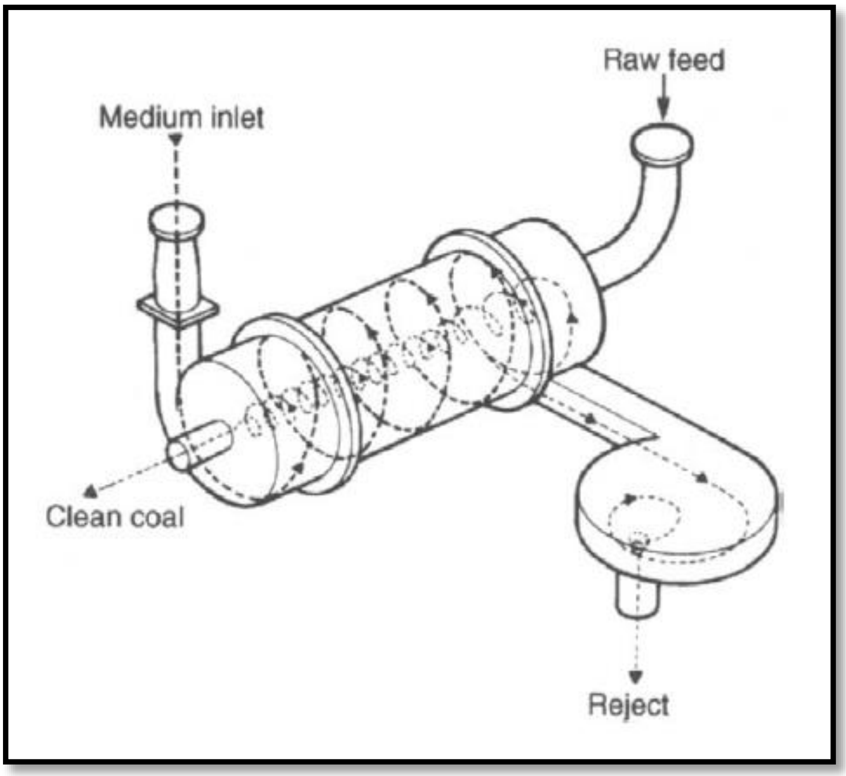

Figure 2.1.7: LARCODEMS (Napier-Munn and Wills, 2006)

2.1.6.4(d) Dynawhirlpool separator

The Dynawhirlpool separator is analogous to the LARCODEMS in design and operation, and is typically used to process coal in the size range of 0.5-30 mm (Wills and Lewis, 1980). The unit is composed of a cylindrical body, with a tangential medium inlet nozzle at the lower end and a duplicate sinks discharge nozzle at the upper end. The device is mounted at an incline of approximately 25° to the horizontal. Separation medium of desired density is pumped into the vessel through the lower inlet nozzle. The tangential entrance of the medium generates a vortex that spirals upwards and exits through the sinks discharge outlet. Raw coal is sluiced into the unit with a small quantity of medium so that negligible interference with the medium vortex is incurred. As the coal moves through the unit, the heavier material is pushed towards the wall under centrifugal action by the outer spiral, and is carried upwards with the medium to the discards outlet. Due to centripetal forces, the lighter coal product is pushed inwards and, together with the rest of the medium, exits by way of the product outlet at the bottom of the device.

The operation of the Dynawhirlpool separator is less energy-intensive than its cyclonic counterparts, as only the medium itself is pumped as opposed to a mixture of medium and raw coal. This contributes to an overall lower operating and capital cost.

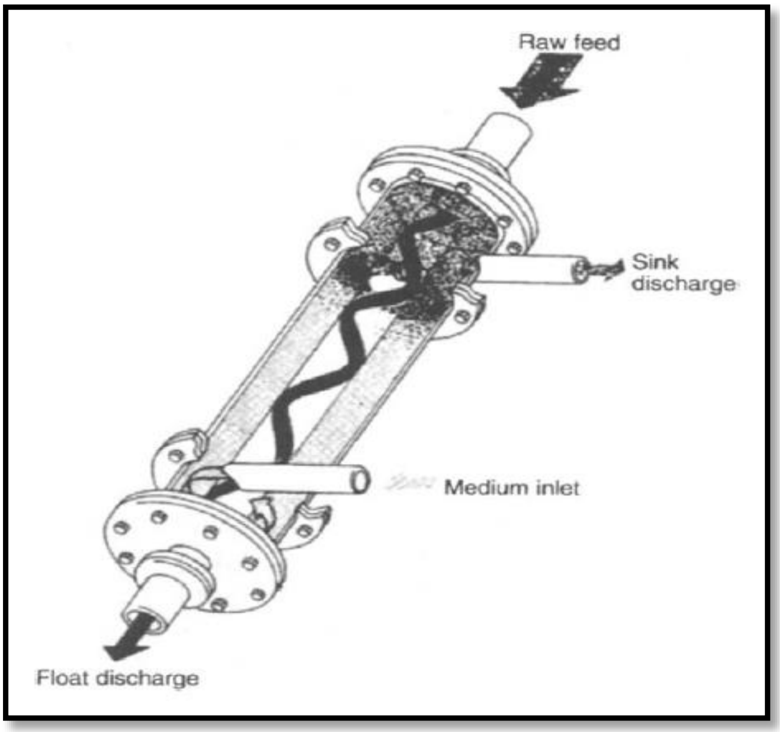

Figure 2.1.8: Dynawhirlpool separator (Napier-Munn and Wills, 2006)

The selected material of construction or cyclonic separators is of major concern as the inner walls of the separator are subjected to considerable abrasion due to the movement of rejects material against the walls. In most designs, ceramic liners are used to assist against excessive erosion. In the case of the Dynawhirlpool, the portion of the vessel subjected to the severest abrasion is shorter than with standard cyclones, as the greatest proportion of rejects material is located near the outlet. This contributes to the longevity of the unit, however, the fabrication of cyclone separators often incorporate wear resistant materials to prolong the working life of the equipment.

2.1.7 Coal beneficiation using Jigs

In the jigging process, a pulsating current of water is used to fluidise a bed of particles so as to produce stratification, and consequently, separation of the material according to density (Napier-Munn and Wills, 2006). Stratification results from both an up-stroke, in which water flows upwards and lifts the bed, and a down-stroke, where water moves downwards resulting in compaction of the bed. It is imperative that the water flowrate is adequate to lift all the particles. Immediately after the up-stroke, the upward current stops briefly. At this instant preceding the down-stroke, the particles settle out. Hindered settling dominates due to the close proximity of the particles to each other (Koper, 2009). Heavier particles settle faster than lighter coal particles of the same size due to the effects of hindered settling (detailed explanation in section 2.2.3). The water conveys both the light material, that is, the coal, and heavier reject material downwards during the down-stroke. Perpetual up-strokes and down-strokes enhance the stratification, and consequently, the separation, of the material.

There are three phenomena that dictate the stratification process in a jig, namely, differential acceleration, hindered settling and consolidation trickling (Vanangamudi et al., 1986).When the particles begin to settle at the peak of the up-stroke, the initial acceleration of the heavier reject material is greater than that of the lighter product. This implies that the initial acceleration of the particles is dependent only on particle and fluid density. If the stroke is rapid and pulse-like, with the period of the particle’s descent being sufficiently short, then the settling of the particles will be more greatly influenced by the differential initial acceleration rather than their terminal velocities. Consequently, settling will take place based on density as opposed to particle size. Accordingly, the separation of dense fine particles from less dense larger particles necessitates a short and frequent jigging sequence (Napier-Munn and Wills, 2006). However, it must be noted that longer and less frequent strokes facilitates superior stratification and better process control, and this is especially true when coarser particles are to be recovered as the product (Napier-Munn and Wills, 2006).

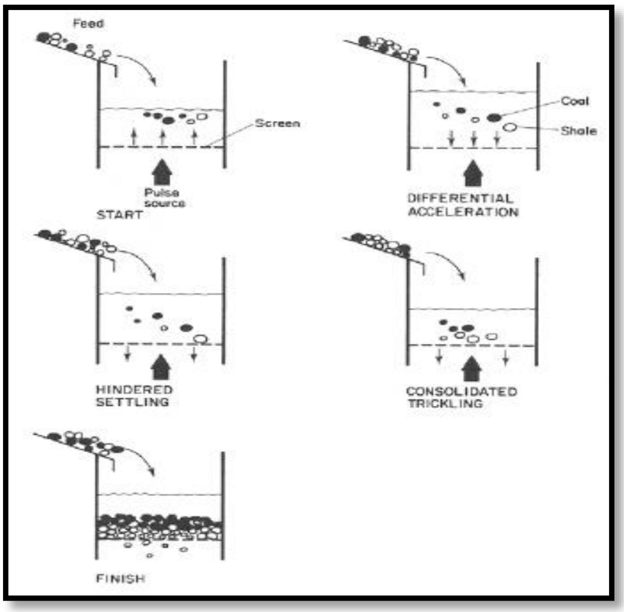

Figure 2.1.9: Ideal jigging process (Koper, 2009)

Hindered settling has a considerable influence on the separation of larger particles. After a certain amount of time, the particles will have reached their terminal velocities, and settling will be dependent on both density and particle size. The loosely packed nature of the bed, together with the interstitial water, promotes the formation of a dense slurry, which ultimately gives rise to hindered settling (Napier-Munn and Wills, 2006). These factors results in the movement of lighter particles being impeded by other particles in close proximity, thus, denser particles settle faster than lighter particles of the same size. The upward flow of water can be regulated to elutriate the fine light particles. The water flowrate can be increased further so that only large dense particles are permitted to settle. However, the similar terminal velocities of large light particles and small heavy particles inhibit efficient separation (Napier-Munn and Wills, 2006).

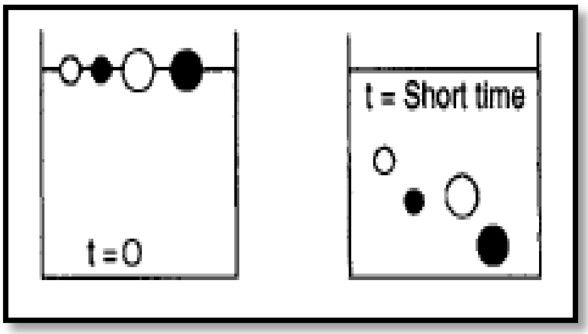

Figure 2.1.10: Hindered settling phase (Napier-Munn and Wills, 2006)

Finally, at the culmination of the down-stroke, the closeness of the particles to each other minimises their mobility. Consequently, the bed compaction begins to occur. The coarser particles intermesh, creating interstices through which finer particles travel downwards under gravitational force (Napier-Munn and Wills, 2006). Small dense reject matter sinks faster than lighter coal of equivalent size. Consequently, discards trickle deeper into the bed than coal during this consolidation trickling phase. This subsequently enhances separation according to density.

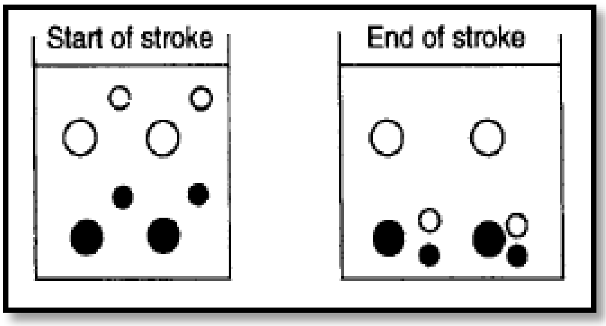

Figure 2.1.11: Consolidation trickling phase (Napier-Munn and Wills, 2006)

It is highly likely that coal preparation plants will incorporate the use of jigs to clean coal. It is the preferred choice of separation when the feed contains a suitably small proportion of near-gravity material (Napier-Munn and Wills, 2006). Unlike dense medium separation which necessitates feed preparation, raw coal can be fed directly to the jig. Of the two principle jigging mechanisms, that is, air pulsated and mechanical pulsated, coal beneficiation usually utilises air pulsated devices (Koper, 2009).

The Baum and Batac devices are the two most widely used air pulsated jigs for the beneficiation of coal (Napier-Munn and Wills, 2006). The Baum jig is more prevalent of the two and it has been used, in one form or another, for nearly a century (Green, 1984). Pressurised air is fed into an expansive compartment located near one end of the unit. This generates an alternating pulsation and suction action to the water in the vessel, which consequently elicits the up-stroke and down-stroke cycle through the screen. Given that the bed of coal rests on the screen, the alternating motion produces stratification. This is the fundamental difference between air-pulsated jigs and mechanical jigs as the latter induces pulsation and suction though the use of a piston. The Baum jig is a high capacity device that is capable of processing up to 1000 tph. Furthermore, it can handle an assortment of particle sizes (Napier-Munn and Wills, 2006). Most modern Baum jigs are equipped with an automated rejects extraction tool to ensure uninterrupted and continuous separation (Adams, 1983). One such method of control employs an appropriately dense float that is submersed in the bed of coal. The float is designed to settle on the layer of heavy reject matter. An accumulation of reject matter elevates the float, which then triggers the discharge of the heavy mineral matter. This may be accomplished by adjusting the flow of water to push the heavy mineral matter over a stationary weir (Wallace, 1979).

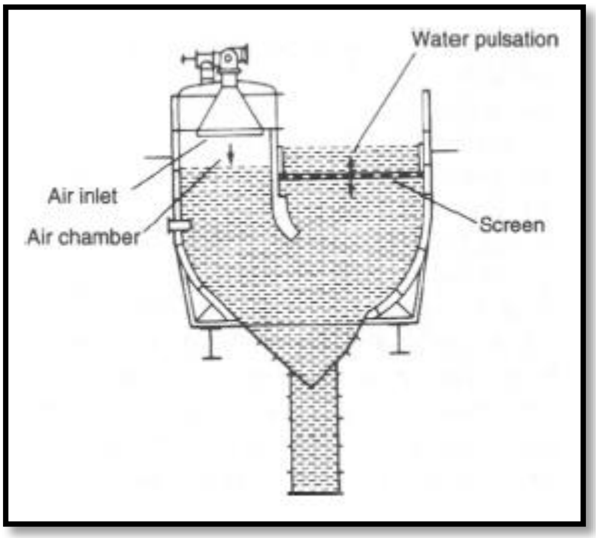

Figure 2.1.12: Baum jig (Napier-Munn and Wills, 2006)

The Batac jig also utilises compressed air, however, unlike the design of the Baum jig which incorporates a side chamber for air, the Batac jig houses multiple air chambers. This design facilitates uniform air distribution. This is an improvement on the Baum unit where the dissemination of the stratification force is somewhat disproportionate due to the asymmetrical location of the air inlet (Napier-Munn and Wills, 2006). Aside from a more uniform force distribution, the Batac jig is capable of infinite variation of the jigging frequency as well as the stroke length, enabling more precise control over the separation. Consequently, the separation of both coarse and fine sizes are well within its capabilities and successful upgrading of iron ore deposits have been achieved that would have otherwise been impossible with dense medium processes (Hasse and Wasmuth, 1988; Miller, 1991).

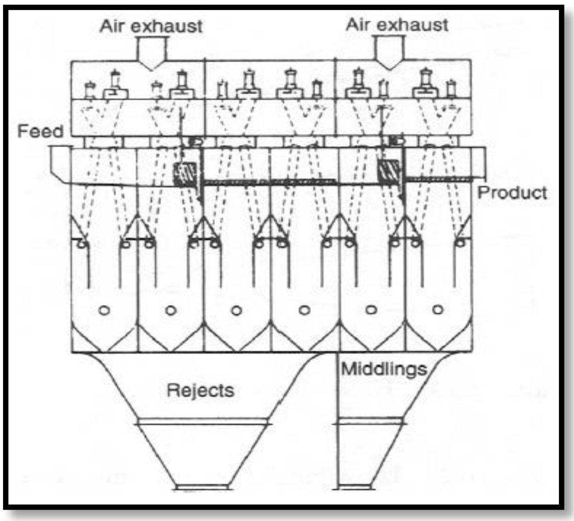

Figure 2.1.13: Batac jig (Napier-Munn and Wills, 2006)

2.1.8 Dry coal beneficiation

On the surface, dry beneficiation techniques may appear more appealing as dry coal is often required for most, if not all, commercial uses. Thus, the notion of wet processing should be diametrically opposed, in principle, to the efficient beneficiation of coal. Dry processes can also be effectively applied in regions where water supply is of particular concern. Moreover, it is more economical in terms of power usage and operating costs.

Even though the benefits of dry processes have been highlighted, the failings of dry techniques require mentioning. Dry processing of coal has not gained widespread usage due to the effectiveness and simplicity of water-based processes. The disadvantages associated with dry processing include reduced separation efficiency and capacity, as well as displaying a high sensitivity to variations in the feed rate, moisture and size distribution (Lockhart, 1984). Furthermore, additional measures for dust control and safety is necessary, and pre-screening into narrow size fractions is required (Lockhart, 1984). It should be noted, however, that some of these shortcomings are a part of water-based processing as well.

Dry beneficiation methods, such as pneumatic cleaning and electrostatic separation, which were commercially prevalent in the past, have steadily declined in usage. This has been predominantly due to an increase in the moisture content of ROM coal, as well as the capability of wet techniques to process broader size fractions.

2.2 Particle settling

This section discusses some of the theoretical concepts that are pertinent to the operation of the reflux classifier. The motion of particles through viscous fluids is reviewed and the prevailing forces acting on the particle are identified. The phenomena of free and hindered settling are thereafter introduced, followed by a more thorough description of hindered settling due to its relevance in the reflux classifier. The principal of classification is then discussed, and the effect of hindered settling in the context of hydraulic classification is examined.

2.2.1 Fundamentals of particle settling

Sedimentation is a method of separation that is commonly applied to particles in finer size ranges. It is characterised by the gravity driven settling of particles in a viscous fluid medium. A solid particle described by diameter d and density ρ_p falling freely in a motionless fluid medium of density ρ_f and viscosity μ_f is subject to three individual forces (Subba Rao, 2011), namely:

- Gravitational force: A downwards acting force characterised by the product of the particle mass (m_p) and gravitational acceleration (g), that is, $m_p g$.
- Buoyancy force: A force governed by Archimedes' principle that opposes gravitational force expressed as the product of the mass of the displaced fluid medium (m_f) and gravitational acceleration (g), that is, $m_f g$.
- Drag force: A velocity dependent force that resists the motion of the particle.

Newton's second law details the motion of the particle as follows (Subba Rao, 2011):

$$\mathbf{m_p g - m_f g - R = m_p \frac{dv}{dt}} \qquad (2.2.1.1)$$

Where **R** represents the particle drag force, **v** is the particle velocity and $\mathbf{\frac{dv}{dt}}$ is the particle acceleration.

The particle resistance, or drag force, increases with the velocity of the particle as it falls. This continues until the drag force equilibrates with the net result of the gravitational and buoyancy force. The acceleration is subsequently reduced to zero and the particle attains its terminal velocity (v_t), which is its constant velocity of descent (Tripathy et al., 2014). With the particle acceleration equal to zero, equation 2.2.1.1 can be used to define R as follows:

$$R = m_p g - m_f g \tag{2.2.1.2}$$

If the particle is assumed to be spherical, equation 2.2.1.2 can be represented as follows:

$$R = g\left(\frac{\pi}{6} d^3 \rho_p - \frac{\pi}{6} d^3 \rho_f\right) \tag{2.2.1.3}$$

$$\Rightarrow R = g \frac{\pi}{6} d^3 \left(\rho_p - \rho_f\right) \tag{2.2.1.4}$$

The resistance experienced by a particle strongly depends on the velocity with which it falls. If a particle falls with a low enough velocity, only the layer of fluid in direct contact with the particle is disturbed, while the surrounding fluid remains stationary (Subba Rao, 2011). The resistance to the particles' motion is largely ascribed to shear forces arising between the falling particle and the surrounding stationary fluid, thus, the viscosity of the fluid is responsible for resistance and it is termed viscous resistance (Napier-Munn and Wills, 2006). Stokes inferred that this viscous drag component may be expressed as $3\pi d \mu_f v$ (Rhodes, 2008). Therefore, with $v = v_t$, equation 2.2.1.4 takes the form:

$$3\pi d \mu_f v_t = g \frac{\pi}{6} d^3 \left(\rho_p - \rho_f\right) \tag{2.2.1.5}$$

Rearranging,

$$v_t = \frac{d^2 g(\rho_p - \rho_f)}{18\mu_f} \tag{2.2.1.6}$$

Equation 2.2.1.6 is known as Stokes' law and it accurately describes particles below 50 µm in diameter, or particles characterised by a Reynolds number lower than 0.1 (Galvin, 2003). It may be applied to larger particles, up to 100 µm in diameter, albeit with some error (Rhodes, 2008). At higher velocities, resulting from larger particles, the resistance is predominantly attributed to the displacement of the fluid medium by the falling particle, with minimal contribution from viscous effects. Consequently, this is referred to as turbulent resistance (Napier-Munn and Wills, 2006). Newton theorised that the resistance was solely attributable to turbulence and computed the resistance to be $0.055\pi d^2 v^2 \rho_f$ (Subba Rao, 2011). Thus, in a similar manner as above, equation 2.2.1.4 may be expressed as:

$$0.055\pi d^2 {v_t}^2 \rho_f = g \frac{\pi}{6} d^3 \left(\rho_p - \rho_f\right) \tag{2.2.1.7}$$

Rearranging,

$$v_t = \sqrt{\frac{3gd(\rho_p - \rho_f)}{\rho_f}} \quad (2.2.1.8)$$

The acceleration of a particle falling in a viscous medium quickly decreases as the terminal velocity is attained regardless of the mode of resistance. The terminal velocity of a particle is dependent on both its size and density, thus, if two particles were to have the equivalent density, the larger particle will attain the higher terminal velocity. Similarly, if two particles were equal in size, the denser particle will attain the higher terminal velocity (Napier-Munn and Wills, 2006). Additionally, the settling velocity of irregularly shaped particles is also a function of its shape (Subba Rao, 2011).

The settling environment and the proximity of particles will determine if a falling particle will be subject to free settling or hindered settling (Tripathy et al., 2014). Taggart (1945) provides a study on free settling characteristics of well-dispersed ore pulps.

2.2.2 Free settling

Free settling is a phenomenon that occurs when the volume of the fluid medium is sufficiently large in comparison with the volume of the particles. Consequently, individual particles having distinct densities, sizes and shapes are suitably distant from each other and fall freely in the medium with negligible interaction with adjacent material (Subba Rao, 2011).

2.2.3 Hindered settling

Hindered settling conditions dominate when the volume of particles in the fluid medium increases. Due to this increase in solids concentration, the particles are in close proximity to each other and crowding of particles ensues (Tripathy et al., 2014). The falling particles come into direct contact with each other and their rate of descent is impaired, thus, particles under hindered settling conditions are characterised by lower settling velocities. Hindered settling conditions amplify the effect of particle density on separation. This phenomenon is illustrated in Figure 2.2.1 where similarly sized particles in free settling conditions descend at almost the same rate; regardless of density (darker particles are denser than lighter particles). Thus, a sharp separation on the basis of density is difficult to obtain under free settling conditions. In contrast, hindered settling reduces the influence of particle size and amplifies the effect of particle density on separation (Napier-Munn and Wills, 2006). This concept is expounded on below.

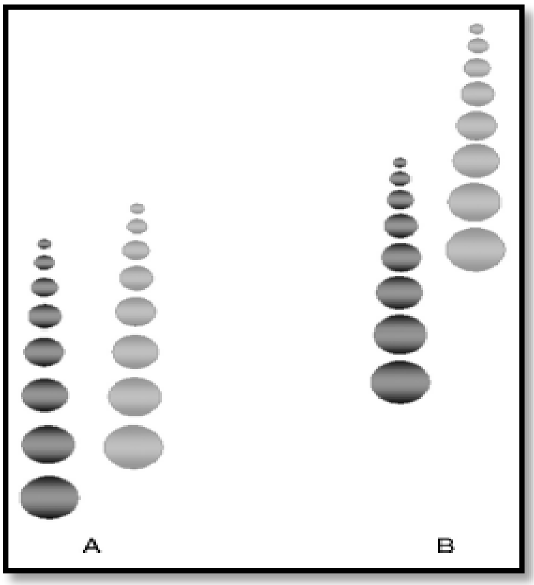

Figure 2.2.1: (a) Free settling; (b) Hindered settling (Tripathy et al., 2014)

2.2.4 Free and hindered settling ratio

For equal settling particles, that is, particles that have identical terminal velocities, the ratio of the diameters of two solid particles having different densities defines a settling ratio (Subba Rao, 2011).When free settling conditions dominate; the ratio is referred to as the free settling ratio. The settling ratio is computed by equating the terminal velocities of the particles. Consider a light particle with diameter d_l and density ρ_{pl}, and a heavy particle with diameter d_h and density ρ_{ph}. If the particle is suitably fine, Stokes' law (equation 2.2.1.6) is employed as follows:

$$v_t = \frac{{d_l}^2 g(\rho_{pl} - \rho_f)}{18\mu_f} = \frac{{d_h}^2 g(\rho_{ph} - \rho_f)}{18\mu_f} \quad (2.2.4.1)$$

Rearranging,

$$\frac{d_l}{d_h} = \left(\frac{\rho_{ph} - \rho_f}{\rho_{pl} - \rho_f}\right)^{0.5} \quad (2.2.4.2)$$

Similarly, using the equation proposed by Newton (equation 2.2.4.1) for coarser sizes:

$$v_t = \sqrt{\frac{3gd_l(\rho_{pl}-\rho_f)}{\rho_f}} = \sqrt{\frac{3gd_h(\rho_{ph}-\rho_f)}{\rho_f}} \tag{2.2.4.3}$$

Rearranging,

$$\frac{\mathbf{d_l}}{\mathbf{d_h}} = \frac{\boldsymbol{\rho_{ph} - \rho_f}}{\boldsymbol{\rho_{pl} - \rho_f}} \tag{2.2.4.4}$$

To illustrate the significance of the settling ratio, consider a blend of coarse galena and quartz, with densities of 7500 kg/m^3 and 2650 kg/m^3 respectively, settling in water (Napier-Munn and Wills, 2006). Applying equation 2.2.4.4, the free settling ratio is:

$$\frac{d_l}{d_h} = \frac{7500 - 1000}{2650 - 1000} = 3.94$$

This implies that a galena particle will have the same settling velocity as a quartz particle that is 3.94 times as large as the galena particle (Napier-Munn and Wills, 2006).

Hindered settling is characterised by an increase in solids concentration in the pulp or slurry. Under these conditions, the system assumes the characteristics of a heavy liquid with a density equivalent to that of the pulp (Napier-Munn and Wills, 2006). Thus, individual solid particles are actually settling in a pulp suspension of other particles and not simply through the fluid medium itself (Subba Rao, 2011). Thus, the effective density, that is, the density difference between the solid particle and fluid medium, essentially becomes the density difference between the solid particle and the pulp. Since the density and viscosity of the pulp will effectively be greater than that of the fluid medium alone, the falling particles are subject to greater resistance. Thus, the terminal velocities of particles under hindered settling conditions are substantially lower compared to free settling conditions. Additionally, the resistance incurred by particles is primarily due to turbulence. Thus, equation 2.2.1.8 may be used to compute the terminal velocity and formulate the hindered settling ratio, with the density of the slurry, ρ_{sl}, substituted in place of the fluid density, ρ_f.

$$v_t = \sqrt{\frac{3gd(\rho_p - \rho_{sl})}{\rho_{sl}}} \tag{2.2.4.5}$$

Essentially, the lighter the particle, the more pronounced the impact of the effective density, $(\rho_p - \rho_{sl})$, in reducing the terminal velocity of the particle. Additionally, as the size of particles increase, so too does the solids volume fraction, and consequently, the slurry density, ρ_{sl} . Thus, the drop in effective density results in lower settling velocities for lighter particles, regardless of size (Subba Rao, 2011).

The hindered settling ratio can be derived as follows:

$$v_t = \sqrt{\frac{3gd_l(\rho_{pl} - \rho_{sl})}{\rho_{sl}}} = \sqrt{\frac{3gd_h(\rho_{ph} - \rho_{sl})}{\rho_{sl}}} \tag{2.2.4.6}$$

$$\Rightarrow \frac{d_l}{d_h} = \frac{\rho_{ph} - \rho_{sl}}{\rho_{pl} - \rho_{sl}} \tag{2.2.4.7}$$

Consider a mixture of galena and quartz with the aforementioned densities settling in slurry with a density of 1500 kg/m^3 (Napier-Munn and Wills, 2006).

$$\frac{d_l}{d_h} = \frac{7500 - 1500}{2650 - 1500} = 5.22$$

Thus, under hindered settling conditions, a galena particle will have the same settling velocity as a quartz particle that is 5.22 times as large as the galena particle (Napier-Munn and Wills, 2006). The free settling ratio for the same mixture equates to 3.94, hence, it is apparent that hindered settling conditions magnifies the influence of density on settling rates (Subba Rao, 2011). The hindered settling ratio always exceeds the corresponding free settling ratio, and it increases accordingly with the slurry density.

2.2.5 Classification

The segregation of a mixture of particles of varying densities, sizes and geometries based on the velocity with which the individual particles settle in a fluid medium is termed classification (Tripathy et al., 2014). Either liquid or gas may be employed as the fluid medium, with water being the preferred medium in mineral processing (Napier-Munn and Wills, 2006). Classifiers that use air are referred to as pneumatic classifiers. Classifiers that utilise a water medium comprise of nonmechanical, mechanical and centrifugal classifiers. Nonmechanical classifiers include hydraulic classifiers, which are wet media classifiers that utilise either free or hindered settling mechanisms to achieve separation (Fuerstenau and Han, 2003). Essentially, particles with a terminal velocity that is lower than that of the upward fluid velocity will be conveyed to the overflow. In a similar manner, particles with a terminal velocity greater than that of the upward current will sink and report to the underflow. This process continues until all particles have been classified into the overflow and underflow fractions. Classification techniques are typically used to separate particles that may be too fine to be processed using conventional methods. Consequently, it finds particular relevance in the current mining climate, as the introduction of mechanical mining techniques and the dwindling reserves of high grade ore have increased the concentration of fines in ROM ore.

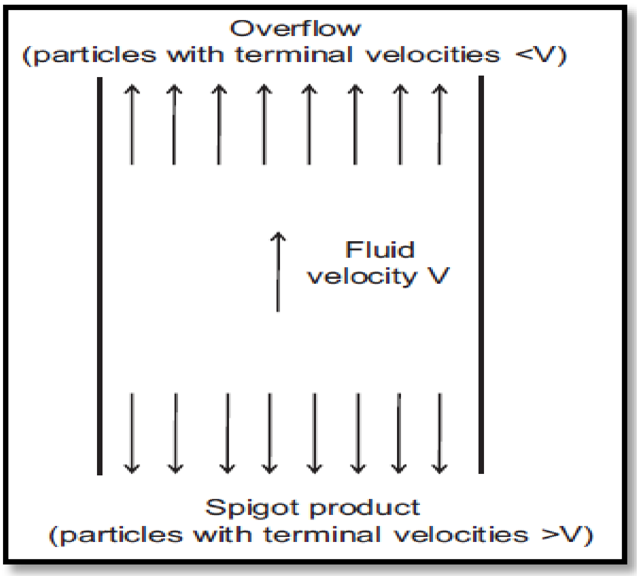

Figure 2.2.2: Schematic of the classification principle (Tripathy et al., 2014)

2.2.6 Hydraulic classification

Hydraulic classifiers incorporate the use of an upward flow of hydraulic water through a column as the fluid medium, within which settling of particles occurs according to size, shape and density (Tripathy et al., 2014). The classifier may encompass a single or multiple columns, and are often referred to as counter current devices as the rising flow of water opposes the direction of the settling particles (Napier-Munn and Wills, 2006). The flow of hydraulic water may be adjusted to achieve a desired separation. There are two categories of hydraulic classifiers, distinguished by their design and mode of operation. The first type functions without fluidisation and includes the Lewis classifier, Linatex classifier and Lavodune classifier. The second type utilises the hydraulic water to fluidise a bed of particles.

Consequently, they are referred to as fluidised bed hydraulic classifiers and include the Stokes' hydrosizer, Floatex density separator and the Reflux Classifier. Fluidised bed hydraulic classifiers typically employ hindered settling mechanisms to achieve particle segregation (Tripathy et al., 2014).

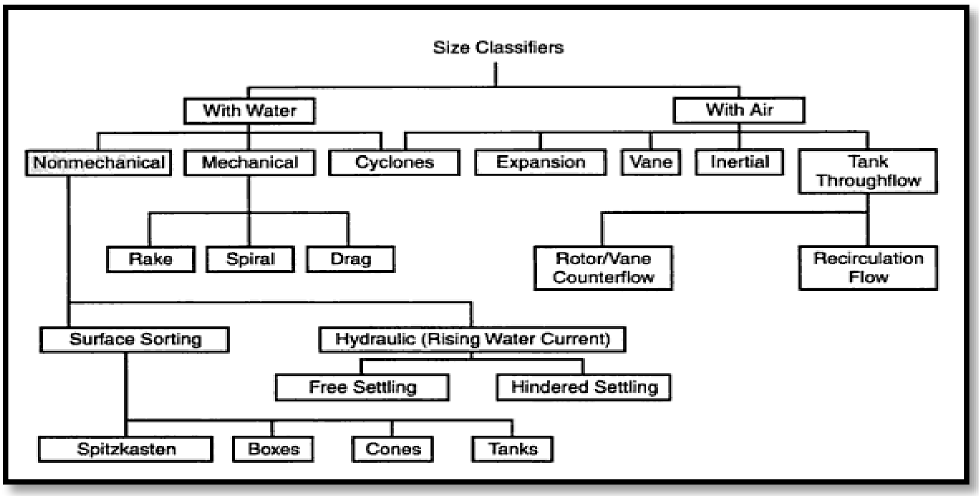

Figure 2.2.3: Types of classifiers (Fuerstenau and Han, 2003)

Free settling classifiers consist of columns with a constant cross sectional area through the entire column length. These classifiers are seldom used in large plants as their throughput-to-size ratio is small in comparison with hindered settling units. Hindered settling hydraulic classifiers are characterised by a constricted column, which may be achieved by either using a tapered column or by incorporating a grid at the base through which the hydraulic water flows.

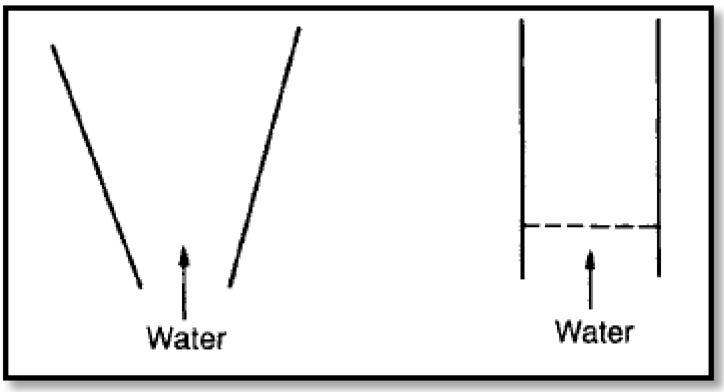

Figure 2.2.4: Common constrictions in hindered settling columns (Napier-Munn and Wills, 2006)

The reduction in cross sectional area due to the constriction results in an increase in the velocity of the hydraulic water at the bottom of the column. Particles settle until a point is reached where its terminal velocity is equivalent to the upward velocity of the hydraulic water. The accumulation of particles above the constriction results in the formation of a fluidised bed **(**Fuerstenau and Han, 2003). The amassment of particles causes an increase in pressure at the bottom of the bed. This facilitates the movement of particles upwards through the centre of the column towards a region of lower pressure, after which they settle once again down the sides of the column. The constant circulation of particles gives rise to a phenomenon known as full teeter, in which fluidised particles are held in place due to their closeness to each other (Napier-Munn and Wills, 2006). The teeter bed behaves as a dense medium through which dense particles settle and passage of lighter solids are inhibited. Particles of intermediate density are confined within the teeter bed **(**Fuerstenau and Han, 2003). Thus, the dependence of the separation on particle size is suppressed and the influence of particle density is enhanced. Additionally, the closeness of the teetering particles causes them to rub against each other. An inherent effect of this scouring action is that entrained slimes are removed and cleaner fractionation is achieved (Napier-Munn and Wills, 2006).

2.2.7 Summary

In mineral processing applications, particles to be separated are typically fluidised with water and separation is initiated by hindered settling mechanisms and stratification. Fluidised bed hydraulic classifiers are predominantly used in mineral processing to attain a desired gravity concentration of a feed. In essence, a fluidised bed hydraulic classifier primarily consists of a sorting column through which fluid flows upwards at a constant rate. The feed is introduced into the hydraulic classifier by way of a feed chute and the water, referred to as teeter or fluidisation water, is fed through the bottom of the column. The fluidised particles form a fluidised bed, also known as a teeter bed, and particles lighter than the teeter bed float and report to the overflow. Heavier particles sink through the teeter bed and report to the underflow.

2.3 Hydrodynamic effects of inclined channels

This section reviews particle transport in inclined channels and its relevance in solid-liquid separation. The phenomenon known as the Boycott effect is discussed, and the mechanisms that result in improved settling rates in inclined channels are reviewed.

2.3.1 Particle settling in inclined channels

The separation of particles from a suspension through gravity settling alone is a relatively slow process, and the rate of separation is further reduced when the particles to be separated are of finer sizes (Acrivos et al., 1983). The need to minimize the settling time of particles has led to the development of lamella settlers, which essentially consists of vertically inclined channels (Davis et al., 1989). A lamella settler may comprise of a single or multiple channels through which particles settle. Various studies have been undertaken to analyse the operation and separation characteristics of lamella settlers in which both monodisperse suspensions (Davis et al., 1988) and polydisperse suspensions (Schaflinger, 1985) were considered. Additionally, the influence of inclined channels on settling characteristics of heavy, buoyant particles in bidisperse suspensions was described by Law et al. (1988).

Davis et al. (1983) proposed that separation of particles based on differences in settling velocity could be achieved using lamella settlers. Figure 2.3.1 below illustrates a single channel inclined from the vertical at an angle of θ.

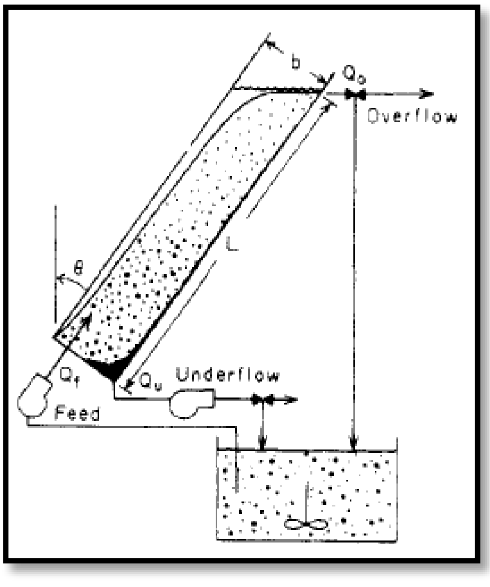

Figure 2.3.1: Continuous lamella settler (Davis et al., 1989)

A feed slurry, denoted Q_f, consisting of particles of varying size and density is fed into the lamella settler. The suspension is fractionated into an overflow (Q_o), consisting of fine particles, and an underflow (Q_u), consisting of larger particles, in a manner similar to that of a typical gravity classifier (see section 2.2.6). The vessel geometry may be adjusted to manipulate the hold-up time of settling particles, and consequently, the cut-point for separation. This is a significant control parameter since an increase in the hold-up time above the required settling time for a particular size of particle will cause particles of this size and larger to settle onto the lower surface of the channel. These large particles will return to the bottom of the channel and report to the underflow. Thus, the overflow will only contain particles smaller than the cut-point size, while the underflow will contain larger particles.

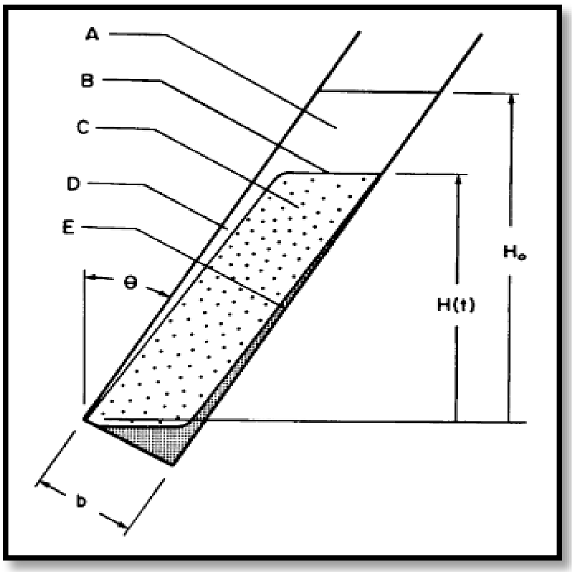

Figure 2.3.2: Varying zones in an inclined channel (Acrivos et al., 1983)

Figure 2.3.2 illustrates the different zones when a suspension settles in an inclined channel. The zones may be described as follows: A, clarified liquid above the suspension; B, interface between the clarified liquid and the suspension; C, suspension of slower settling particles; D, clarified liquid layer; E, faster settling particles accumulating on upward facing surface to form a sediment layer.

2.3.2 The Boycott effect

Aside from its application in particle classification, the principal advantage of the lamella settler compared to a conventional vertical settling tank is the substantial increase in the settling rate of particles. The improved settling rate was first observed by Boycott (1920) who noted that blood corpuscles settled faster in inclined test tubes as opposed to vertical test tubes. This phenomenon, coined “the Boycott effect”, is also applicable to solid-liquid separations in inclined channels.

It can be observed, in Figure 2.3.2, that a particle falling through a vertical channel settles a distance of O(H), where O, that is, Landau’s symbol, describes the settling distance as a function of the vertical height of the channel. However, when the channel is inclined, the settling distance of the particle becomes a function of the perpendicular distance between adjacent plates making up the channel, that is, O(b). Consequently, the settling rate is amplified by a factor of $O\left(\frac{H}{b}\right)$ which may be enlarged by reducing the perpendicular spacing (b) between adjacent plates (Acrivos et al., 1983). Essentially, particles settling in an inclined channel travel a relatively short distance before reaching the upward facing surface of the bottom plate, whereas particles settling in a conventional vertical vessel will fall a considerably larger distance before reaching the bottom.

Additionally, when the channel is inclined, the effective settling area becomes equal to the projected area of the channel height, which is considerably larger than the cross-sectional area that is available for settling in the corresponding vertical unit with equivalent dimensions. The settling area may be further increased by incorporating multiple channels in a lamella settler. The accumulation of settled particles on the surface of the upward facing plate results in the formation of a concentrated sediment layer. This sediment layer slides down to the bottom of the device due to gravitational force. Due to the incompressible nature of the suspension, as well as the continuous removal of particles from the suspension, a layer of particle-free fluid is produced. This clarified fluid layer is produced along the surface of the upper plate (see Figure 2.3.2, zone A). The buoyancy of this clarified fluid layer is considerably greater than that of the suspension, thus, this fluid rapidly moves to the top of the lamella settler. The PNK theory, jointly developed from the works of Ponder (1925) and Nakamura and Kuroda (1937), details a kinematic approach to describing the throughput advantage associated with lamella settlers as a result of the increase in effective sedimentation area.

Studies conducted by Acrivos and Hervolzheimer (1979) as well as Leung (1983) showed that the enhancement in settling rate due to increased settling area was valid only if the flow profile through the channel was laminar. Consequently, the PNK theory can only be used to describe the improvement in settling rate if laminar flow conditions prevail and the layer of clarified fluid remains stable (Doroodchi et al., 2004). The formation of waves at the interface between the particle suspension and the layer of clarified liquid (zones C & D respectively in figure 2.3.2) were observed under turbulent flow conditions in the study conducted by Acrivos et al. (1983). These waves propagated as they moved upwards through the channel and broke before reaching the surface of the suspension. This occurrence, referred to as wave-break-up, was found to be disadvantageous to the settling mechanism as fluid from the particle-free layer (zone D in figure 2.3.2) was re-introduced into the suspension (Acrivos et al., 1983).

2.4 Development and performance of the Reflux Classifier

The fundamental concepts discussed in sections 2.2 and 2.3 reach their culmination in this sub-chapter, in which the theoretical foundation required to support this study is provided. The theory underlying the principal operation of the reflux classifier is discussed, as well as a brief outline of the history preceding its development. A concise review of the performance of the reflux classifier from pilot-scale through to full-scale implementation is included, and the influence of inclined channels on the expansion behaviour of the fluidised bed is analysed. Thereafter, previous studies involving laboratory-scale investigations are examined, in particular, those relating to the suppression of the effects of particle size on separation.

2.4.1 Overview and operation

The reflux classifier (RC) is a novel gravity concentration device that is adept at both density separation and size classification (Nguyentranlam and Galvin, 2001). Structurally, the RC consists of a set of inclined channels fixed onto the top of a fluidised bed separator. Thus, the device incorporates the uniform flow conditions of the liquid fluidised bed and the well-established throughput advantage of the lamella settler. The inclined plates span the entire cross-section of the rectilinear fluidised bed. The reflux classifier has already had considerable success in Australia in separating coal mineral matter in both pilot and full-scale applications (Galvin et al., 2002; 2005). The fluidised bed section achieves separation primarily through hindered settling mechanisms which are directly related to particle size and density. Ordinarily, a fluidised bed separator is somewhat inept at separating fine denser particles and coarse lighter particles that settle with the same velocity. This flaw is overcome by the integration of the inclined lamella settler which increases the effective area for sedimentation thereby improving separation. Furthermore, Galvin et al. (2009) found that differently size particles were elutriated at a common hydraulic velocity when laminar flow conditions prevailed in closely spaced channels, consequently promoting density separation. This phenomenon is examined in more detail in section 2.4.6.

Figure 2.4.1 indicates the basic diagram of a laboratory-scale reflux classifier. The feed enters the device through a feed chute and it is suspended by a rising current of fluidisation water. The feed suspension is fluidised into the inclined channels. The primary purpose of the fluidisation zone is to ensure that the feed is evenly distributed into to each channel as successful separation is highly dependent on identical particle classification occurring in each channel (Nguyentranlam and Galvin, 2001). During this process, light particles are conveyed upwards through the channels, while entrained fine, dense particles settle out from the bulk fluid flow onto the upward facing surface of the inclined plate (see section 2.3.2). A concentrated sediment layer is formed on the plate surface that subsequently slides continuously down to the fluidised zone below. The formation of clarified liquid occurs below the downward facing surface of the inclined plate which is a direct consequence of heavy particles settling out of the suspension onto the lower plate. In pilot and full-scale systems, the unit usually features an underflow valve that opens to allow the discharge of heavy particles when the fluidised bed density exceeds a specified set point. The lighter particles are elutriated and are conveyed through the channels and exit as the overflow. Studies conducted by Acrivos and Herbolzheimer (1979) and Davis et al. (1989) identified the formation of three distinct layers within the inclined channel, that is, a suspension of particles travelling through the channel sandwiched between a particle-free liquid zone below the downward facing surface, and a coating of sediment on the upward facing surface of the channel. A reflux effect arises as a result of heavier particles returning to the bulk suspension below, and separation is enhanced due to this inherent recycling of particles (Nguyentranlam and Galvin, 2001).

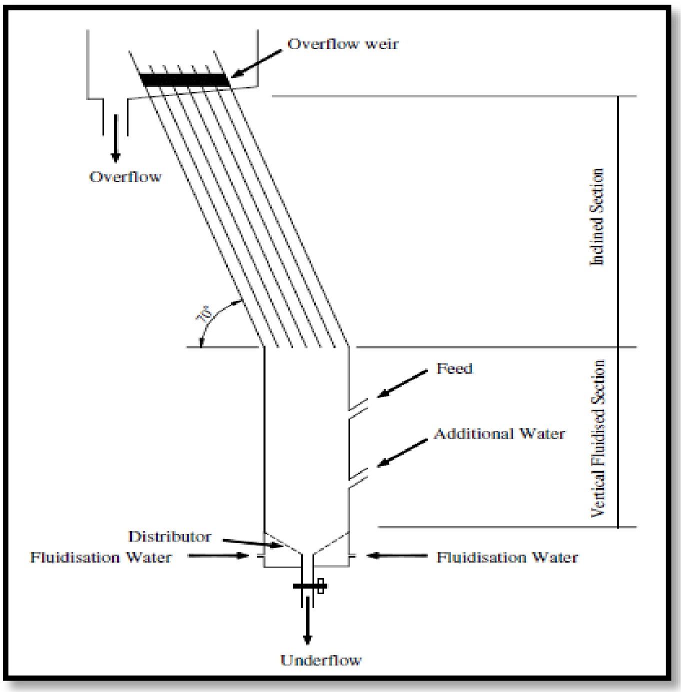

Figure 2.4.1: Schematic representation of the RC (Zhou et al., 2006)

Although it is a fairly new technology, extensive research has been carried out on the separation applications of the reflux classifier. Professor K.P Galvin, of the University of Newcastle, Australia, is considered a pioneer of this technology, and he engaged in over 10 years of collaborative research and development with Ludowici Australia before the prototype of the separator was fabricated. Moreover, Professor Galvin has reported extensively on the economic profitability and improved separation of coal and mineral matter with the RC technology (Galvin et al., 2010a).

2.4.2 Development of the reflux classifier

The study by Boycott (1920) established the basis for the relevance of inclined settling technology to mineral processing. Ponder (1925) and Nakamura and Kuroda (1937) built on Boycott's work and developed the earliest recognised theoretical description of this phenomenon, widely accepted as the PNK kinetic model (Galvin, 2012). The development of the industrial application for inclined sedimentation as well as the synergy between settling particles and inclined channels was examined in several papers (Acrivos and Herbolzheimer, 1979; Davis et al., 1989; Zhang and Davis, 1990; Galvin et al., 2001). Professor Galvin first took an interest to sedimentation in inclined channels after working on a simple coal beneficiation system consisting of a single inclined tube with a length of 1 m and a diameter of 25 mm (Thompson and Galvin, 1997). Following this, Galvin engaged in work on the application of teetered-bed separators (TBSs) to the beneficiation of coal and mineral matter (Galvin et al., 1999). The rationale behind the introduction of TBSs in mineral processing was the need to attain a higher recovery of coal than was possible with conventional spirals. After involvement in these projects, the incorporation of these two technologies to create the reflux classifier was undertaken as described in the patent, a reflux classifier (Galvin, 2001), and further research and development ensued.

2.4.3 Pilot-scale research

Pilot-scale work was initiated while the reflux classifier technology was still in its infancy. This was largely due to the notion that the straightforwardness of the idea, as well as existing knowledge on the practical and theoretical operation of the TBS and fluidised beds, would result in successful implementation. However, multiple problems were faced in the first 6 months of trial work and the entire system was subsequently redesigned (Galvin, 2012). The primary concerns pertained to inadequate control of the feed delivery system, underflow discharge valve and feed entry (Galvin, 2012).

Galvin et al. (2002) reviewed the pilot plant trial of the reflux classifier. The experimental work took place at a coal beneficiation plant using a device with a 0.6 m × 0.6 m cross-section. The feed slurry was introduced into the reflux classifier with an average pulp density of 47% solids and consisted predominantly of -2 mm coal particles. The vessel included three distinct lamella sections, all of which were inclined at 60°, to extract a rejects, middling and product stream. The rejects plates were located immediately above the fluidisation zone and consisted of 0.6 m long plates with a channel spacing of 100 mm. The middlings section above the rejects plates consisted of 0.6 m long plates with a spacing of 50 mm. The final set of plates, 1.2 m long and 30 mm apart, was located above the middlings section. The configuration is shown in figure 2.4.2 below.

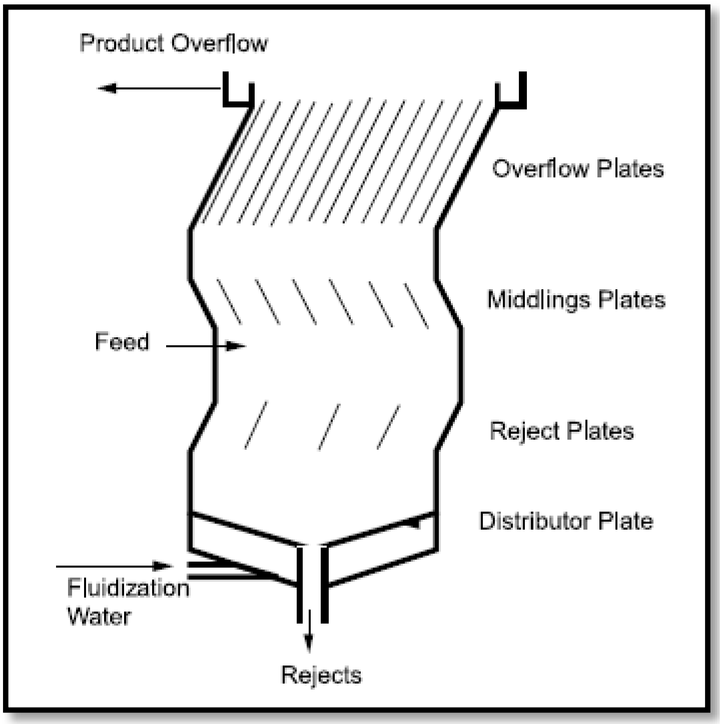

Figure 2.4.2: Schematic of pilot-scale RC (Galvin et al., 2002)

The results obtained during these tests were compared with those obtained using a TBS. It was noted that as the fluidisation rate in the TBS was increased, a considerable drop in the suspension density in the fluidised zone was observed. Consequently, large light particles sank to the underflow, and separation was impaired. It was noticed that a higher recovery of large light coal particles was possible when using the RC (Galvin et al., 2002). Consequently, the RC was more flexible in its application, and the loss of large valuable coal to rejects that was evident in the TBS was minimised in the RC (Galvin et al., 2002). After a full washability analysis was undertaken; it was evident that the RC indicated a markedly lower variation in separation density with particle size, thus achieving a better separation. Additionally, it was discovered that the fluidisation water required with respect to the feed was approximately 30% of that of the TBS. This was remarkably low as the RC throughput was many times greater than that of a conventional TBS. A solids loading of 47 t/m^{2}h and an E_p of 0.14 across the feed size range was attained, and the trial was deemed successful (Galvin, 2012).

2.4.4 Inclined channels and expansion behaviour

The empirical model developed by Richardson and Zaki (1954) fully describes the homogeneous expansion of suspensions in a fluidised bed (Galvin, 2012). In a study conducted by Galvin and Nguyentranlam (2002), the effects of integrating parallel inclined plates with a liquid fluidised bed were examined. The experiment consisted of progressively lowering the plates into the fluidisation zone while maintaining a constant fluidisation rate. The suspension was allowed to expand into the system of inclined channels. Heavy particles settled out of the bulk flow and formed a sediment layer on the lower plates, which subsequently returned to the fluidisation zone below. During the test, the fluidisation water was maintained at a rate that was too low to result in particles traversing the entire channel and reporting to the overflow. Consequently, the entire initial inventory of solids was retained in the system, and it was observed that the suspension density increased as the plates were gradually lowered. Galvin and Nguyentranlam (2002) developed a model based on their findings to explain the effects of a reduced fluidisation zone height on the suspension density as well as the length of the sediment layer along the inclined channel. The determination of the inclined channel length that was needed to facilitate complete segregation of the particles from the bulk flow onto the sediment layer was vital. The model shared traits with PNK kinematic description for inclined settling, and it was based on a simple system consisting of a single channel and a mono-dispersed suspension. A theoretical application of their model showed that a wide range of suspension densities could be obtained using a single fluidisation rate which was not possible when using a conventional fluidised bed alone. Additionally, the validity of the model was examined by conducting experiments using a 13 channel lamella settler built over a liquid fluidised bed. These tests showed that sufficiently high suspension densities could be maintained even when a superficial velocity several times larger than the particle terminal velocity was used. This is important to solid-liquid separations as a suitably high suspension density will promote separation according to density, in a manner similar to dense medium separation. This was primarily due to the incorporation of inclined plates, as high superficial velocities in conventional fluidised beds leads to inversion and a marked reduction in suspension density (Moritomi et al., 1982).

Further work on this subject was conducted by Doroodchi et al. (2004) and an improved version of the model proposed by Galvin and Nguyentranlam (2002) was developed. Doroodchi et al. (2004) conducted more rigorous experiments consisting of both mono-dispersed and binary suspensions. The effects of both fluidisation rate and solids inventory on the expansion characteristics of the bed were analysed, and the model accounted for certain parameters that were omitted during the original work by Galvin and Nguyentranlam (2002). The suspension densities as well as the length of the sediment layer along the inclined channel were described as a function of superficial velocity. Such models adept at predicting the sediment layer length is vital when designing units in which the total inventory of particles is to be retained, and knowledge on the suspension concentration is crucial in applications such as crystallisation and adsorption (Nguyentranlam and Galvin, 2004).

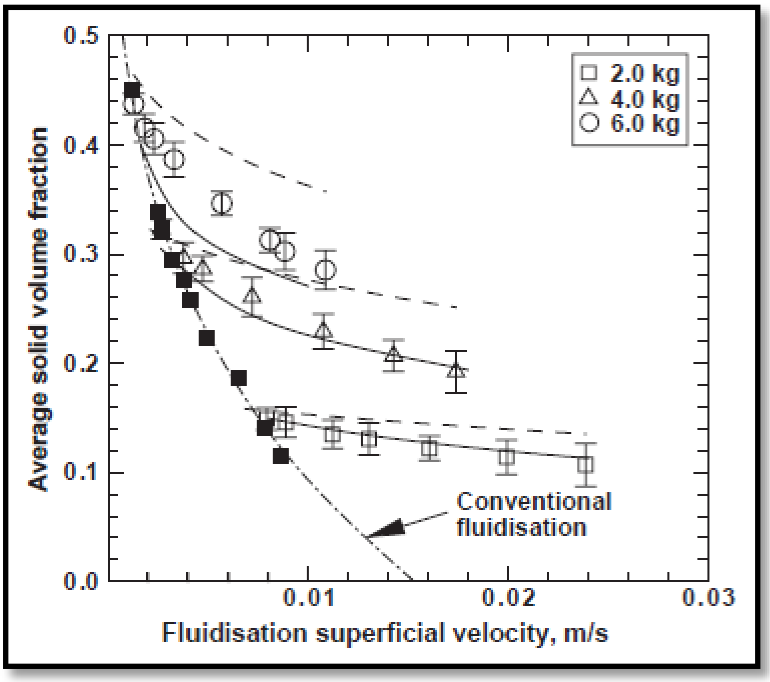

Figure 2.4.3: Average solids volume fraction as a function of superficial velocity (Doroodchi et al., 2004)

Figure 2.4.3 above indicates the influence of superficial velocity on the expansion characteristics of a mono-dispersed suspension of ballotini glass spheres. The theoretical results, predicted from the model, and experimental results for a conventional fluidised bed are indicated by the dot-dashed curve and filled squares respectively. The behaviour encountered experimentally when the suspension was allowed to expand into inclined channels is indicated by the open squares, triangles and circles, which correspond to varying solids inventories. The improved model by Doroodchi et al. (2004) was used to produce the continuous curves, while the original model by Galvin et al. (2002) corresponds to the dashed curves.

From figure 2.4.3, it can be deduced that the relationship between the average solids volume fraction and superficial velocity for the conventional fluidised bed, depicted by the dot-dashed curve, represents a bijective function, or one-to-one correspondence. There is a severe deviation from the dot-dashed curve when the suspension was allowed to expand into the lamella section, and the one-to-one correspondence is no longer applicable as varying suspension densities can be generated at the same fluidisation rate by increasing the solids inventory. For the system under investigation in the report by Doroodchi et al. (2004), the terminal velocity of the particles was determined to be 0.015 m/s. It is apparent that a significant bed density is still possible when fluidisation rates in excess of the terminal velocity are employed. It can also be seen that the experimental data obtained during expansion into the inclined channels agrees more closely with the model by Doroodchi et al. (2004).

2.4.5 Full-scale application

The positive results attained from the pilot-scale tests, as well as further advancements in the understanding of the synergy between fluidised bed expansion and inclined channels, led to the implementation of a full-scale unit. The first full-scale reflux classifier, model RC1800, was installed in 2003 at Bloomfield Collieries in New South Wales, Australia (Galvin, 2012). In a similar manner to the pilot-scale study, there was an onset of design issues in the early stages of the trial. The scaling-up of the device resulted in a major problem with the overflow weir. The larger horizontal distance that the overflow fraction had to traverse to reach the overflow weir led to particles unexpectedly settling out of the bulk flow and sedimenting over large sections of the device. Additionally, the suspension was not uniformly distributed into each channel. In order to eliminate these issues, the design of an overflow launder was undertaken to reduce the horizontal distance traversed by the particles and facilitate identical flow through each channel (Galvin and Munro, 2004). Multiple overflow launders were incorporated into the housing of the lamella section to intersect with the channels. Another issue that required attention was the abrasion of the fluidisation water jets as well as erosion of the underflow valve (Galvin, 2012). Solid particulate matter in the fluidisation water sometimes obstructed the fluidisation water jets, resulting in erratic bed expansion. However, these issues were rectified and the RC1800 was permanently integrated into the processing circuit of Bloomfield Collieries in late 2004 (Galvin, 2012).

In addition to the study undertaken at Bloomfield Collieries, Galvin et al. (2005) reported comprehensively on the separation performance of a full-scale device, as well as its sensitivity to varying density set points, fluidisation velocities and feed rates. The operation of a device measuring 1.8 m × 1.9 m in cross-section and 3.5 m in height was tested at the same coal preparation plant as the pilot-scale unit (Galvin et al., 2002). The inclined section housed plates of 1.0 m in length with a perpendicular spacing of 120 mm. The internal launder design developed by Galvin and Munro (2004) was incorporated into the unit. The initial feed to the unit was 60 tph, which constituted approximately 10% of the total plant feed. A rate of 15 l/s, which amounted to a superficial velocity of 0.0044 m/s, was used for fluidisation water and additional water at 3.5 l/s was used to dilute the feed. A relative density set point of 1.55 was selected. The relative density of the bed was determined in a similar manner to the pilot-scale unit using pressure transducers situated along the height of the vertical fluidisation column. The analysis of the ash content of the feed, overflow and underflow revealed that variations in the fluidisation water rate produced an extremely subtle effect on the separation. This was particularly true for particles in the -2 mm + 0.25 mm size range, which represented roughly 80% of the feed. The minimal interference with the separation was partly due to the ability of lamella section to minimise conveyance of fine dense solids to the overflow. Another contributing factor was the tight control of the PID in maintaining the set point regardless of the fluidisation rate. The prospect of pursuing separations based on both higher and lower ash contents was determined by varying the density set point between 1.22 and 1.65 relative density units (RD). This investigation showed that the cut point varied in direct response to the set point. Additionally, it was observed that the cut point was typically 0.2 RD greater than the selected set point. The partitions curves depicted similar trends to those of the pilot-scale study (Galvin et al., 2002). Furthermore, the variation of the separation density (D_{50}) and E_p value with particle size was again similar to those obtained during the pilot-scale trials, thus, it was concluded that the separation performance was successful.

2.4.6 Laboratory-scale studies

As the reflux classifier continued to gain wide spread interest, the phenomenon of elutriating particles based solely on their density by inertial lift became an area of prime research and development. The work of Boycott (1920), Ponder (1925) and Nakamura and Kuroda (1937) described, in fundamental terms, the improvement in separation capacity of the reflux classifier that resulted from the use inclined channels. This underlying throughput advantage over typical fluidised beds, denoted F, can be quantified by employing the principles of the PNK kinetic model. The throughput advantage accredits the improved rate of separation to the larger effective area available for particle segregation, and it is essentially the segregation area in a reflux classifier relative to segregation area in a typical fluidised bed (Laskovski et al., 2006).

$$F = 1 + \left(\frac{L}{z}\right)\cos\theta\sin\theta \tag{2.4.6.1}$$

Where the ratio of the channel length (L) and the perpendicular channel width (z) is referred to as the aspect ratio, and θ denotes the angle of inclination of the channel relative to the horizontal.

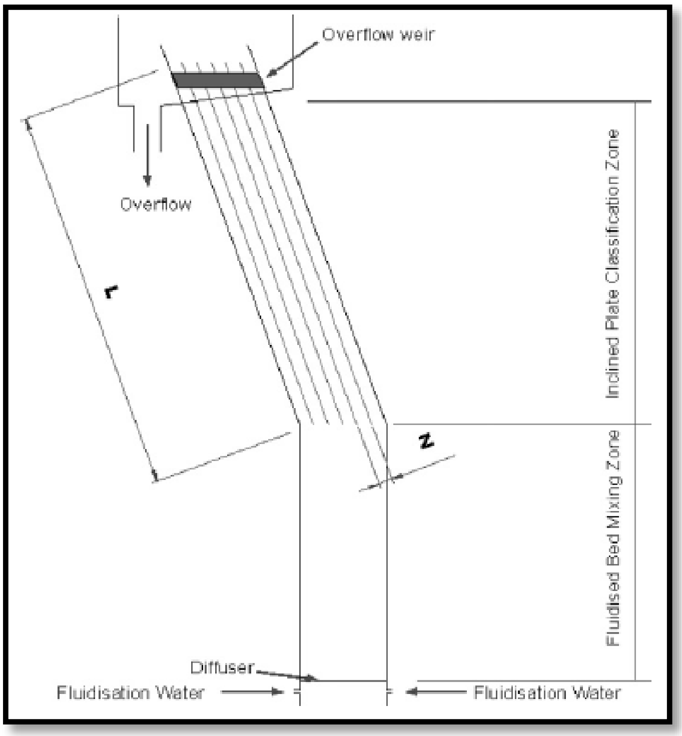

Figure 2.4.4: Diagram of RC showing plate length (L) and channel spacing (z) (Walton et al., 2010)

The expression simply states that the effective segregation area is larger than the cross-sectional area of the vertical section by a factor of F. It is evident from equation 2.4.6.1 that the throughput advantage of a reflux classifier will increase inexorably as the aspect ratio is increased, which is unreasonable. Thus, equation 2.4.6.1 describes the theoretical throughput advantage defined by the PNK model.

Laskovski et al. (2006) conducted a series of comprehensive batch experiments in a laboratory-scale reflux classifier where the fluidisation zone had a cross-section 0.10 m × 0.060 m. The study reviewed, in detail, the effects of varying the superficial velocity, length of inclined channels (L), perpendicular channel width (z) and the inclination angle (θ) on the separation achieved. The experiments revealed that optimum elutriation on the basis of density occurred when the channels were inclined at 70° from the horizontal. The simple laboratory-scale device allowed plates to be inserted into the lamella section to create the channel, thus, varying numbers of channels could be used during the tests. Consequently, the channel width (z) could be either increased or decreased based on the number of channels used. The investigation revealed that the actual throughput advantage is less than F, and can be approximated by the ratio of the superficial fluidisation velocity through the vertical section, v, relative to terminal velocity of the particle that only just reaches the overflow, v_t, in suspensions with low solids contents (Zhou et al., 2006). Furthermore, Laskovski et al. (2006) presented the idea of segregation efficiency within inclined channels:

$$\eta = \frac{v/v_t}{F} \tag{2.4.6.2}$$

Thus, the segregation efficiency, η, is the ratio of the actual throughput advantage relative to the theoretical throughput advantage.

During their campaign, Laskovski et al. (2006) examined the influence of particle density and size by testing a range of systems. A solids volume fraction of roughly 0.05 was used in each test, thus, equation 2.4.6.2 could be used to evaluate the actual segregation efficiency. It was observed that as increase in the aspect ratio, by using more channels, was met with a corresponding decrease in the particle separation size. After subsequent tests involving the use of even more channels, it was seen that the separation size began to increase after eventually reaching a minimum. It was suggested that the eventual increase in separation size was a consequence of the increased proclivity for re-suspension of lower density particles in the sediment layer. It was noted that the re-suspension was a result of higher shear and lift forces in channels with high aspect ratios (Galvin et al., 2010b). Using the results obtained from the variety of tests, Laskovski et al. (2006) developed an empirical model that was capable of determining the segregation efficiency of the inclined channels, shown below:

$$\eta = \frac{1}{1 + 0.134\cos\theta {Re_t}^{0.33}\left(\frac{L}{z}\right)} \tag{2.4.6.3}$$

Where Re_t is the Reynolds number of the particle that has an equal likelihood of reporting to either the overflow or underflow.

Essentially, the actual segregation efficiency of the channel steadily decreases as the channels become narrower. Intuitively, this can be deduced from equations 2.4.6.2 and 2.4.6.3 where an increase in F, resulting from a higher aspect ratio, leads to a reduction in η.

It is important to note that the segregation efficiency, η, is an entirely different concept from separation efficiency in gravity concentration. Lower channel segregation efficiencies actually promote the hydraulic transport of light particles through the channel towards the overflow. In contrast, heavier particles experience higher segregation efficiencies as inertial lift forces from increased shear within the channel typically have a negligible effect on them. Consequently, these denser particles experience a greater settling area, and slide down the channels to be conveyed to the underflow (Galvin et al., 2010c). The synergistic effect of the contrasting segregation efficiencies results in a better separation between heavy and light particles, and consequently, improved separation efficiency (Galvin et al., 2010c).

The notion of particle re-suspension is crucially important in the context of separation within inclined channels. Acrivos and Herbolzheimer (1979) found that the re-suspension of light particles entrained in the sediment layer was enhanced by convection resulting from buoyancy forces. The development of these buoyancy driven forces were encouraged by the formation of clarified liquid below the surface of the upper plate of the inclined channel, which was subsequently promoted by a higher aspect ratio. It was also noted that a rotation of the suspension in the channel as a result of the combined effect of the downward motion of the sediment and the upward motion of the convection currents further aided re-suspension of lighter particles, and consequently, a sharper separation according to density.

The actual throughput advantage, that is, the ratio of the superficial velocity relative to the particle terminal velocity, can be determined by combining equations 2.4.6.1, 2.4.6.2 and 2.4.6.3.

$$\frac{v}{v_t} = \eta F \tag{2.4.6.4}$$

$$\frac{v}{v_t} = \frac{1 + \left(\frac{L}{z}\right)\cos\theta\sin\theta}{1 + 0.134\cos\theta {Re_t}^{0.33}\left(\frac{L}{z}\right)} \tag{2.4.6.5}$$

The dependence of the actual throughput advantage on the aspect ratio and the particles Reynolds number, Re_t, is valid for a broad range of conditions, however, reliable results are only obtained when θ is between 45° and 70° (Zhou et al., 2006). Equation 2.4.6.5 indicates that the actual throughput advantage of a reflux classifier increases with the aspect ratio until a maximum limit is reached. Thereafter, it behaves asymptotically with respect to this limit, as the increased tendency for re-suspension reduces segregation efficiency, which in turn limits the actual throughput advantage (Galvin et al., 2010a).

Figure 2.4.5 indicates that the highest throughput advantage can be achieved for an angle of inclination in the range 68-72° for relatively high aspect ratios.

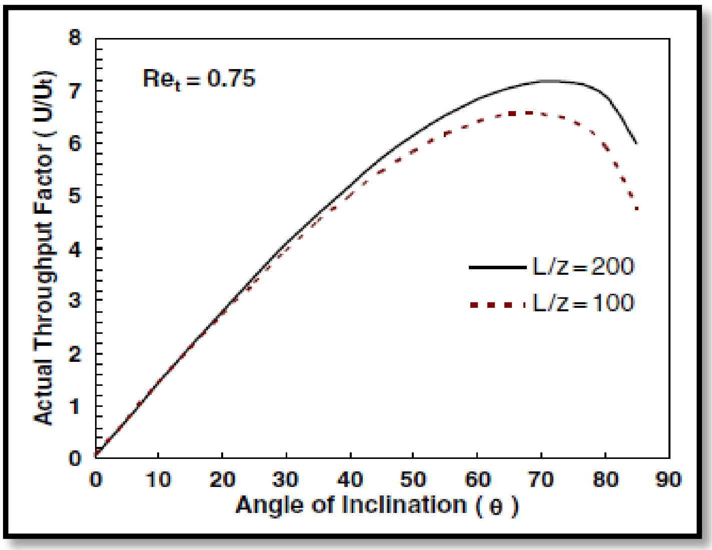

Figure 2.4.5: Actual throughput advantage as a function of inclination angle (Zhou et al., 2006)

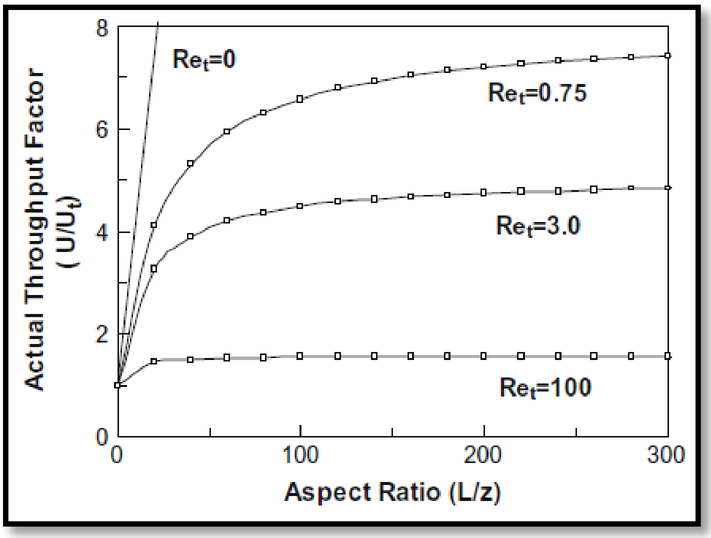

Figure 2.4.6: Throughput advantage as a function of aspect ratio for varying particle Reynolds numbers (Galvin et al., 2010c)

Figure 2.4.6 depicts the effect of the aspect ratio of the channels on the throughput advantage achieved in a reflux classifier. The throughput advantage approaches the asymptotic limit determined by the Reynolds number of the critical particle that is only just conveyed to the overflow. The curve for a Reynolds number of zero represents the throughput advantage defined by equation 2.4.6.1, and it is seen that an unrealistic and indefinite increase in the throughput advantage is possible. The remaining three curves are generated from equation 2.4.6.5 and correctly depict the asymptotic nature of the actual throughput advantage.

Laskovski et al. (2006) demonstrated that by evaluating the limit of equation 2.4.6.5 as the aspect ratio approaches infinity, the throughput advantage for high aspect ratio channels can be described as follows:

$$\frac{v'}{v_t} = 7.5{Re_t}^{-0.33} \tag{2.4.6.6}$$

In the above equation, $v' = v/\sin\theta$, is the superficial velocity of the fluid within the inclined channel, and the model is independent of channel gap, z. Essentially, equation 2.4.6.6 defines the superficial velocity through the channel, v', that is necessary to transport a particle of particular size and density through the channel and to the overflow (Galvin et al., 2010c). Figure 2.4.7 below illustrates the variation in separation density as a function of particle size. The curves shown are plotted for a fixed channel superficial velocity, v', that occurs in reflux classifiers, and for a fixed terminal velocity, v_t, that is characteristic of conventional fluidised bed separators.

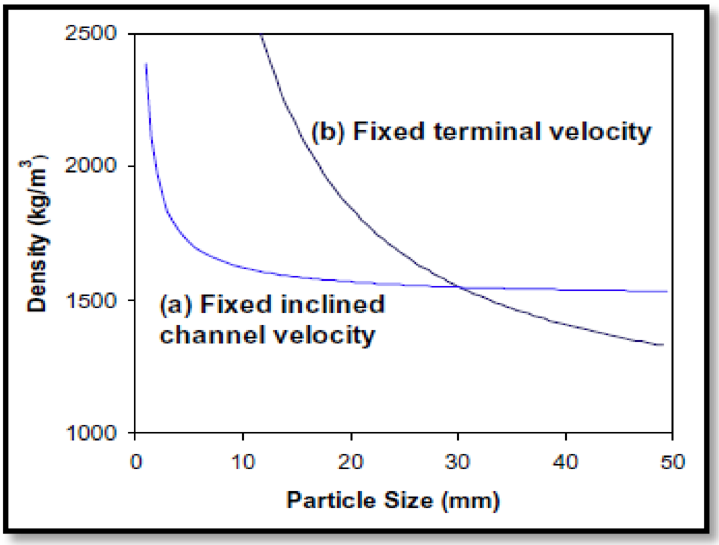

Figure 2.4.7: Separation density as a function of particle size (Galvin et al., 2010c)

Both curves (a) and (b) show that heavy fine particle and light coarse particles are transported by the same velocity, however, the phenomenon that occurs under conditions of fixed channel velocity is very different to that of a fixed terminal velocity. Curve (a) shows that particles varying widely in size are conveyed at roughly the same density, therefore, the hydrodynamics of inclined channels encourage separation according to density, with little dependence on particle size. Curve (b) depicts significant variation in the particle density with particle size, thus, particle size affects separation in conventional fluidised beds to a larger degree (Galvin et al., 2010c).

The work of Laskovski et al. (2006) greatly contributed to the understanding of the principle of operation of the reflux classifier. The study showed that particle transport within the inclined channels became progressively more dependent on particle density as the channels became narrower. This was observed when the channel spacing was reduced to 8.90 mm and lighter PVC particles were re-suspended and transported through the channel. However, it was also noted that particle size still contributed to the separation achieved. In this regard, the investigation failed to identify the conditions that enabled density-based separation, and further work on this subject was required. Galvin et al. (2009) conducted an investigation with the aim of significantly reducing the influence of particle size on transport through the channels, thereby enabling consistent and controlled elutriation of particles based entirely on density. The campaign involved the use of closely spaced channels to suppress the effects of particle size. It was discovered that the model by Laskovski et al. (2006), that is, equations 2.4.6.5 and 2.4.6.6, gave unrealistic and incorrect predictions when applied to the results obtained. It was determined that while the empirical model developed by Laskovski et al. (2006) was valid for a broad range of conditions, it appeared to be more relevant to channels that were more widely spaced apart. Galvin et al. (2010a) categorised channels with a perpendicular spacing (z) greater than 9 mm as widely spaced for coal processing.

The study by Galvin et al. (2009) adopted a novel approach of reducing particle size effects, and utilised a radical inclined section geometry, consisting of 24 channels with a length (L) of 1000 mm and a perpendicular spacing (z) of 1.77 mm. A broad range of tests were performed, and the results were used to develop a new model that was specifically applicable to closely spaced channels. The experiments were conducted under batch conditions, and the narrow spacing of the channels resulted in stable flow conditions in the laminar flow regime. Another vital effect of the narrower channels was the formation of an intense shear-induced lift force within the channel that aided the transport of particles through the channels. An important aspect of the method of approach was the shift in the hydrodynamics of transport through the channels, in particular, its effect on the channel superficial velocity, v′.

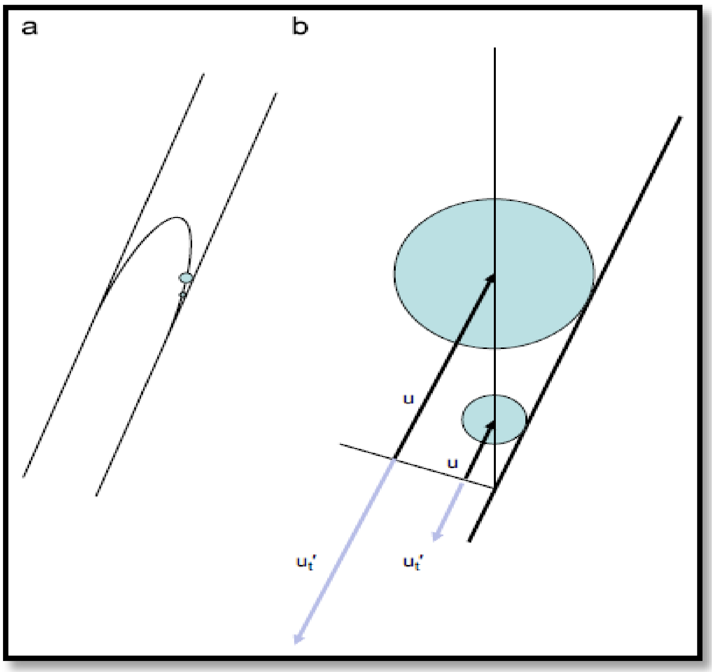

Figure 2.4.8: (a) Parabolic laminar velocity profile in the channel; (b) Schematic of differently sized particles adjacent to channel wall (Galvin et al., 2009)

Figure 2.4.8(b) shows two particles of different sizes situated on the surface of the lower plate of the inclined channel. Under normal circumstances, the particles in the sediment layer along the surface will slide downward to the fluidisation zone below, before reporting to the underflow. In this scenario, the drag force exerted on the particle by the upward flow of liquid through the channel is inadequate to oppose the downward sliding of the particles. However, the use of exceptionally close spaced channels produces an immense shear force within the channel, which consequently gives rise to larger local elutriation velocities close to the surface of the lower plate where the particle resides. Vance and Moulton (1965) showed that for particles characterised by particle Reynolds numbers between 1 and 500, that is, particles settling in the intermediate regime, the terminal velocity of the particle shares an approximately proportional relationship with the its diameter. A similar relationship is applicable within the channel in which the local elutriation velocity adjacent to the channel surface varies in direct proportion with the particle diameter due to the high shear rates within the channel. Additionally, a lift force is exerted on the particle in the normal direction with respect to the channel surface, rendering contact friction with the surface almost negligible

(Krishnan and Leighton, 1995). Essentially, small dense particles are subject to correspondingly low local elutriation velocities, and therefore remain in the sediment layer and slide down the channel. Small, light particles are readily elutriated and report to the overflow. Large, light particles experience correspondingly large local elutriation velocities as well as inertial lift, and are consequently transported upwards through the channel to the overflow. Thus, differently sized particles can be elutriated using a common channel superficial velocity, v' (Galvin et al., 2009). As a result of these effects, separation occurs primarily according to density (Galvin et al., 2010b).

Through rigorous derivation, Galvin et al. (2009) showed that the superficial velocity of the fluid within the inclined channel, v', that was necessary to transport a specific particle through the channel, with a perpendicular spacing of z, could be expressed as:

$$\frac{v'}{v_t'} = \frac{z}{3d} \qquad (2.4.6.7)$$

In the model above, v_t' is the terminal velocity of the particle, with a diameter d, in the tangential direction with respect to the channel surface. Through a range of elutriation experiments and the application of both the model by Laskovski et al. (2006) and the newer model shown above, Galvin et al. (2009) developed an expression that could be used to determine if a channel spacing may be classified as either wide or narrow.

$$z = 26dRe_t^{-0.33} \qquad (2.4.6.8)$$

A channel is classified as wide if the perpendicular spacing of the channel exceeds the result from equation 2.4.6.8, and the model by Laskovski et al. (2006) would be applicable. A channel would be categorised as narrow if the perpendicular spacing of the channel was less than that predicted by 2.4.6.8. Accordingly, the model developed by Galvin et al. (2009) would be used to describe particle transport through the channel in this scenario. The applicability of both models is only valid if the solids volume fraction is sufficiently low so that the formation of an autogenous dense medium does not take place. Typically, a solids volume fraction of 0.05 is used in batch elutriation experiments (Laskovski et al., 2006; Galvin et al., 2009).

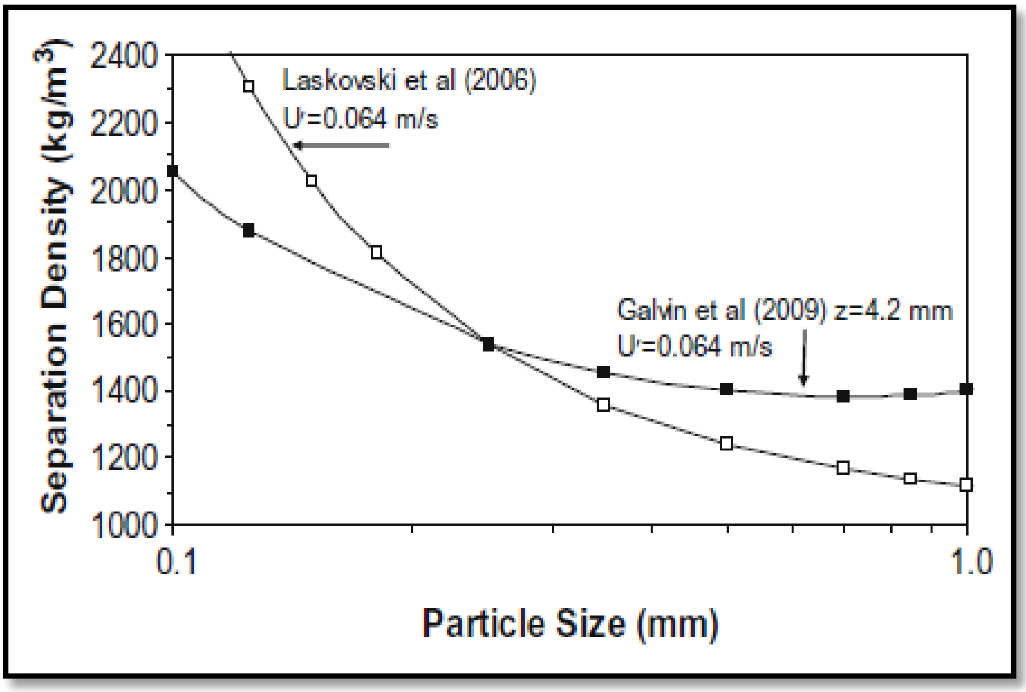

Figure 2.4.9: Comparison of model predictions (Galvin et al, 2010b)

Figure 2.4.9 depicts the variation in separation density with particle size as predicted by the model for wider channels, denoted by the unfilled squares, and the model for narrow channels, denoted by the filled squares. The curves were generated for a fixed channel superficial velocity, v′, of 0.064 m/s. The curve generated by the model of Laskovski et al. (2006) shows significantly more variation in separation density with particle size than that predicted by the model of Galvin et al. (2009) for narrow channels. Although some variation occurs for extremely small particles sizes, it is evident that the use of narrower channels promotes elutriation of particles based on density even without the formation of an autogenous dense medium (Galvin et al., 2010b).

The advancement in the theoretical description of the reflux classifier, as well as the identification of the conditions required to suppress the effects of particle size on separation, inspired further investigations into achieving selective density separation in systems involving both fine and coarse particles. Galvin et al. (2010b) conducted continuous steady-state separation tests on coal. In their study, a laboratory-scale reflux classifier was used consisting of 12 channels with a perpendicular channel spacing of 4.20 mm. With this configuration, an E_p of 0.06 was obtained across the size range 0.25 to 2.0 mm, and reasonable separation was attained down to a particle size of 0.075 mm. Figure 2.4.10 depicts the Ecart probable error as a function of particle size. In the figure, the data obtained from

Galvin et al. (2010b) is compared with that obtained from the full-scale trial (Galvin et al., 2004), in which a channel spacing of 120 mm was used. Figure 2.4.10 shows that the E_p values obtained during the laboratory tests are much lower than those obtained during the full-scale trial over a large size range.

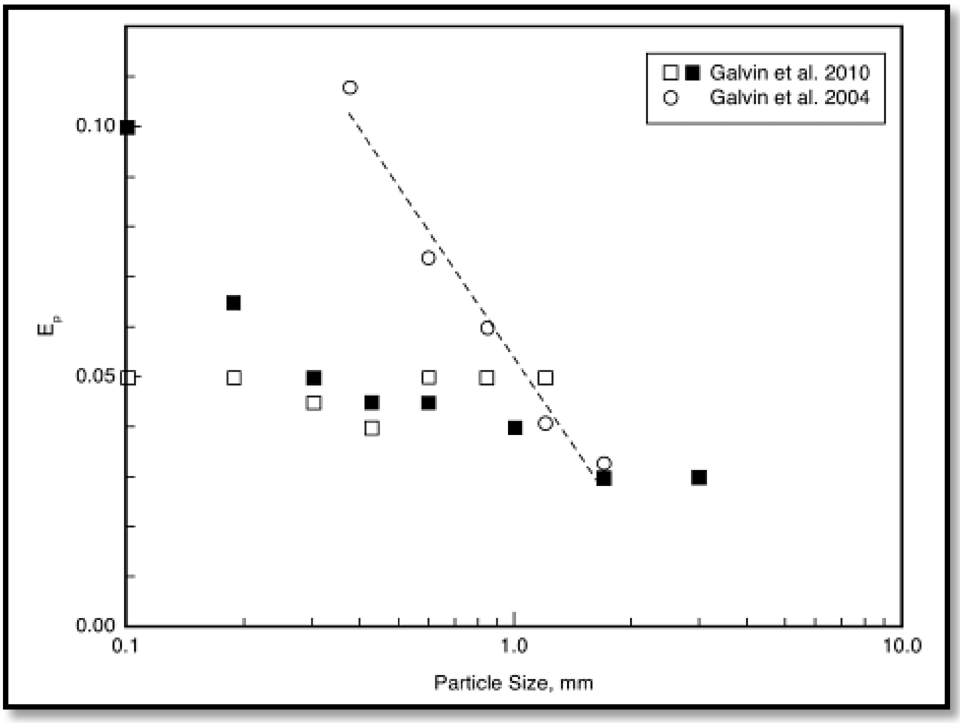

Figure 2.4.10: Ecart probable error as a function of particle size (Galvin, 2012)

The benefits of using closely spaced channels led to Ludowici Australia designing the RC2020, a completely new model that promoted laminar flow through the channels by incorporating a narrow channel spacing of 6 mm (Galvin, 2012). The first unit was sold in June 2009 and wide spread interest resulted in seven countries purchasing the RC2020 in the same year. Sedgman, a mineral processing company in Australia, undertook a full-scale trial of the RC2020 towards the end of 2009. An E_p of 0.07 was obtained across the size range of 0.25 to 2.0 mm, and the variation of separation density with particle size closely agreed with data obtained from previous laboratory-scale tests (Galvin, 2012).

2.4.7 Summary of laboratory-scale reflux classifier design

Previous studies undertaken using a laboratory-scale reflux classifier routinely incorporated a vertical fluidisation column characterised by a cross-sectional area of $60 \times 100\ \mathrm{mm}^2$ (Laskovski et al., 2006; Zhou et al., 2006; Galvin et al., 2010b; Galvin et al., 2010c). Additionally, it was found that the angle of inclination of the lamella section that effected separation the most was 70°. In cases where various channel gaps were required for testing, the lamella section was constructed with grooves along the inside of the front-facing and back-facing walls into which varying numbers of plates could be inserted to form channels with the required perpendicular width (Laskovski et al., 2006; Zhou et al., 2006). A simpler approach to this design was undertaken in the current project, and the details of which are outlined in section 3.1.

CHAPTER 3: METHODOLOGY

3.1 Experimental equipment: Overview of the Reflux Classifier

A laboratory scale reflux classifier was constructed from Perspex and designed as 3 detachable sections, namely, the inclined lamella section, the vertical fluidisation column section, and an inverted square pyramid below the column that housed both the distributor plate and the inlet fluidisation water port. The advantage of dividing the device into 3 separable sections was that it facilitated maintenance and repairs as the unit could easily be broken down and transported to the workshop. However, the primary purpose of this design was to enable the use of interchangeable inclined sections with varying channel widths.

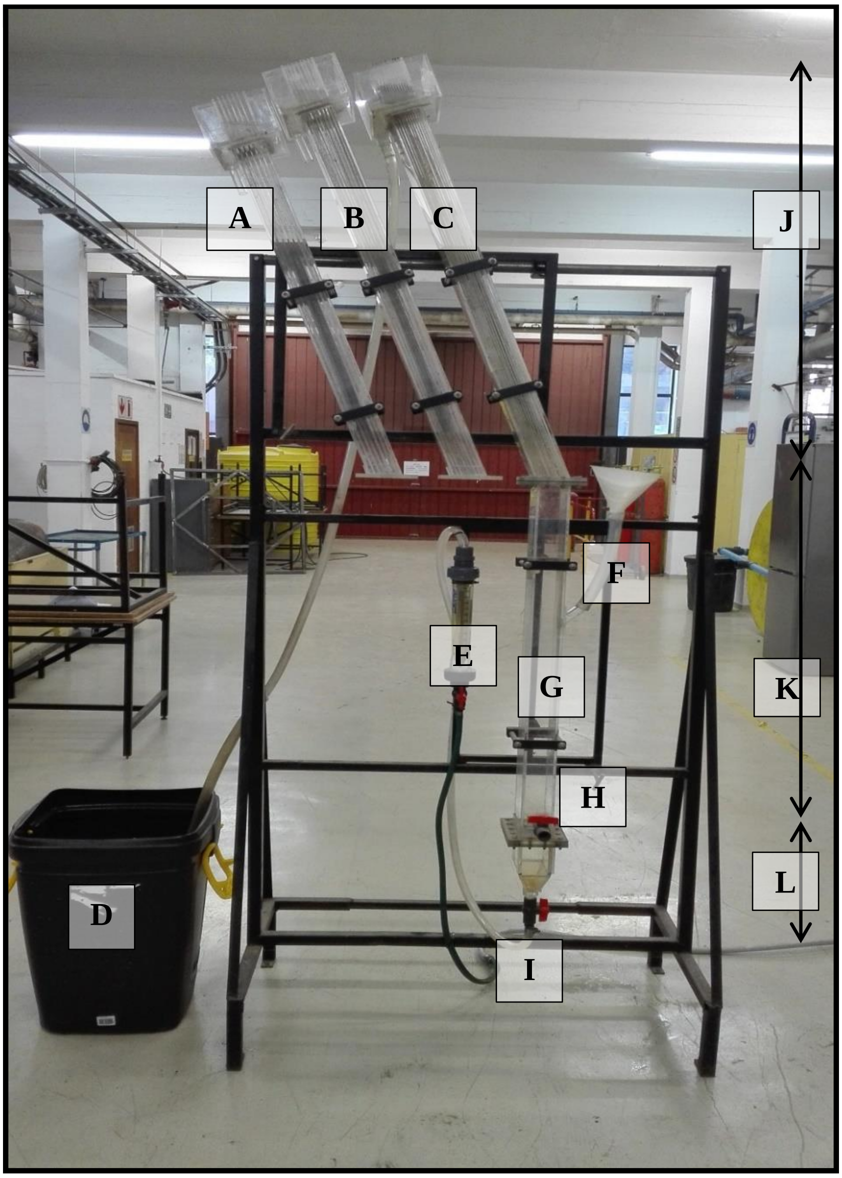

Figure 3.1.1: Photograph of device with most important components labelled

Table 3.1.1: Primary components of the Reflux Classifier seen in figure 3.1.1

Legend	Component indicated
A	6 Channel inclined section
B	8 Channel inclined section
C	12 Channel inclined section
D	Overflow product collection
E	Rotameter
F	Feed chute with attached funnel
G	Vertical fluidisation column
H	Outlet port for recovery of remains
I	Fluidisation water inlet
J	Inclined lamella section
K	Vertical column section
L	Distributor plate section

Figure 3.1.1 shows the major components of the laboratory scale unit and the 3 individual sections of the device (J, K and L) are highlighted. The detachable nature of the device allowed the incorporation of 3 distinct lamella sections inclined at 70° from the horizontal. The choice of angle was motivated by data previously reported in literature. Laskovski et al. (2006) conducted an experimental campaign in which various lamella sections with angles of inclination ranging from 45°-70° were examined. The results indicated an optimum angle of inclination of 70°, which was also verified by Zhou et al. (2006). Each inclined section consisted of 6, 8 and 12 equally spaced channels with perpendicular channel widths of 6.50, 4.50 and 2.10 mm respectively. The 3 inclined sections were mounted onto a cylindrical cross-piece along which each inclined section was free to move horizontally. Thus, each channel configuration could be easily interchanged and tested independently by sliding the relevant inclined section horizontally until it aligned with the vertical fluidisation column below. Figure 3.1.2 shows the back view of the inclined sections.

The vertical fluidised column was characterised by a width (front) of 60 mm, a depth (side) of 100 mm and a height of 1000 mm. The feed chute was located 600 mm from the bottom of the column, with an internal nozzle diameter of 15 mm. The outlet nozzle on the front face of the column had an internal diameter of 15 mm and was located 30 mm from the bottom, and facilitated the recovery of the material that remained behind after the run (underflow or "remains"). The column was mounted onto a mechanism that allowed vertical movement which enabled it to be lifted and lowered from the interchangeable inclined sections.

Figure 3.1.2: Back view of the 3 inclined sections showing the sliding mechanism

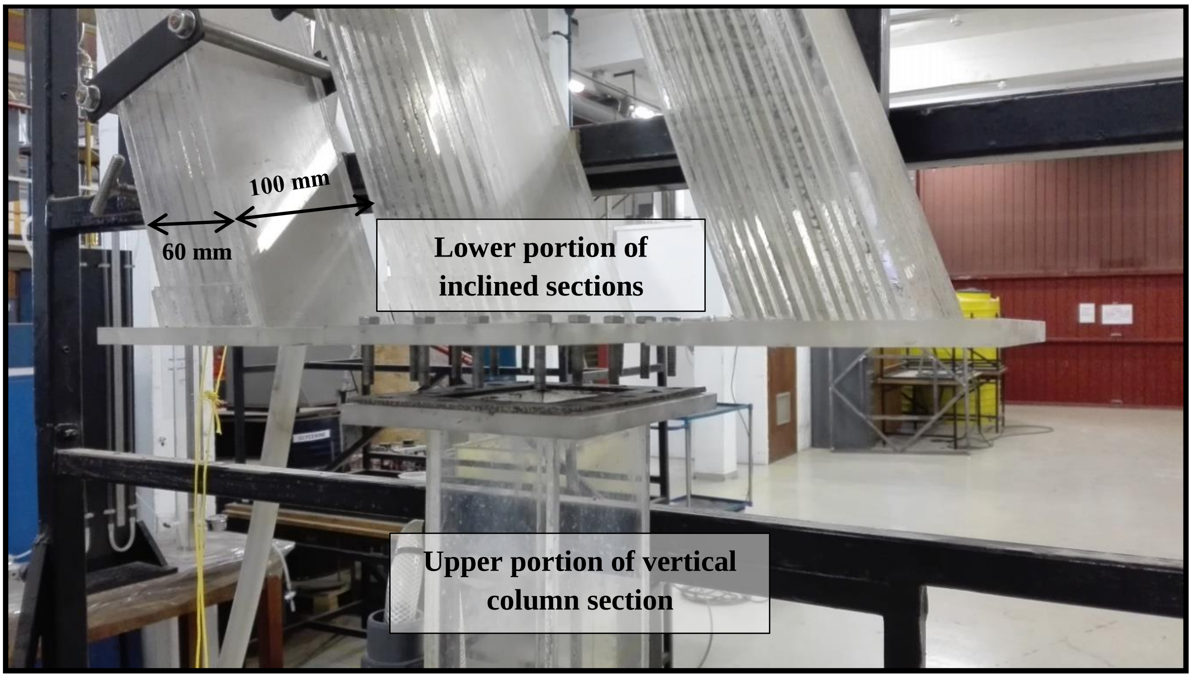

Figure 3.1.3: Close up view of the inclined section aligning with the vertical fluidisation column below upon interchanging

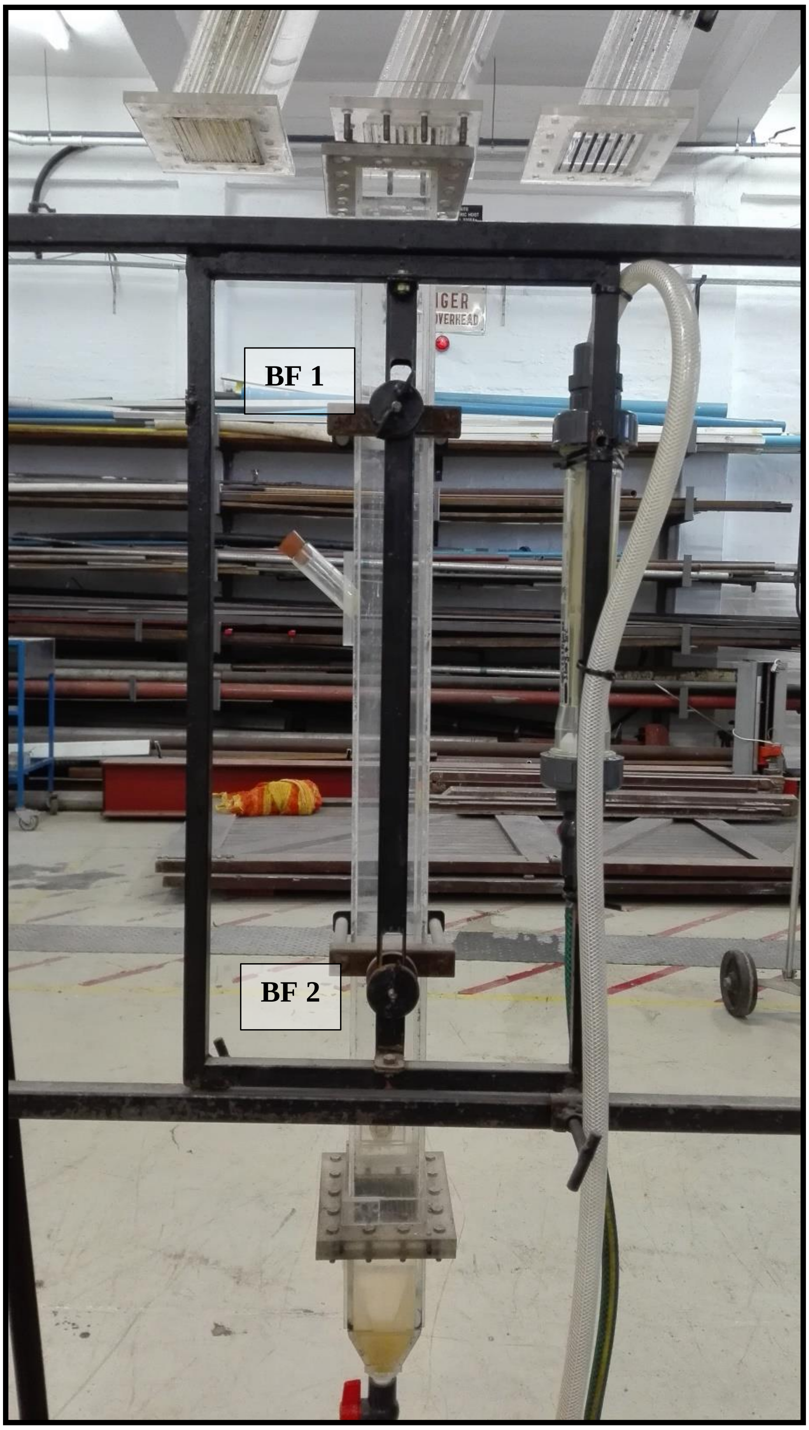

Figure 3.1.4: Close up view of the back of the vertical column showing the strut along which the column moves vertically

Figure 3.1.4 above shows the vertical column fixed to a strut in which horizontal grooves were cut out near the mounts. Loosening the butterfly nuts (BF 1 & 2) enabled the column to move up and down when attaching and detaching the inclined section.

The individual inclined sections had an internal width (front) of 60 mm, a depth (side) of 100 mm and a length of 865 mm, 965 mm and 965 mm for the 6, 8 and 12 channel sections respectively. Thus, the aspect ratios (inclined length: channel width) of each configuration were approximately 133, 214 and 460 for the 6, 8 and 12 channel sections respectively. Laskovski et al. (2006) studied the effects of aspect ratios ranging from 18-309 on separation, and the results attained indicated that higher aspect ratios showed the tendency of minimizing the effect of particle size on separation. Consequently, the 3 inclined sections of the laboratory scale unit were designed to have relatively high aspect ratios, and were made to be sufficiently different so that their impact on the gravity concentration of the finer coal could be clearly identified.

It should be noted that the dimensions mentioned are inside lengths, as the material used for the walls of the unit had a thickness of 6 mm. The overflow box (seen in figure 3.1.2) mounted at the top of each inclined section extended 100 mm outwards in each direction and had a height of 100 mm. A drainage nozzle, with an inside diameter of 20 mm, was attached to a hose to enable the flow of the overflow product from the overflow box to the collection bucket. The Perspex plates that formed the channels were sufficiently long so that they extended roughly 40 mm higher than the overflow weir. This feature was integral in ensuring uniform flow through each channel (Galvin et al., 2002). The distributor plate, through which fluidisation water entered the vessel, was composed of a 38 μm sieve inserted between 2 thin metal plates, which provided support and rigidity, with 1 mm holes drilled through them.

The flanges that affixed the inclined section to the fluidisation column, and the fluidisation column to the distributor plate housing were 10 mm thick and extended outwards in each direction by 25 mm, and were secured by 14 × 5 mm bolts. A 3 mm cork gasket was used between the adjacent flanges of the inclined section and the fluidisation column. The flange of the lower pyramidal section was machined to cut a 2 mm deep groove, in which rubber tubing was placed to form an O-ring seal between it and the fluidisation column. This can be seen in figure 3.1.5. An additional indentation was cut out along the inside rim of the flange to allow the distributor sieve/plate set-up to be seated securely over fluidisation water inlet. The inlet fluidisation water nozzle had an internal diameter of 20 mm.

Figure 3.1.5: Photograph of pyramidal distributor plate housing

3.2 Experimental procedure

3.2.1 Feed preparation

3.2.1.1 Feed size reduction

The feed material used in the experimental campaign consisted of Waterberg coal that was readily available at UKZN; however, the coal lumps were excessively large and was unsuitable for testing as is. Consequently, several stages of comminution were required to obtain a suitably sized feed. The feed coal, ranging in size from 8 cm-15 cm, was first processed through a jaw crusher to obtain a product size between 2 cm-5 cm. A mild steel rod mill, with a diameter of 240 mm rotating at a fixed speed of 75 rpm, was subsequently utilised to grind the feed down to the necessary size for the investigation, that is, -1000 µm, to enable the liberation of fine coal. Figure 3.2.3 shows the milling vessel as well as the accompanying SS 316 rods used. A total of 30 rods, consisting of 20 × 15 mm diameter and 10 × 10 mm diameter, constituted the grinding media. The set-up included an associated funnel which directed the material from the mill into a bucket, which assisted in minimizing losses when collecting the milled product. Approximately 2 kg of dry coal was initially loaded into the vessel together with the rods and milled for 12 minutes. Following this, the material was unloaded and screened using a 1000 µm laboratory test sieve, and the undersized material was collected and stored. The oversized material (+1000 µm) was fed back into the mill, together with the coarser crushed coal to make up a total of roughly 2 kg, and ground for 8 minutes before collecting the product, performing size classification, and re-loading the mill as before. The reduced run time from 12 minutes ensured that an excessive amount of fines was not produced from the recycled material. The milling procedure was repeated until a total of 40 kg of -1000 µm coal was amassed.

A photograph of a polished cross-section of the feed coal is shown in figure 3.2.2. It can be seen that thin layers of coal are interlocked with large portions of gangue material. The image acutely highlights the high ash and low quality nature of the feed material.

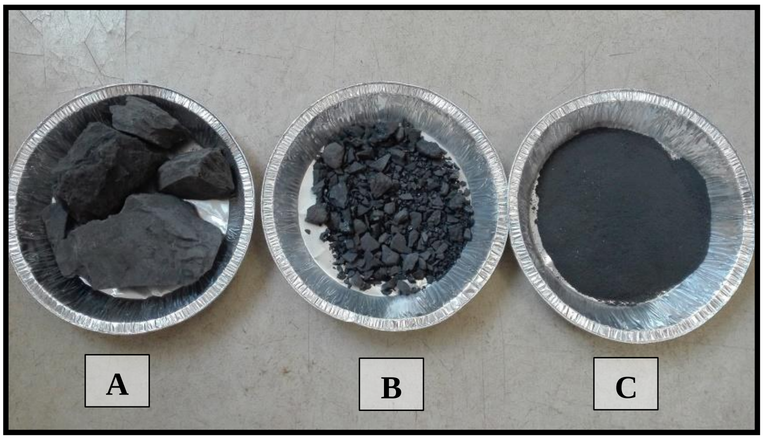

Figure 3.2.1: Photograph of coal before size reduction (A) and after crushing (B) and grinding (C)

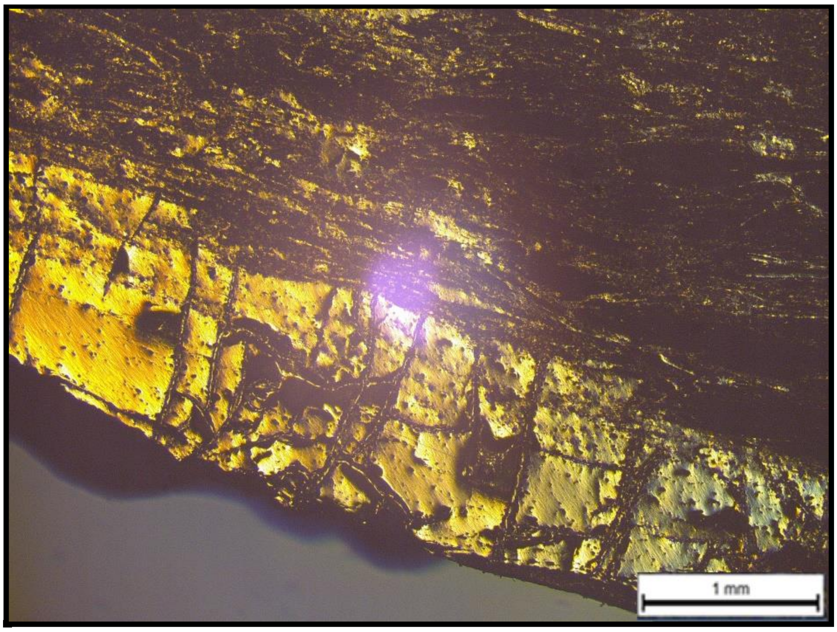

Figure 3.2.2: Photograph of polished cross-section of feed coal

Figure 3.2.3: Rod mill set-up

3.2.1.2 Particle size distribution and evaluation of ash content

The total sample was spread over a large sheet of thick plastic and thoroughly mixed using a shovel. The cone and quartering technique was employed to aid the retrieval of 60 × 515 g (approximately) representative samples, which were subsequently bagged and stored as the feed for the separation tests.

A riffle splitter, shown in figure 3.2.4, consisting of multiple chutes ordered such that the material flowing through the splitter is arbitrarily distributed into two piles of equivalent size, was then used to obtain a representative sub-sample of the bagged feed samples by successively splitting the feed down to a suitable sub-sample (roughly 125 g) for subsequent analysis.

Figure 3.2.4: Photograph of a riffle splitter

Thereafter, an examination of the particle size distribution (PSD) was undertaken on the sub-samples of the feed. Laboratory test sieves with aperture sizes of 600 µm, 500 µm, 355 µm, 212 µm, 150 µm, 106 µm and 75 µm were chosen, thus, a total of 8 size fractions were examined over the -1000 µm size range of the feed. The size fractions within the -1000 + 75 µm range were chosen based on the availability of laboratory test sieves. A $\sqrt{2}$ series of test sieves was selected for the size analysis, as recommended by Napier-Munn and Wills (2006).

Following the determination of the particle size distribution, the ash content of the material in each size fraction was analysed. The method that was adopted to determine the ash content of the coal adhered to ASTM standards and regulations for laboratory practice (Hibbard and Udall, 1967). After recording the mass of the material in each size fraction to determine the PSD, approximately 1 g of coal from each size fraction was placed inside a 25 ml ceramic crucible for ash analysis (the mass of each crucible was recorded prior to the coal addition). The 1 g of coal was amassed incrementally by random grab sampling using a spatula to ensure a representative sub-sample of the size fraction. The remaining coal was added to the rest of feed coal from which it was sub-sampled and stored for the ensuing separation tests. The 8 crucibles, which contained roughly 1 g of coal from each size fraction, were then placed inside an electric muffle furnace set to 815 °C for 5 hours. After which, the crucible containing the residue was left to cool for approximately 2 hours and then weighed. The mass of the ash inside each crucible was determined by difference. The ash content of each size fraction was expressed as a percentage of the residue mass that remained in the crucible relative to the initial mass of the coal placed inside the crucible (approximately 1g). This procedure was repeated for each bagged sample prior to each separation test to characterise the feed.

Figure 3.2.5: Coal before incineration in a muffle furnace

Figure 3.2.6: Residue ash left behind after the ash test

3.2.2 Separation procedure

3.2.2.1 Preliminary batch tests

The preliminary test scope focused on ascertaining the performance of the device under increasingly higher fluidisation rates, with particular emphasis on finer feed sizes. Consequently, a total of 5 feed sizes were tested, that is, -1000 µm, -600 µm, -500 µm, -355 µm and -212 µm. Each system configuration (6, 8 and 12 channels) was tested independently with each feed size, thus, the preliminary campaign amounted to 15 batch separation tests. For a fixed system of feed size and channel width, the following procedure was followed:

The fluidisation water was first switched on to a relatively low flowrate (roughly 1 l/min), and allowed to flow into the inlet fluidisation water port until the water level was approximately 10 cm above the distributor plate. The flow was then stopped and approximately 500 g of feed coal was added to the reflux classifier through the feed chute. This constituted a solids volume fraction of about 0.05 based on the geometry of the fluidisation zone of the device (as recommended by Galvin et al., 2006). It should be noted that a pump was not necessary and the fluidisation water came from the laboratory mains water supply as the water pressure was sufficient to sustain the fluidisation rates. The feed port was then plugged and the fluidisation water was then introduced at the required rate, which was read off a rotameter. This initial flowrate was the lowest required rate to enable the bed to expand into the channels and for separation to commence. With the flowrate fixed, all particles that could be elutriated at this fluidisation rate was collected via the overflow and stored in a bucket, and the system was allowed to operate under this flowrate until it was clear that no more solids appeared in the overflow. The solids recovered at this flowrate were designated “flow fraction 1”. Having recovered the first flow fraction, the fluidisation rate was then raised to a slightly higher rate, which resulted in more particles reporting to the overflow, and hence a new sample designated “flow fraction 2” was recovered. This process was repeated 4 times, resulting in the recovery of 4 “flow fraction” samples. Following this, the fluidisation water was shut off and the water remaining in the system was drained through the fluidisation water inlet port after removing the hose. Thereafter, the inlet hose was reconnected and the coarser, dense particles remaining in the fluidisation zone was washed out through the outlet port (just above the distributor plate) by pulsating fluidisation water up through the distributor plate (continuously opening and shutting the flow). These dense particles were collected in a separate bucket and labelled “remains”.

The 4 overflow product samples and the remains, which were each stored in separate collection buckets, were then individually filtered through a pressurised vessel filter. The pressure was supplied via a constant injection of compressed air at 5 bar (abs). Each filter cake was then dried in a drying oven. Thereafter, particle size distribution analysis was performed on each of the 4 flow fractions as well as the remains and the recovered mass was used to deduce the yield. A sub-sample of each flow fraction and the remains was acquired through riffle splitting in a manner similar to that explained in section 3.2.1.2 above. The ash content of the material in each size fraction in each of the 4 product flow fractions as well as in each of the remains size fractions was then determined in the same way as that of the feed (see section 3.2.1.2), where 1 g of sample was incinerated in a muffle furnace at 815 °C for 5 hours.

This method is termed double fractionation because the recovered flow fractions are further fractionated based on size through the use of sieves. According to Galvin et al. (2006, 2009a, 2009b, 2010, 2014), this enables the construction of a more detailed and accurate yield-ash curve and is routinely used in batch reflux classifier tests.

3.2.2.2 Primary batch separation tests

The experimental procedure for the main batch separation tests was similar to that of the preliminary testing method; however, a single flowrate was used throughout the entire run. Additionally, the feed material consisted of particles covering the full size range (-1000 µm) for all separation tests. A total of 4 fluidisation rates were tested, namely, 3 l/min, 6 l/min, 9 l/min and 12 l/min. Each channel configuration was again tested individually; however, 2 additional repeat runs after each test were also included. Thus, a total of 36 batch tests were completed. A detailed experimental procedure is outlined below.

For a fixed system of fluidisation rate and channel width, the following procedure was followed:

The fluidisation water was first switched on to a relatively low flowrate (roughly1 l/min), and allowed to flow into the inlet fluidisation water port until the water level was approximately 10 cm above the distributor plate. The flow was then stopped and approximately 500 g of feed coal, with particles covering the entire size range, was added to the reflux classifier via the feed chute. This mass inventory was again chosen based on the suggested solids volume fraction of 0.05. The fluidisation water was once more supplied through the mains water supply. The feed chute was plugged and the flowrate was increased to the designated fluidisation rate that the test called for (either 3, 6, 9 or 12 l/min). The test ran for a total of 60 minutes, and the product collected in each 15 minute interval was stored in separate collection buckets. The product collected in the first 15 minutes was designated "time fraction 1", and the subsequent overflow products were designated time fractions 2, 3 and 4. The dense solids remaining in the vessel was retrieved in the same way as explained above, and again labelled "remains". The 4 product fractions gathered in each 15 minute interval, as well as the remains, were individually filtered and dried. Finally, the particle size distribution and ash content of the material present in each size range (-1000 + 600 µm, -600 + 500 µm, -500 + 355 µm, - 355 + 212 µm, -212 + 150 µm, -150 + 106 µm, -106 + 75 µm, -75 µm) in each of the 5 fractions (4 product fractions and remains) was determined (see section 3.2.1.2).

After completion of the 2 additional repeat tests, the above procedure was followed for all permutations of channel width and flowrate (see section 3.3 for a breakdown of the experimental scope).

3.2.3.3 Semi-continuous tests

A total of 3 semi-continuous tests (1 test and 2 additional repeats) were undertaken on the 12 channel configuration with a flowrate of 9 l/min. An initial feed of approximately 500 g of coal was again added to the device by way of the feed chute, and the material remaining in the separator was supplemented with an extra 250 g of coal (approximately) every 15 minutes over the course of 120 minutes. Thus, within each 15 minute interval, overflow product was collected and stored separately as before, and the fluidisation water was subsequently shut off and the unit was drained until the water level was roughly 10 cm above the distributor plate. The supplementary feed was then added to the device via the feed chute. The test was then resumed at the flowrate of 9 l/min. Additional feed was added after 15, 30, 45, 60, 75, 90 and 105 minutes. Upon completion of the test, the 8 product time fractions and the remains fraction were analysed individually as before to ascertain the ash content and subsequent upgrades.

3.3. Summary of test conditions

Table 3.3.1: Preliminary tests

Test	Feed size (µm)	Channel configuration
1 A	-1000	6
2 A	-1000	8
3 A	-1000	12
4 A	-600	6
5 A	-600	8
6 A	-600	12
7 A	-500	6
8 A	-500	8
9 A	-500	12
10 A	-355	6
11 A	-355	8
12 A	-355	12
13 A	-212	6
14 A	-212	8
15 A	-212	12

Table 3.3.2: Primary batch tests

Test	Flowrate (l/min)	Channel configuration
1	3	6
2	3	6
3	3	6
4	3	8
5	3	8
6	3	8
7	3	12
8	3	12
9	3	12
10	6	6
11	6	6
12	6	6
13	6	8
14	6	8
15	6	8
16	6	12
17	6	12
18	6	12
19	9	6
20	9	6
21	9	6
22	9	8
23	9	8
24	9	8
25	9	12
26	9	12
27	9	12
28	12	6
29	12	6
30	12	6
31	12	8
32	12	8
33	12	8
34	12	12
35	12	12
36	12	12

Table 3.3.3: Semi-continuous tests

Test	Flowrate (l/min)	Channel configuration
37	9	12
38	9	12
39	9	12

CHAPTER 4: RESULTS & DISCUSSION

4.1 Preliminary batch separation tests

Prior to a detailed investigation into the separation of coal, the newly built reflux classifier was commissioned by performing several batch separation tests. Waterberg coal with an average head ash of approximately 50%, and covering a large size range, constituted the feed material. The primary aim of these scoping tests were to determine if the device was indeed capable of generating a noticeable upgrade in the available feed coal, as well as to establish if the chosen size range of the feed (-1000 µm) was within the separation capability of the unit. Additionally, the fluidisation rates that prompted separation under the various channel configurations were ascertained. The size fractions within the -1000 + 75 µm range were chosen based on a standard $\sqrt{2}$ series, and this was also considered when determining the operational size fractions (Napier-Munn and Wills, 2006). A total of 15 tests were carried out, and the separation procedure was based on groundwork laid by Galvin et al. (2006, 2009, 2010a, 2010b), The preliminary tests encompassed running each channel configuration independently with the feed coal being successively screened down to finer sizes in each subsequent test. Thus, the feed sizes tested included -1000 µm, -600 µm, -500 µm, -355 µm and -212 µm. This was undertaken to understand the effect of increasingly finer feed on the separation performance of the unit. Published methods for batch testing on coal and other materials routinely used the double fractionation procedure (Galvin et al., 2009; 2010b). Consequently, this experimental scheme was adopted for the preliminary runs. The feed mass of approximately 500 g, which translated to a solids volume fraction of roughly 0.05, was chosen based on the work described in Laskovski et al. (2006). Due to the relatively low solids concentration, the particle slip velocity could be assumed to be the same as its terminal velocity (Rhodes, 2008). It was assumed that the particle motion could be described by Newton's equation due to the fine feed size and the need to promote a laminar flow through the channels, thus equation 2.2.1.8 was used to determine the terminal velocity of the mean size particle in each size fraction. However, the choice of the preliminary fluidisation rates was based on the knowledge that the system could be operated at superficial velocities much greater than the particle terminal velocities due to the synergistic effects of the channels and the fluidised suspension beneath (Nguyentranlam and Galvin, 2004). Consequently, the fluidisation rates were determined by slowly increasing the flowrate arbitrarily to a level sufficient to expand the bed and for elutriation and overflow to occur, and thereafter further increasing it for subsequent overflow fraction. This approach, routinely used in previous studies (Galvin et al., 2009, 2010b), enabled the flowrates that effected separation to be quickly and easily determined. The fundamental information obtained from these initial tests provided the necessary framework to perform further batch and semi-continuous separation tests on the full sized feed.

4.1.1 Tests 1A-3A: -1000 μm Feed

Table 4.1.1: Overall product ash (feed ash shown at 0 l/min)

Fluidisation rate (l/min)	Ash (%)		
	6 channels (1A)	8 channels (2A)	12 channels (3A)
0	44.70	44.93	46.66
1.5	47.81	52.14	47.54
3	45.55	43.30	38.48
5.75	49.86	44.16	23.58
9.75	31.10	43.05	18.13
Remains	44.76	45.42	61.08

Table 4.1.2: Overall product upgrade compared to feed

Fluidisation rate (l/min)	Upgrade (%) relative to feed (Yield %)		
	6 channels (1A)	8 channels (2A)	12 channels (3A)
1.5	-6.96 (13.49)	-16.06 (8.71)	-1.87 (9.78)
3	-1.89 (1.94)	3.63 (1.95)	17.53 (1.71)
5.75	-11.54 (2.23)	1.71 (2.21)	49.46 (5.97)
9.75	30.43 (4.42)	4.17 (5.23)	61.14 (25.72)

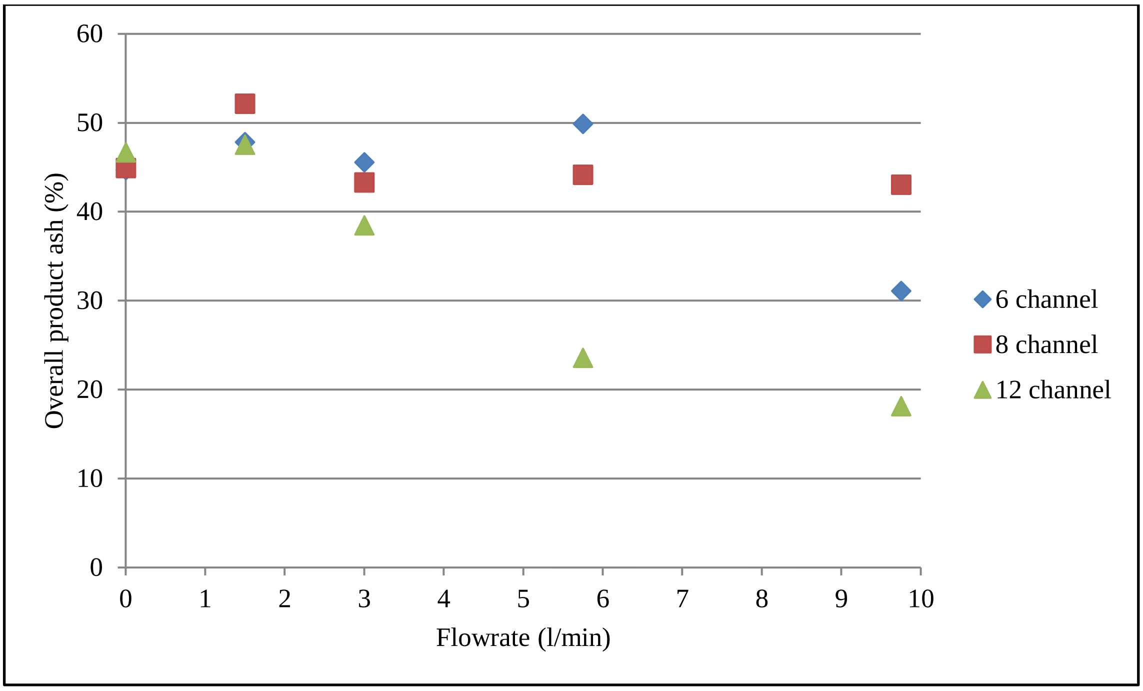

Figure 4.1.1: Effect of fluidisation rate on the product ash content over the full size range

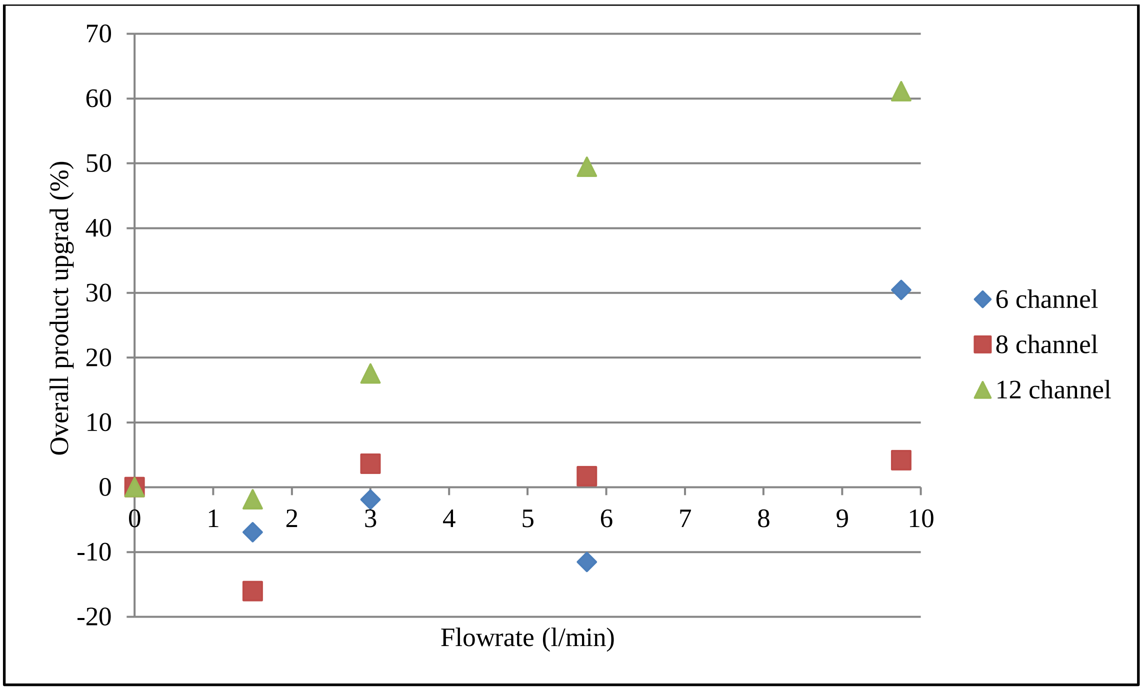

Figure 4.1.2: Effect of fluidisation rate on the overall upgrade achieved over the full size range

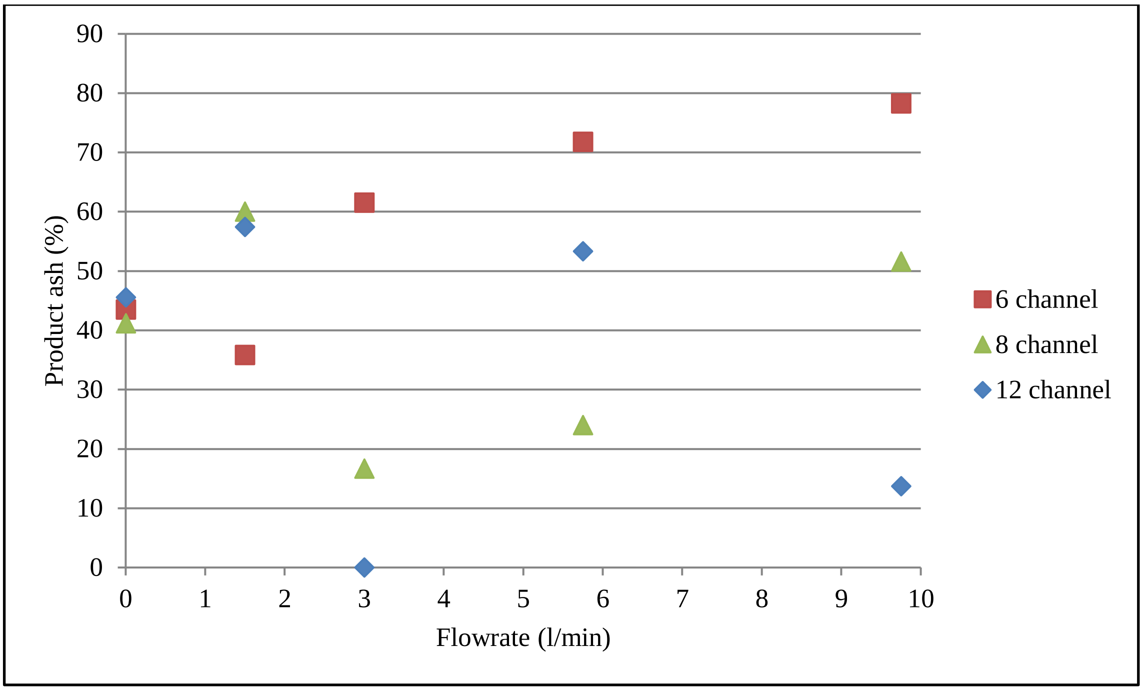

Figure 4.1.3: Effect of fluidisation rate on product ash content (-1000+600 micron fraction)

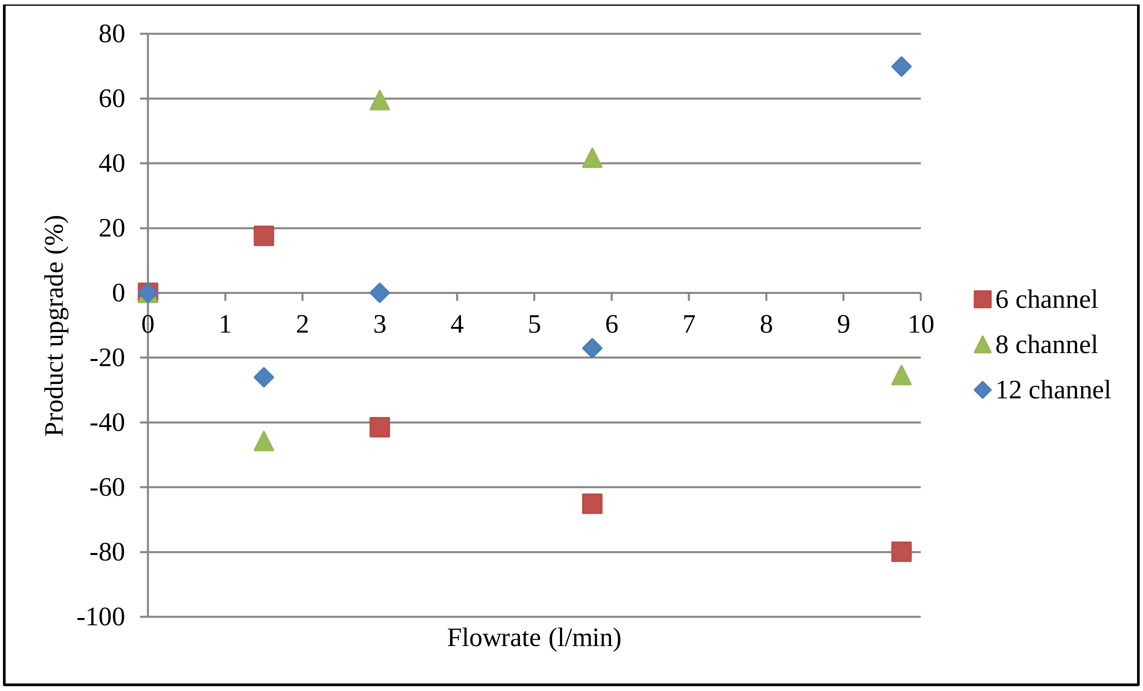

Figure 4.1.4: Effect of fluidisation rate on upgrade (-1000+600 micron fraction)

Table 4.1.2 indicates the upgrade in product achieved relative to the feed ash content for the entire size range (-1000 μm) at each fluidisation rate for each of the experimental configurations. The percentage upgrade was determined by first finding the total ash in the overflow product after each subsequent increase in fluidisation rate and thereafter calculating the difference between this total product ash and the initial amount of ash in the feed. This is presented in the formula below:

$$\text{Upgrade (\%)} = \frac{\text{\%Feed ash} - \text{\%Product ash}}{\text{\%Feed ash}} \times 100 \qquad (4.1.1)$$

It should be noted that the negative percentages indicates an actual increase in ash content in the product compared to the feed as opposed to a desired reduction in ash content. The overall product ash content and upgrade achieved at the various flowrates are plotted in figures 4.1.1 and 4.1.2 respectively. It is evident that the 6 channel and 8 channel configurations performed relatively poorly when viewing the overall upgrade, with no clear separation attained, however, it should be mentioned that there still could be upgrades seen in individual size fractions, and this will be highlighted later on. Despite the lacklustre performance of the 6 channel and 8 channel configurations, the 12 channel arrangement distinctly shows a noticeable upgrade for the 2 highest flowrates, that is, 5.75 and 9.75 l/min. A reduction, albeit a small one, in ash content compared to the feed is also seen when 3 l/min was used. Moreover, the 12 channel configuration keenly highlights a trend of higher fluidisation rates resulting in better separations.

Figures 4.1.3 and 4.1.4 illustrates the effect of the fluidisation rate on the product ash content and upgrade achieved for the coarsest size fraction (-1000 + 600 μm) respectively. It should be noted that the 0% ash yield at 3 l/min for 12 channels is due to the negligible amount of material that was collected in the overflow at this flowrate using 12 channels. It is observed from figure 4.1.3 that for the 12 channel configuration the ash content of the overflow at the lowest flowrate (1.5 l/min) is slightly higher than the feed ash content of 45.54%. From equation 2.2.1.8, it was found that the terminal velocity of the arithmetic mean sized particle in this fraction (800 μm) was approximately 0.114 m/s while the fluidisation rates of 1.5 l/min, 3 l/min, 5.75 l/min and 9.75 l/min translated to fluidisation velocities of 0.0042 m/s, 0.0083 m/s, 0.016 m/s and 0.027 m/s respectively based on the dimensions of the rectangular vertical section. The terminal velocity was calculated based on the average bulk density of 1553.94 kg/m^3 of bituminous coal (Green and Perry, 2008). This alludes to the presence of large light particles and small heavy particles (middlings) that results in misplacement at the low flowrate. A similar explanation can be offered for the performance of the 6 and 8 channel tests, with separation being further hindered by the use of wider channels. However, at fluidisation rates of 5.75 l/min and 9.75 l/min, there is a definite decrease in the ash content of the overflow product using the 12 channel configuration. At the highest flowrate, the ash content is reduced to 13.73% from an initial content of 45.54%, which, from figure 4.1.4, translates to an upgrade of approximately 70%. The noteworthy performance of the 12 channel configuration was expected as previous campaigns conducted by Galvin et al. (2009) and Laskovski et al. (2006) provided similar results.

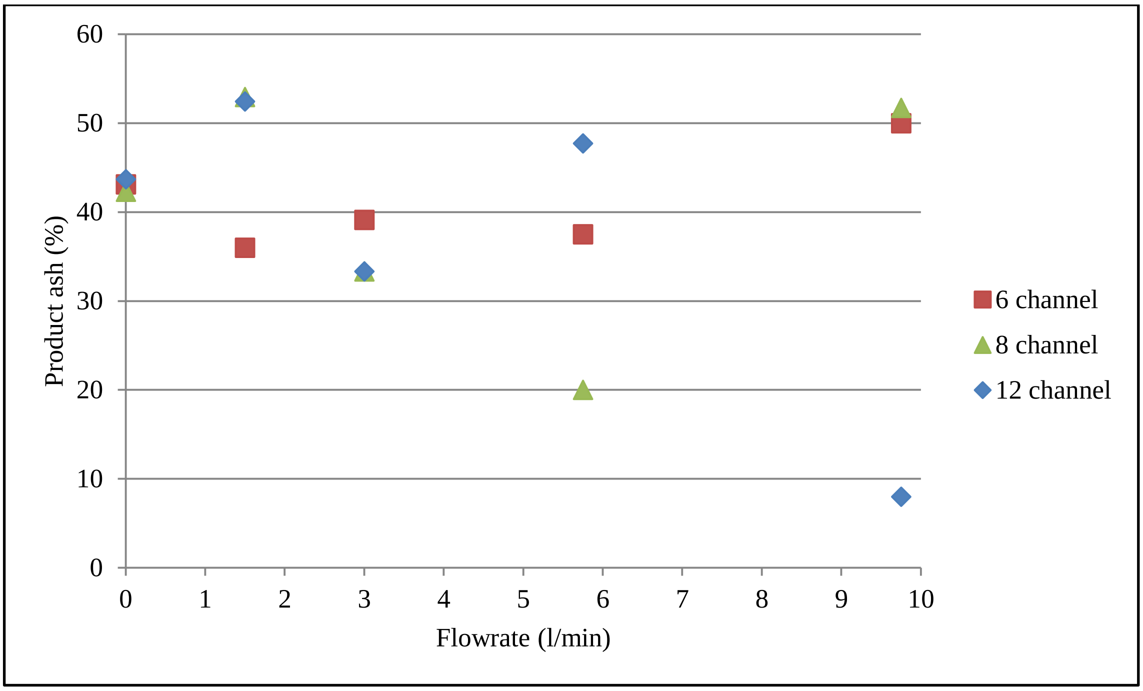

Figure 4.1.5: Effect of fluidisation rate on product ash content (-600+500 micron fraction)

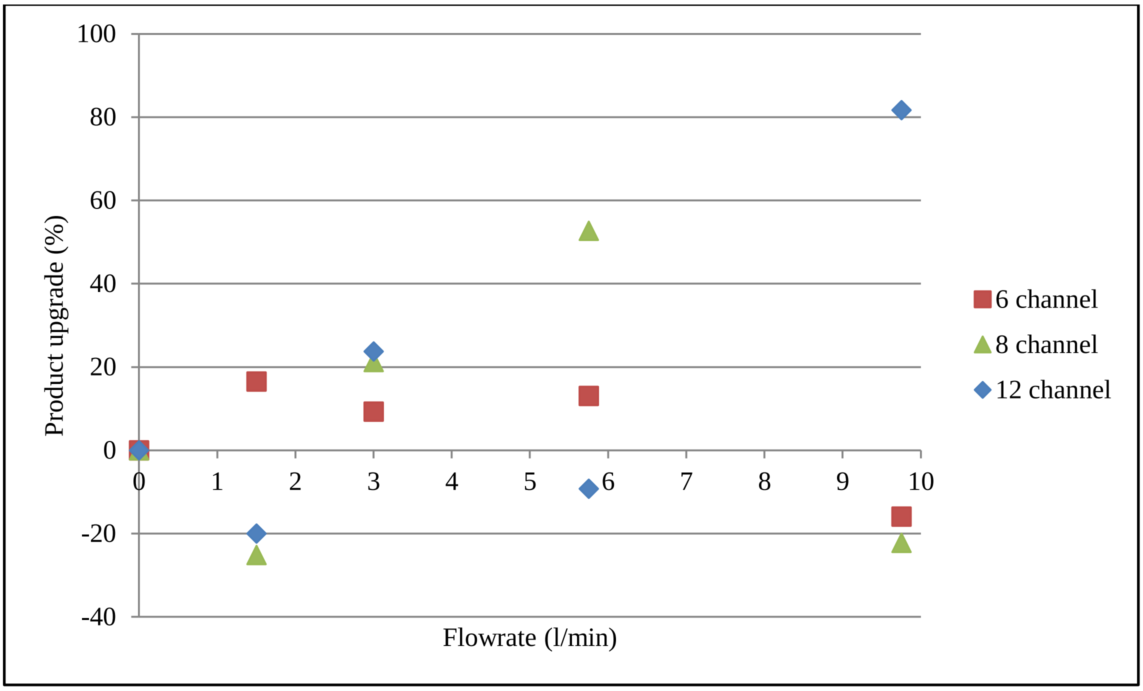

Figure 4.1.6: Effect of fluidisation rate on upgrade (-600+500 micron fraction)

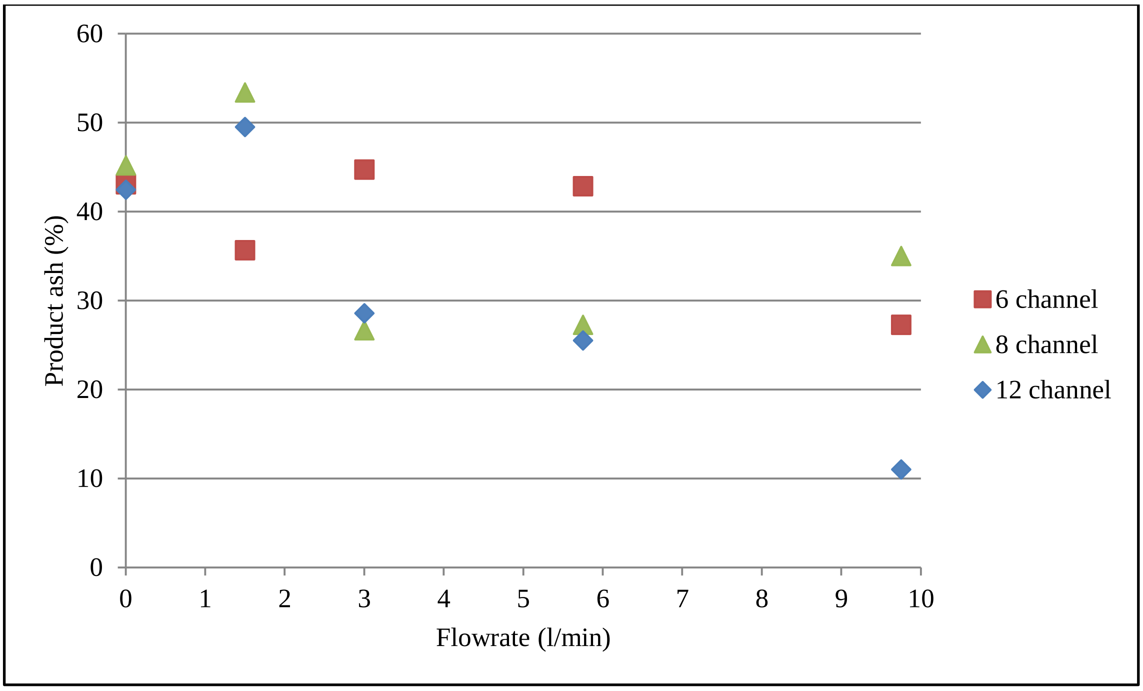

Figure 4.1.7: Effect of fluidisation rate on product ash content (-500+355 micron fraction)

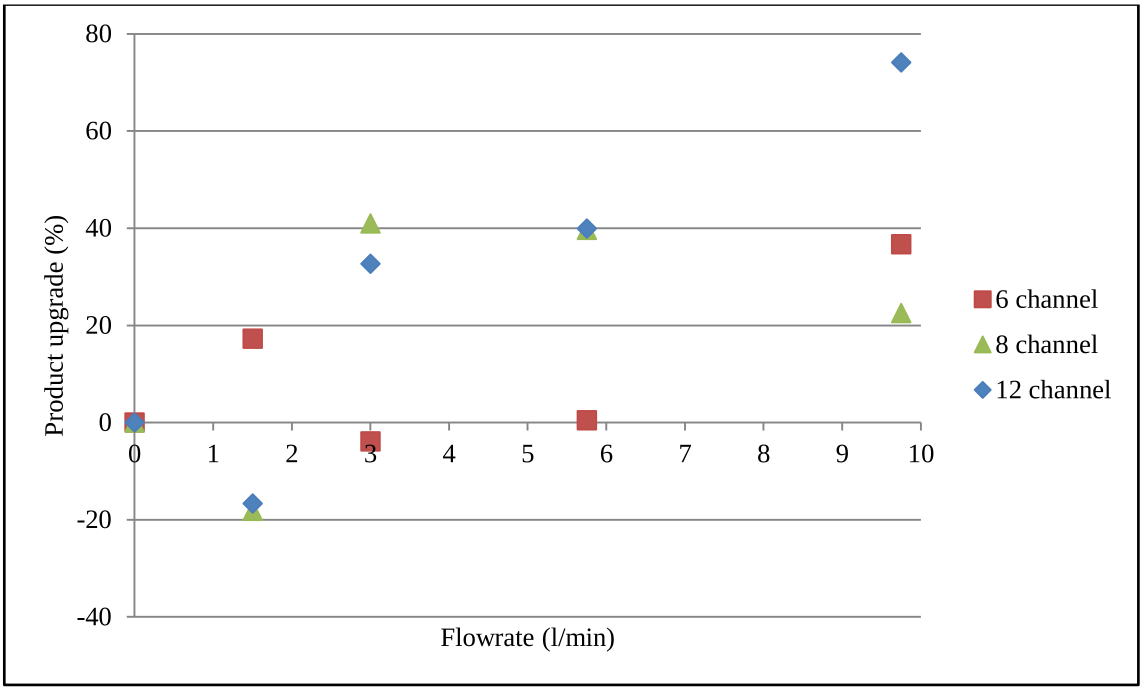

Figure 4.1.8: Effect of fluidisation rate on upgrade (-500+355 micron fraction)

The 12 channel set-up continued to perform well in the next 2 size ranges i.e. -600 + 500 µm and -500 + 355 µm, particularly at the highest flowrate (9.75 l/min). Figure 4.1.5 indicates a considerable reduction in the product ash content using 9.75 l/min as the fluidisation rate, with a final ash content of roughly 8% (compared to a 43.69% feed ash content). Some discrepancy is observed at the lower flowrates; however, this may be a result of insufficient particle lift through the channels as well as viscous wall effects (Galvin et al., 2010b). Additionally, the 8 channel configuration performed reasonably well at the second highest flowrate (5.75 l/min), showing an upgrade of around 53% (from figure 4.1.6). At 9.75 l/min, the ash content of the overflow showed an increase using 8 channels. This could possibly be due to all of the clean coal being elutriated to the overflow at the previous flowrate (5.75 l/min), leaving only the gangue and high ash material to be washed over at the higher flowrate. Inefficient liberation of the coal, in which the gangue remains interlocked with “clean” coal, could also lead to inconsistencies. Similar trends were noted for the -500 + 355 µm fraction (figures 4.1.7 and 4.1.8).

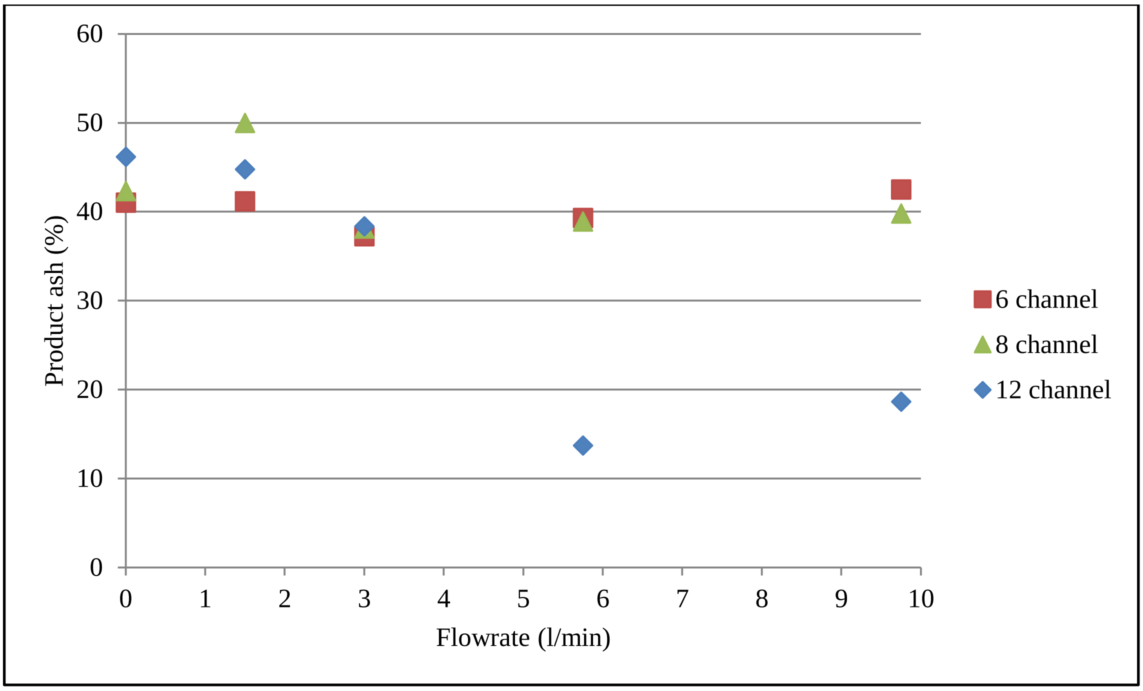

Figure 4.1.9: Effect of fluidisation rate on product ash content (-355+212 micron fraction)

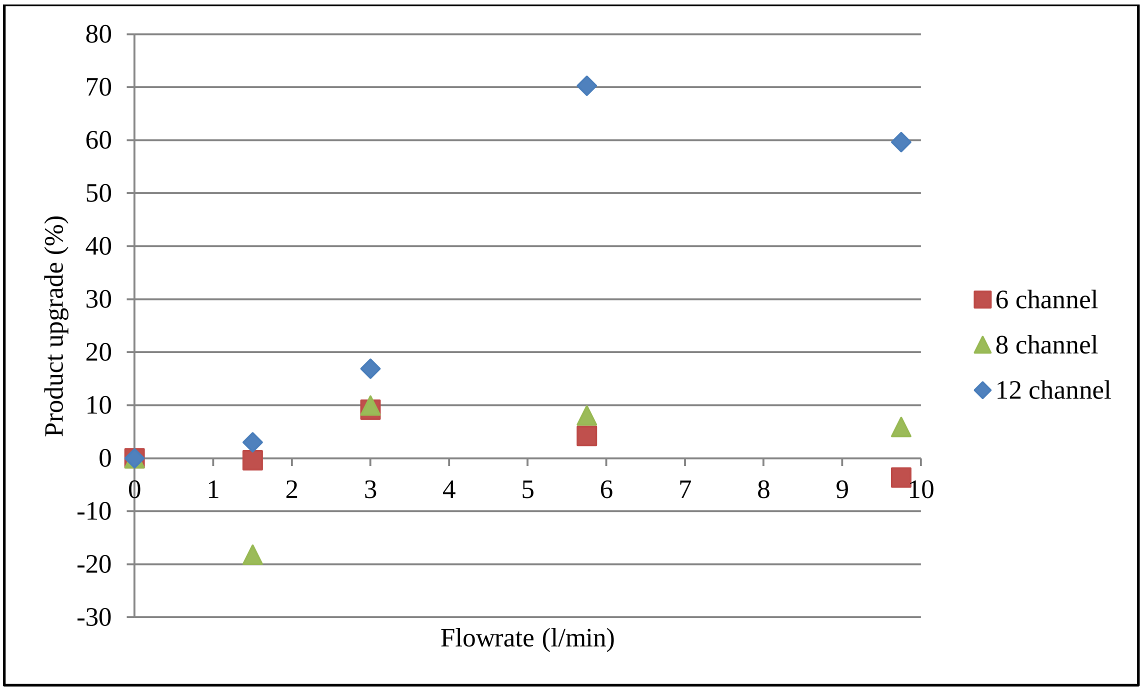

Figure 4.1.10: Effect of fluidisation rate on product ash content (-355+212 micron fraction)

In the -355 + 212 µm size fraction, the 6 channel configuration showed slight upgrades for the first 3 flowrates as seen in figures 4.1.9 and 4.1.10. The product ash content using 9.75 l/min for the 12 channel run was slightly higher than that achieved at the previous flowrate, however, a significant reduction in product ash content is seen throughout the entire run, which is especially remarkable as the feed ash in the 12 channel run (46.15% feed ash) was higher than that of the 6 channel and 8 channel tests. Figure 4.1.9 shows minor upgrades at 3 l/min and 5.75 l/min using 6 channels and continued upgrades are seen using 12 channels for all fluidisation rates except the lowest.

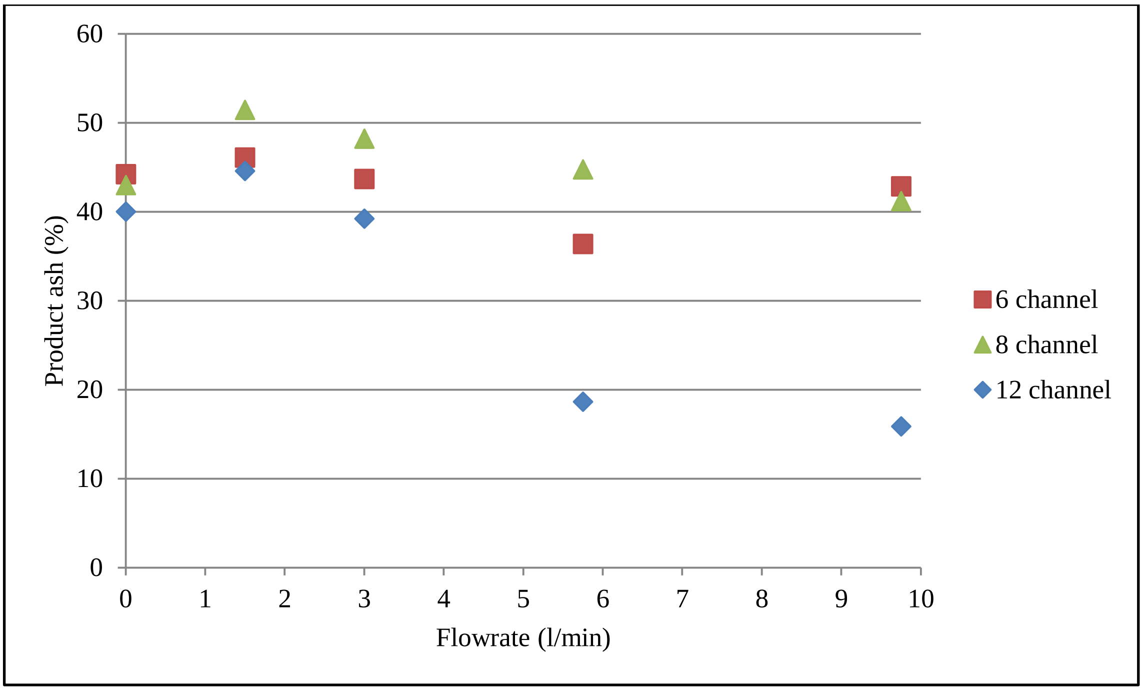

Figure 4.1.11: Effect of fluidisation rate on product ash content (-212+150 micron fraction)

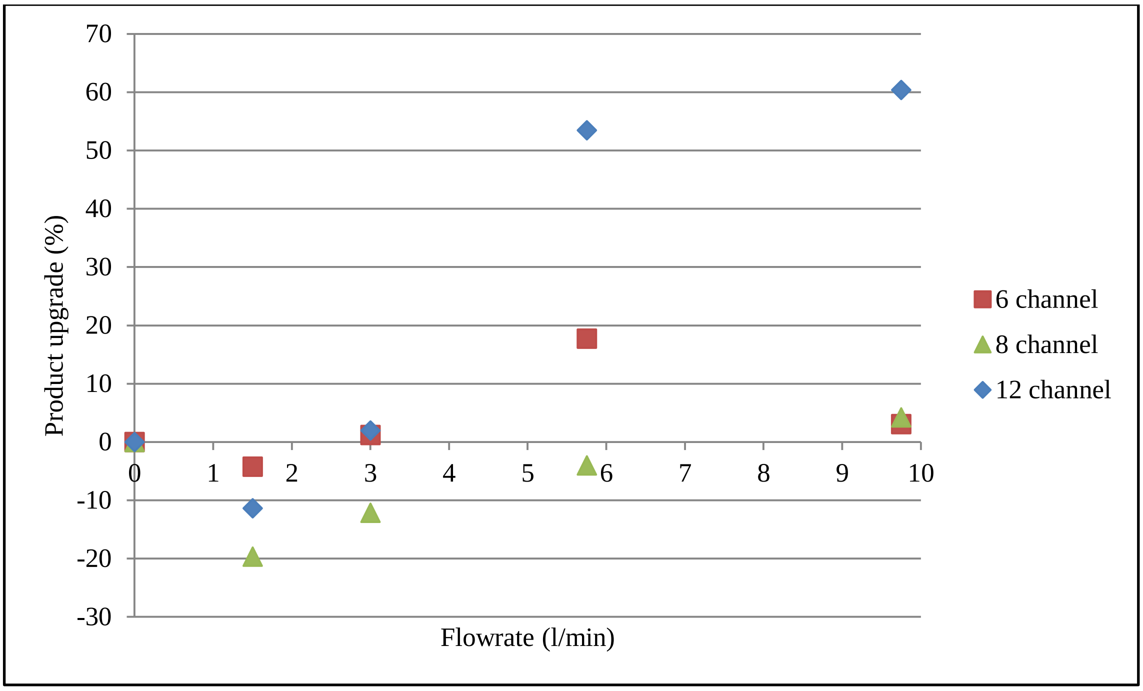

Figure 4.1.12: Effect of fluidisation rate on upgrade (-212+150 micron fraction)

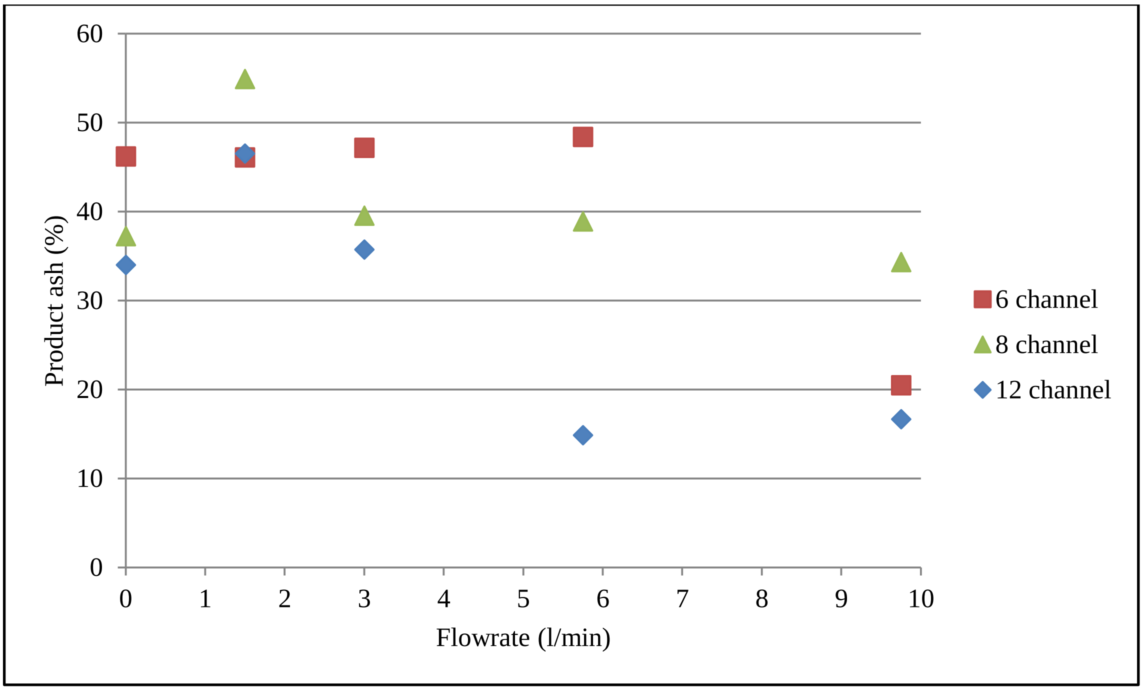

Figure 4.1.13: Effect of fluidisation rate on product ash content (-150+106 micron fraction)

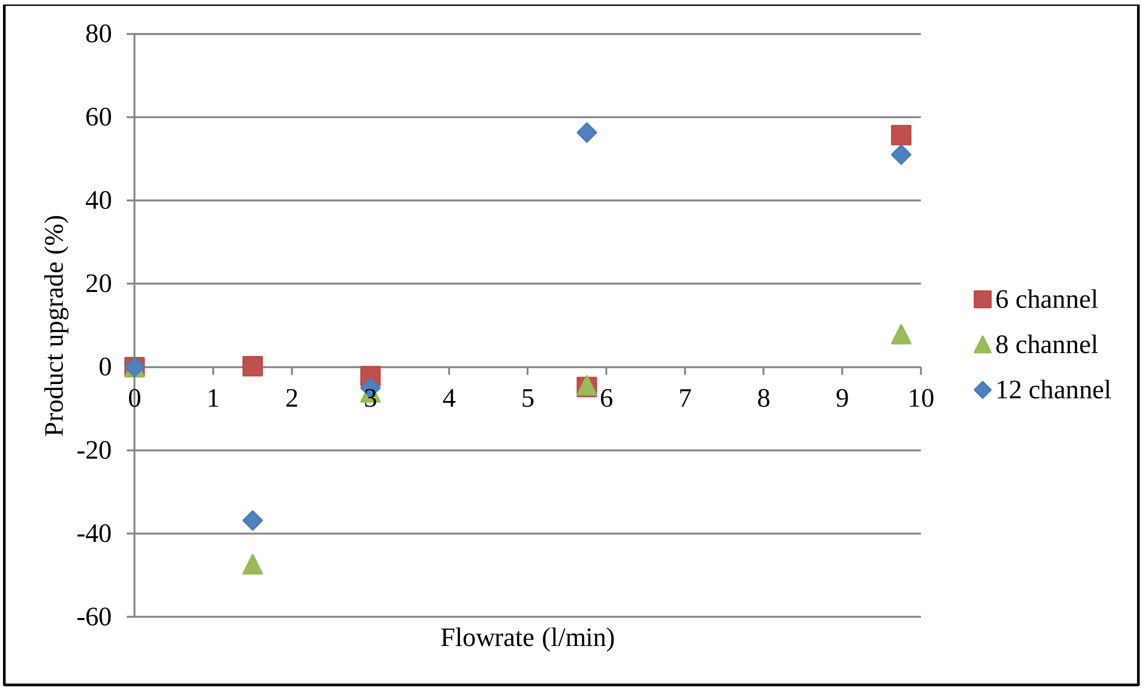

Figure 4.1.14: Effect of fluidisation rate on upgrade (-150+106 micron fraction)

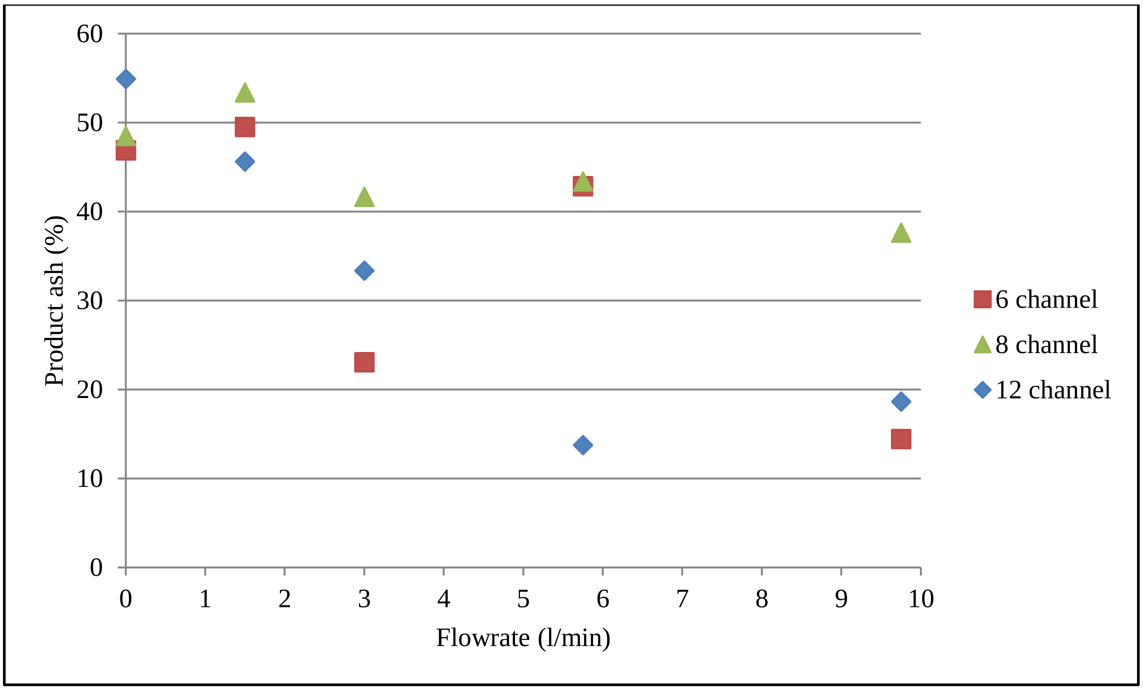

Figure 4.1.15: Effect of fluidisation rate on product ash content (-106+75 micron fraction)

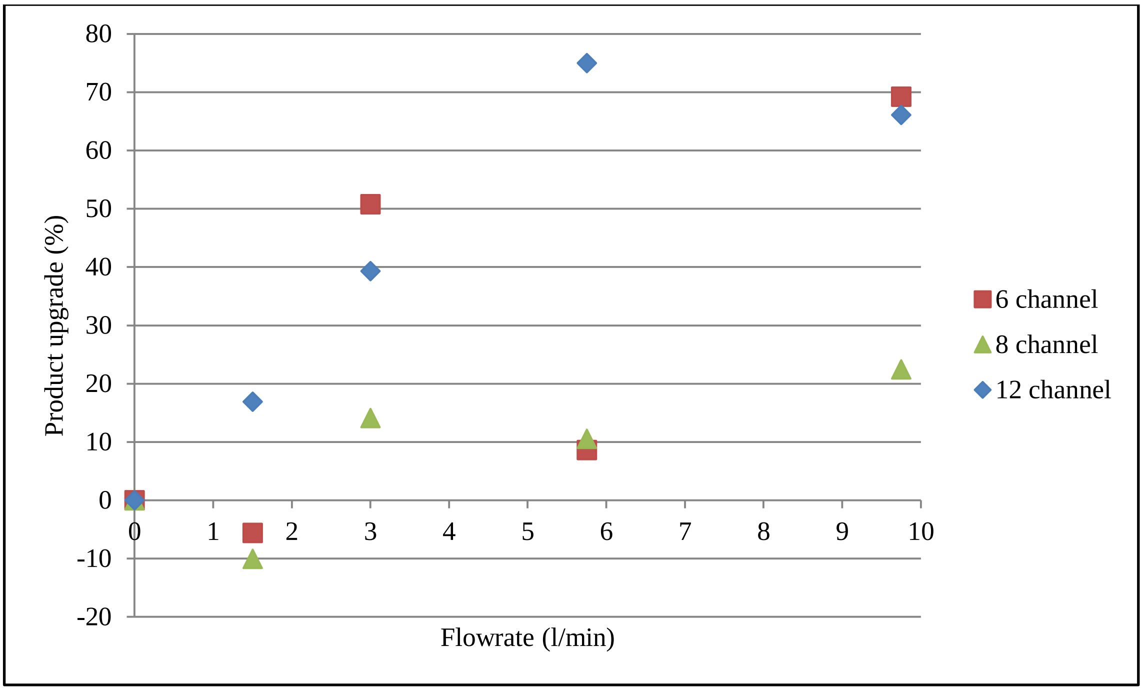

Figure 4.1.16: Effect of fluidisation rate on upgrade (-106+75 micron fraction)

Figures 4.1.13 to 4.1.16 shows that by using 12 channels and fluidisation rates exceeding 3 l/min, the laboratory scale device can successfully upgrade coal with roughly 47% feed ash down to a particle size of 75 µm. The 8 channel configuration works reasonably well for particles above 355 µm, and finer material tends to produce more erratic results at the tested flowrates. For material finer than 75 µm, a slight reduction in ash content is seen when using 12 channels (figures 4.1.17 and 4.1.18), which is still significant since gravity concentration methods are known to be inefficient for very fine particles (Napier-Munn and Wills, 2006). The product ash content, as well the ash content of the underflow, attained for each individual size fraction for tests 1A-3A can be viewed in tables A-1.1 to A-1.15.

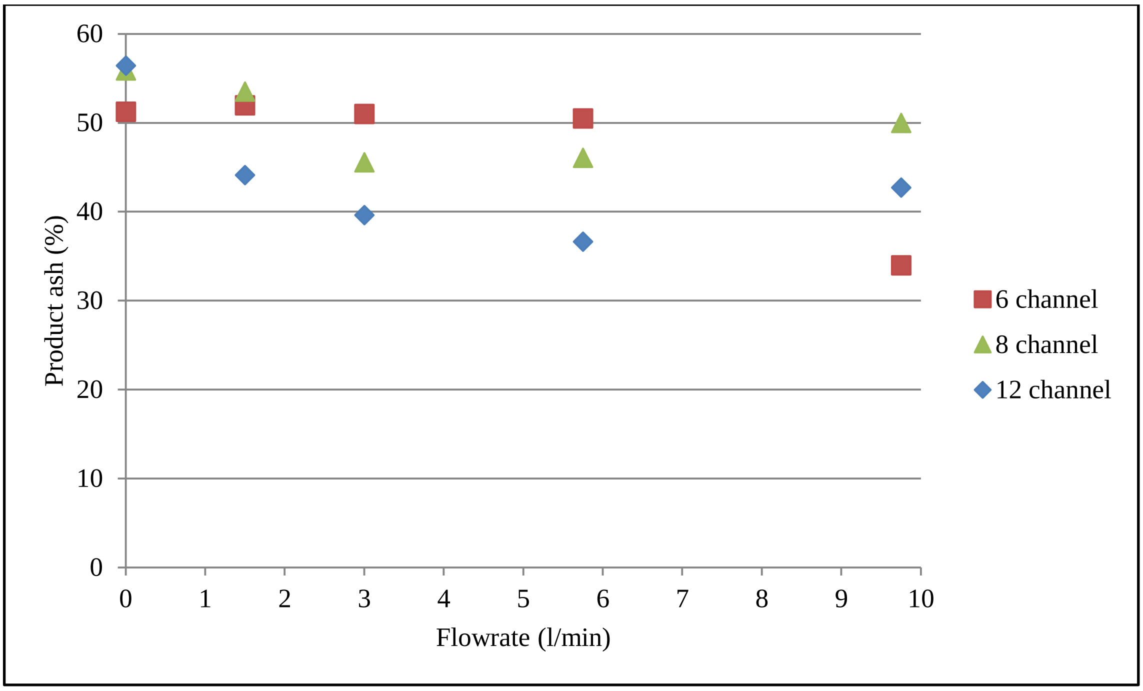

Figure 4.1.17: Effect of fluidisation rate on product ash content (-75 micron fraction)

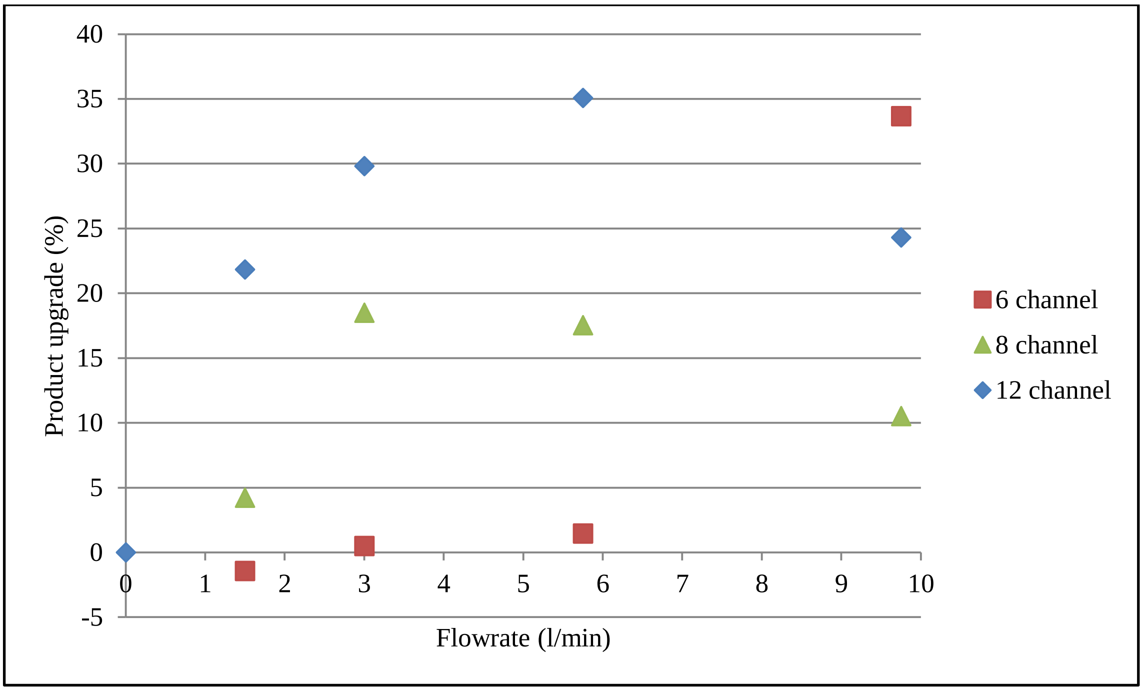

Figure 4.1.18: Effect of fluidisation rate on upgrade (-75 micron fraction)

4.1.2 Tests 4A-6A: -600 µm Feed

Table 4.1.3: Overall product ash (feed ash shown at 0 l/min)

Fluidisation rate (l/min)	Ash (%)		
	6 channels (4A)	8 channels (5A)	12 channels (6A)
0	46.36	58.52	50.14
1.5	52.73	56.42	46.27
3	46.05	43.51	44.01
4.75	61.42	39.78	30.06
6.75	41.18	45.81	17.28
Remains	43.08	59.74	56.02

Table 4.1.4: Overall product upgrade compared to feed

Fluidisation rate (l/min)	Upgrade (%) relative to feed (Yield %)		
	6 channels (4A)	8 channels (5A)	12 channels (6A)
1.5	-13.74 (15.23)	3.59 (9.92)	7.71 (8.95)
3	0.66 (1.19)	25.65 (3.20)	12.21 (3.15)
4.75	-32.49 (3.97)	32.03 (2.05)	40.04 (4.81)
6.75	11.16 (3.99)	21.72 (3.09)	65.55 (18.49)

It can be seen from tables 4.1.3 and 4.1.4 above that both the 8 channel and 12 channel configurations performed consistently well for the entire range of fluidisation rates despite the finer feed. A distinct separation is evident between the ash content of the dense material remaining at the end of the test (remains/underflow) and that of the overflow product suggesting separation favouring a density basis. It was found that approximately 50% of the feed was below 212 µm in these tests while roughly 35% of the feed was below 212 µm in the previous group of tests which included the -1000 + 600 µm fraction (tests 1A-3A). As a result, the last 2 fluidisation rates were reduced slightly (from 5.75 l/min to 4.75 l/min and from 9.75 l/min to 6.75 l/min) to prevent particle misplacement and to safeguard against the possibility of a large proportion of the feed being indiscriminately washed through the channels into the overflow.

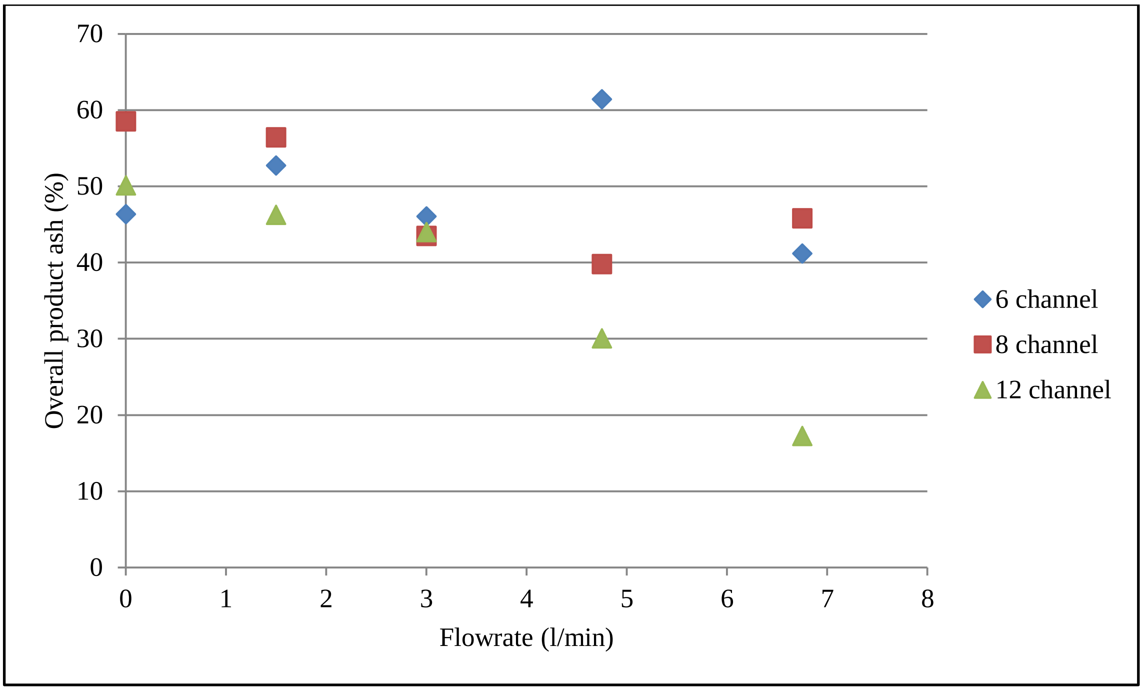

Figure 4.1.19: Effect of fluidisation rate on the overall product ash content (-600 micron feed)

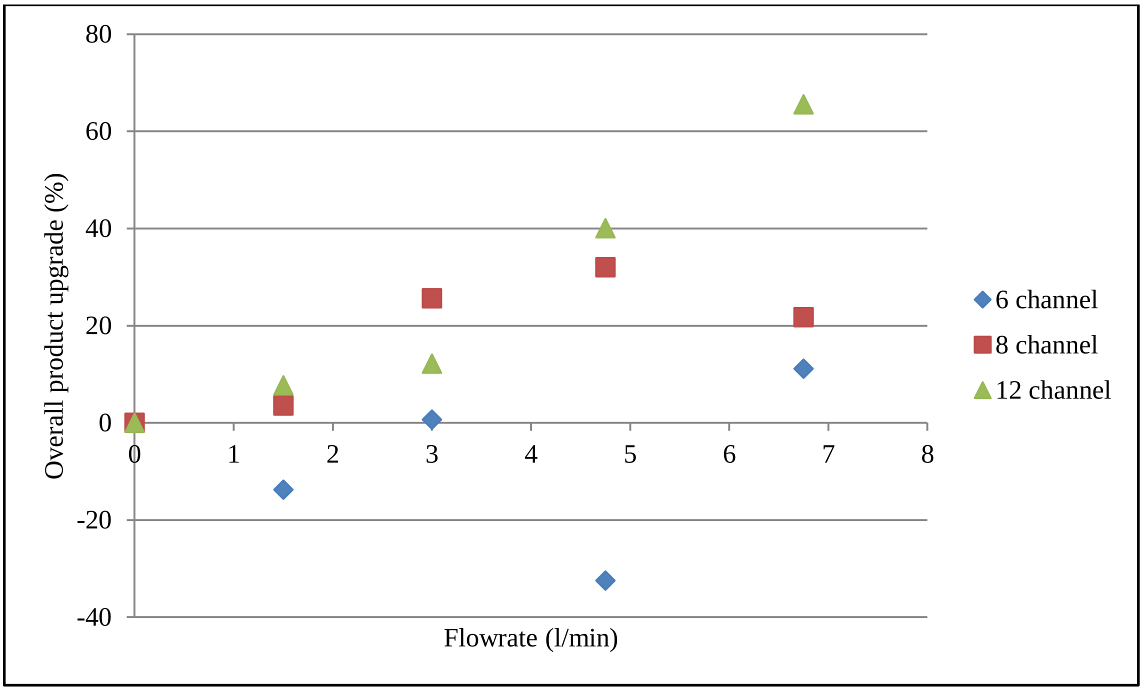

Figure 4.1.20: Effect of fluidisation rate on the overall product upgrade (-600 micron feed)

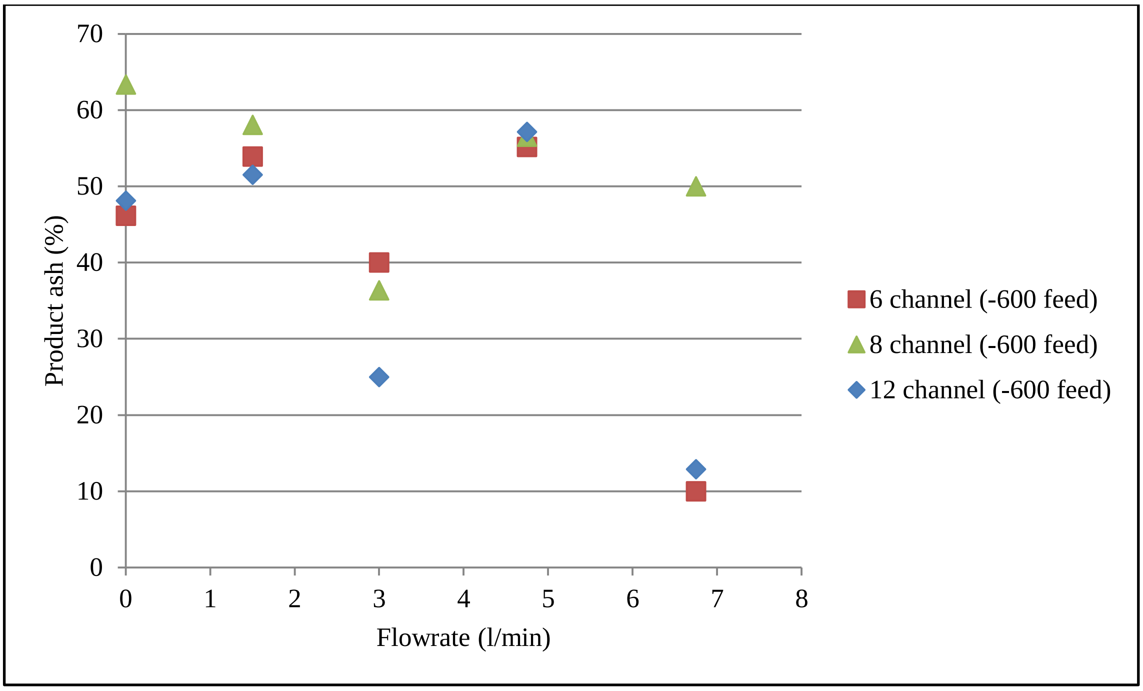

Figure 4.1.21: Effect of fluidisation rate on product ash content (-600+500 micron fraction)

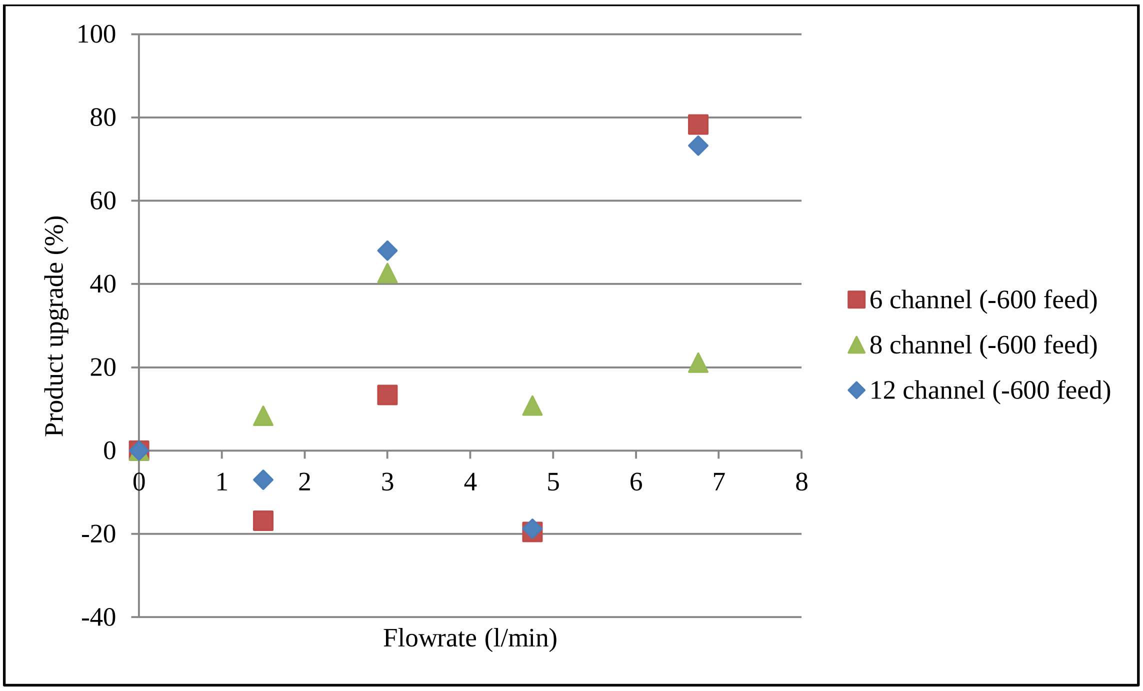

Figure 4.1.22: Effect of fluidisation rate on upgrade (-600+500 micron fraction)

Despite the lower fluidisation rates, a general decrease in ash is seen for the first 3 flowrates using 8 channels. The 12 channel configuration still produces a high upgrade at 6.75 l/min in the -600 + 500 µm fraction, with a reduction in ash content from 48% to roughly 13% (from figure 4.1.21). Fairly consistent separation is noted as the 12 channel configuration previously resulted in a decrease in ash from 44% down to 8% for the same size fraction (figure 4.1.5). In figures 4.1.23 and 4.1.24, it can be observed that the 8 channel configuration results in an upgrade to some degree in the -500 + 355 µm fraction, with the ash content decreasing from 57% to approximately 42% at both 4.75 l/min and 6.75 l/min flowrates. It should be noted that even at a lower flowrate of 6.75 l/min and a higher feed ash compared to the conditions of test 3A, the 12 channel set-up still produces a reduction in ash from 48% to 9% (A decrease from 43% to 11% was seen in the test 3A with the +600 µm feed material included, illustrated in figure 4.1.7). The product ash content, as well the ash content of the underflow, attained for each individual size fraction for tests 4A-6A can be viewed in tables A-1.16 to A-1.30.

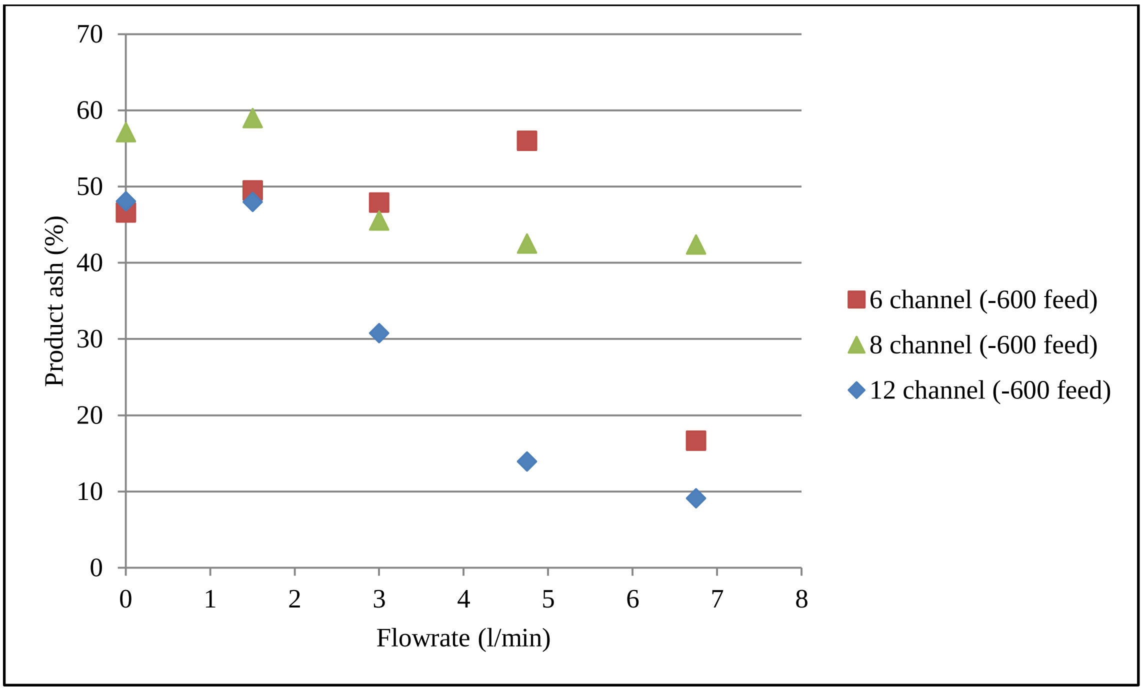

Figure 4.1.23: Effect of fluidisation rate on product ash content (-500+355 micron fraction)

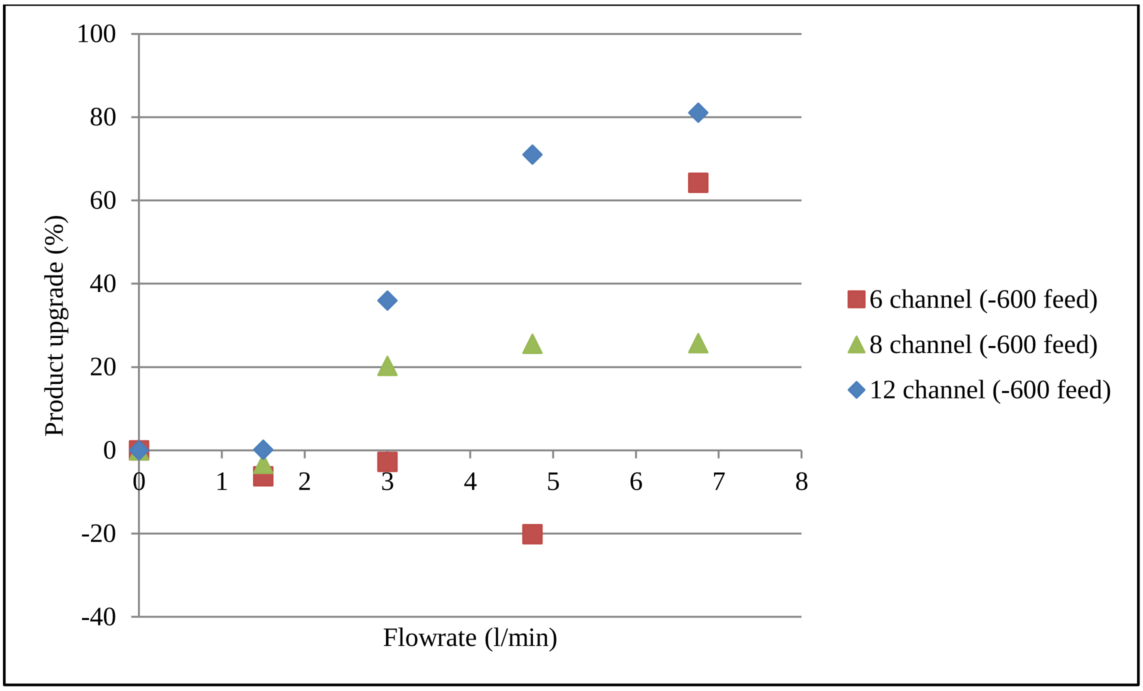

Figure 4.1.24: Effect of fluidisation rate on upgrade (-500+355 micron fraction)

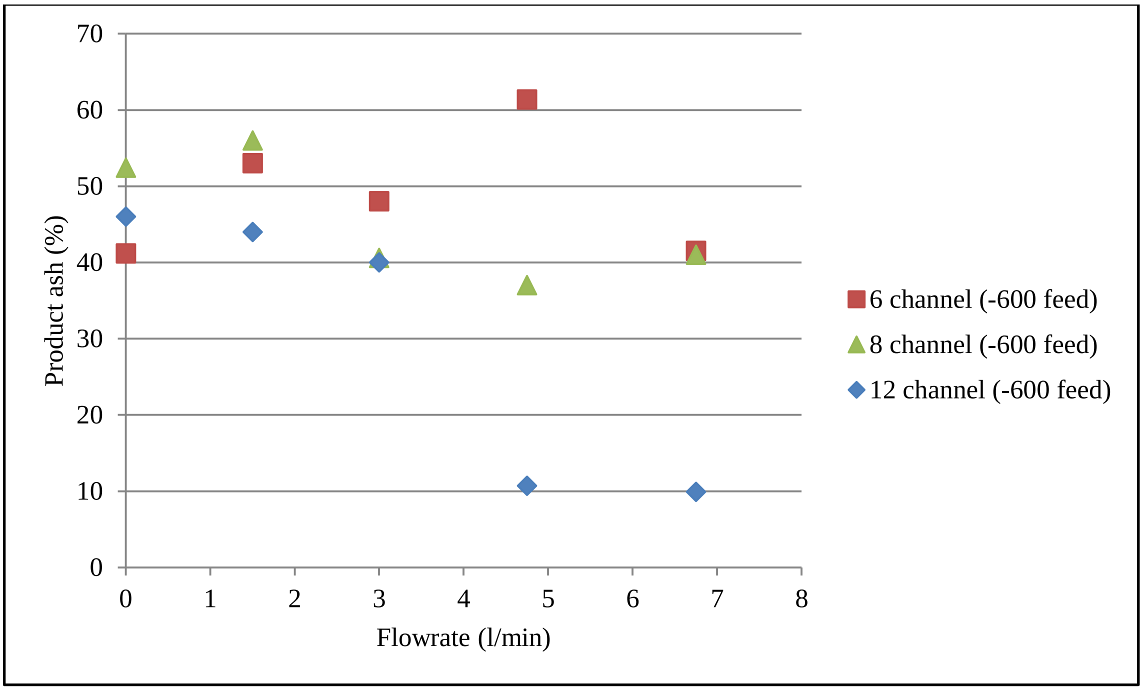

Figure 4.1.25: Effect of fluidisation rate on product ash content (-355+212 micron fraction)

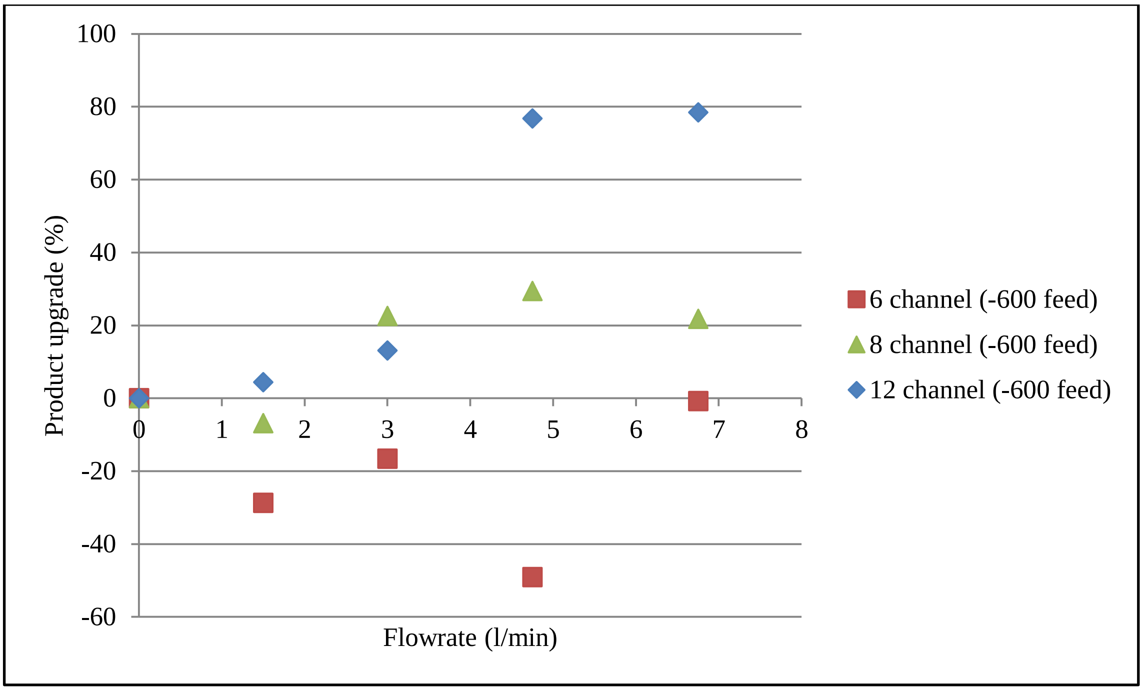

Figure 4.1.26: Effect of fluidisation rate on upgrade (-355+212 micron fraction)

A similar trend is observed for the size ranging from 355 µm to 150 µm in figures 4.1.25-4.1.28 with both the 8 channel and 12 channel set-ups performing well with upgrades improving at higher fluidisation rates. A definite separation occurred despite increased loading with finer material.

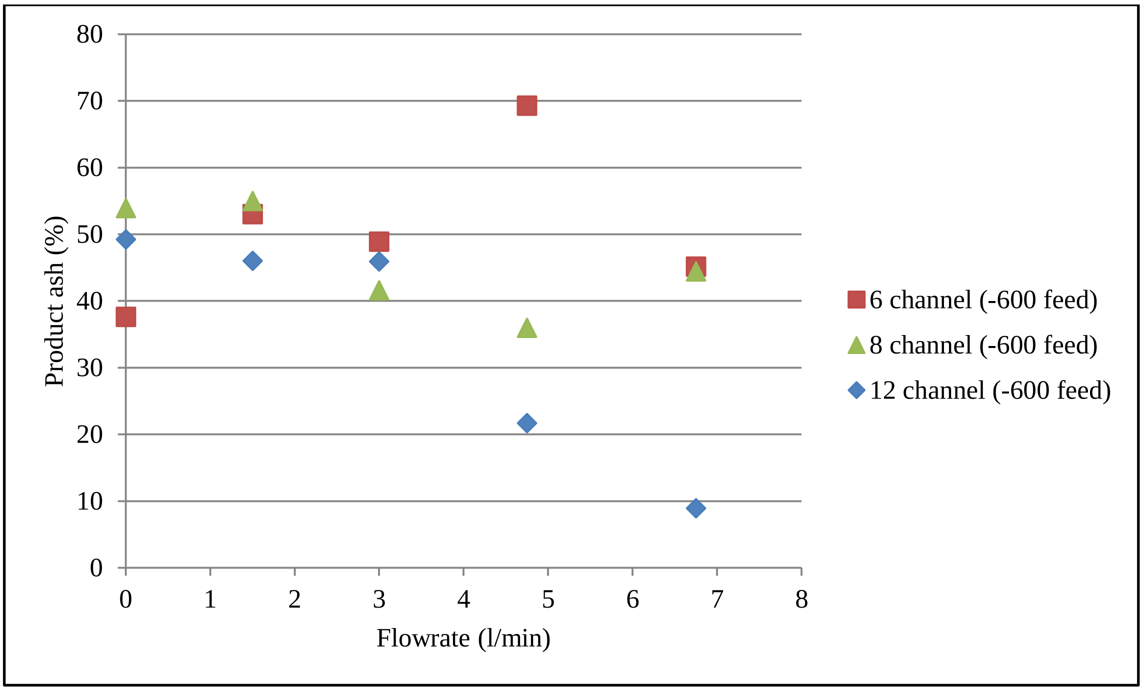

Figure 4.1.27: Effect of fluidisation rate on product ash content (-212+150 micron fraction)

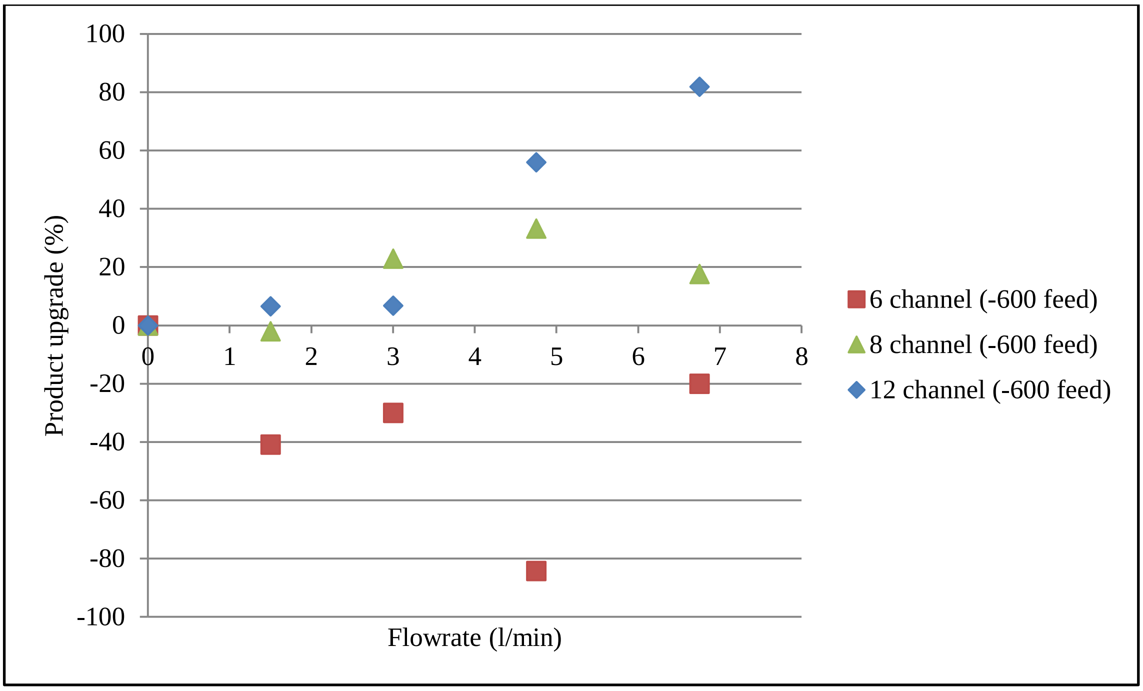

Figure 4.1.28: Effect of fluidisation rate on upgrade (-212+150 micron fraction)

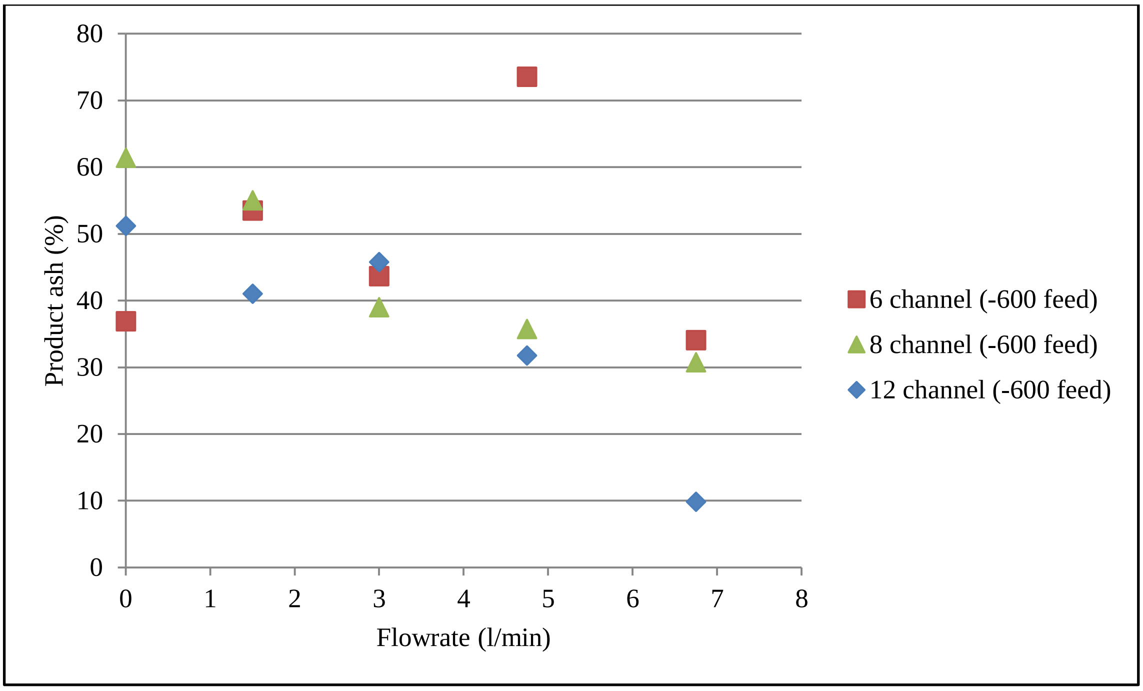

Figure 4.1.29: Effect of fluidisation rate on product ash content (-150+106 micron fraction)

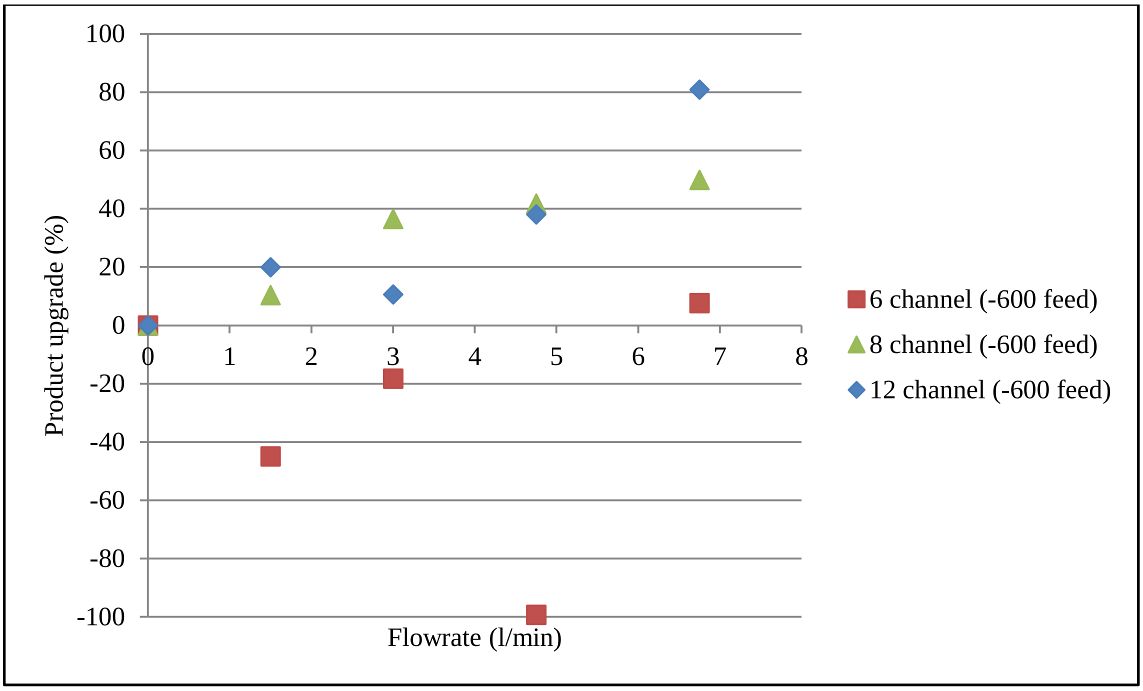

Figure 4.1.30: Effect of fluidisation rate on upgrade (-150+106 micron fraction)

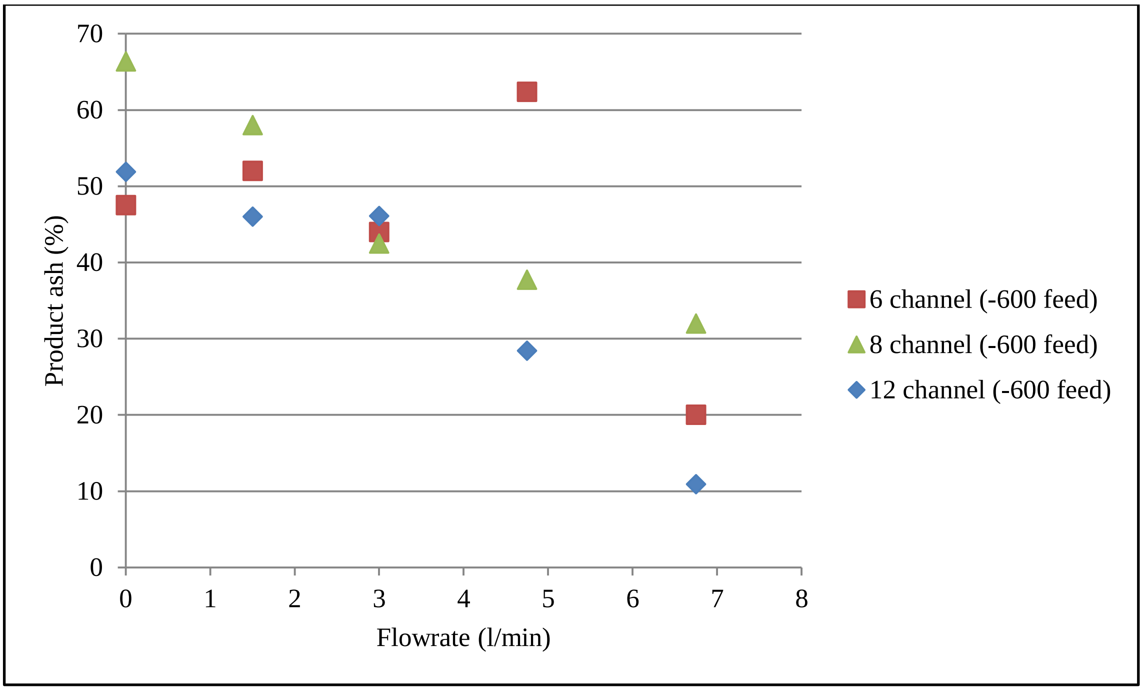

Figure 4.1.31: Effect of fluidisation rate on product ash content (-106+75 micron fraction)

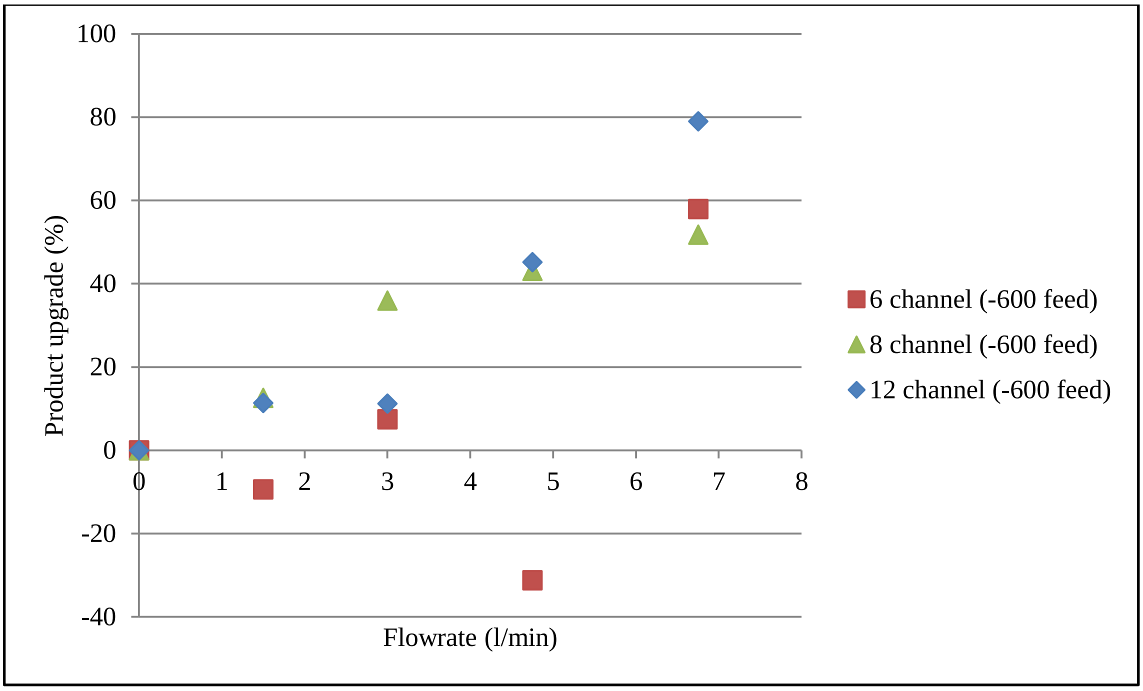

Figure 4.1.32: Effect of fluidisation rate on upgrade (-106+75 micron fraction)

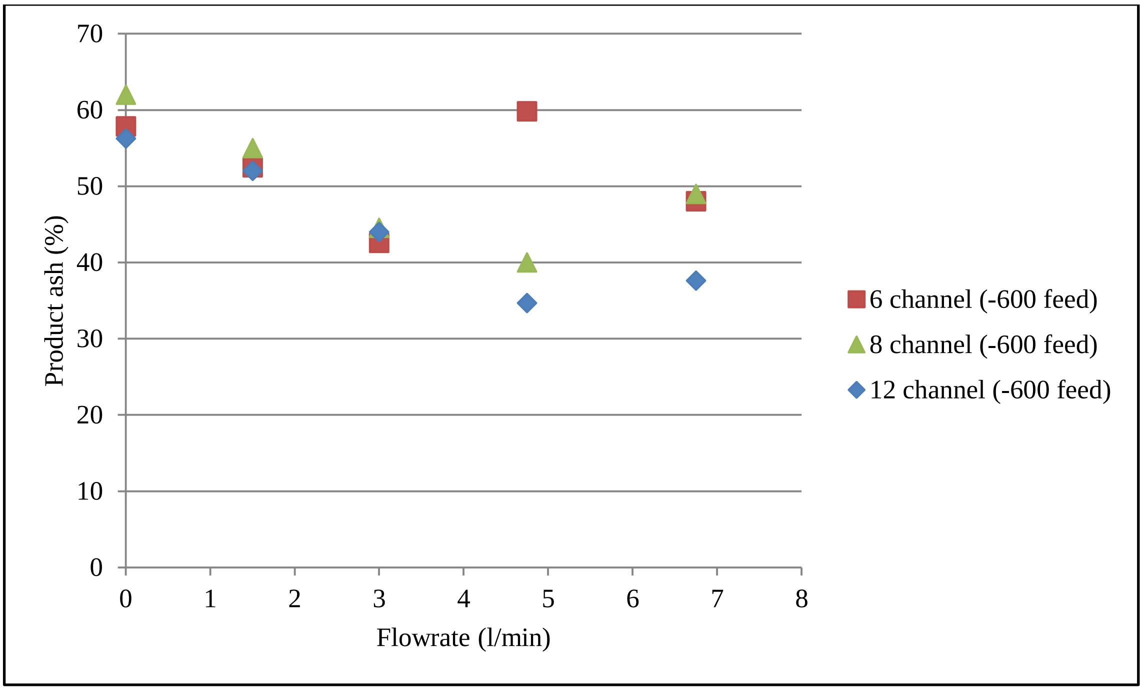

Figure 4.1.33: Effect of fluidisation rate on product ash content (-75 micron fraction)

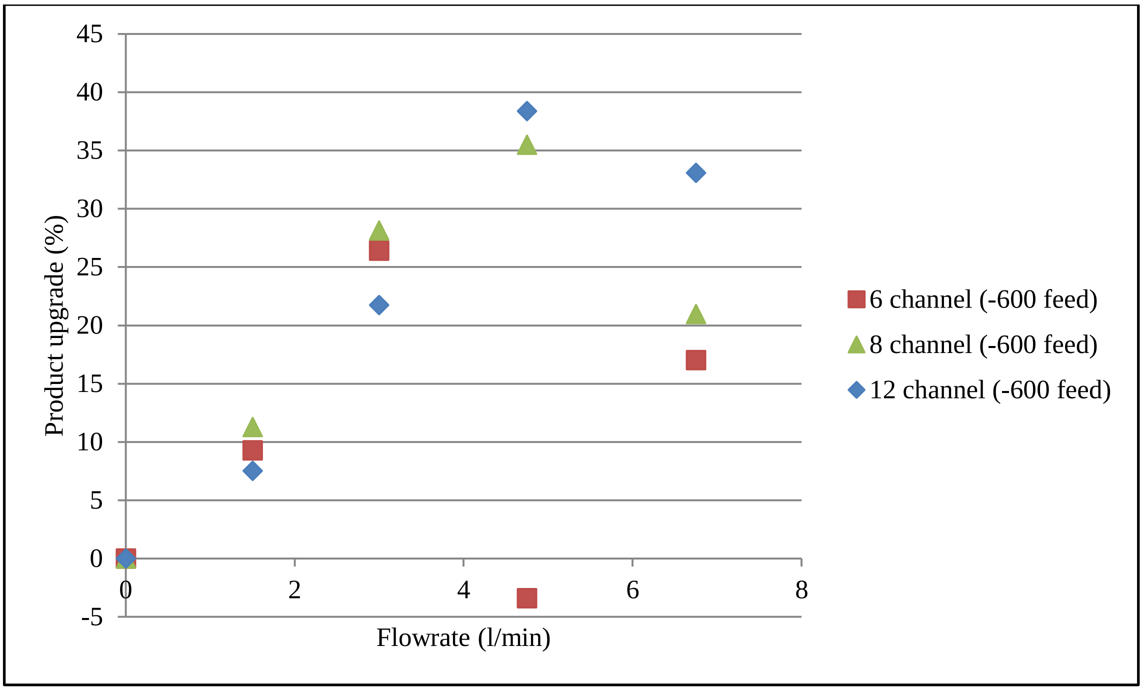

Figure 4.1.34: Effect of fluidisation rate on upgrade (-75 micron fraction)

4.1.3 Tests 7A-9A: -500 µm Feed

Table 4.1.5: Overall product ash (feed ash shown at 0 l/min)

Fluidisation rate (l/min)	Ash (%)		
	6 channels (7A)	8 channels (8A)	12 channels (9A)
0	46.03	46.08	45.59
1.5	55.70	58.98	46.55
3	42.87	45.51	37.36
4.75	39.05	43.85	20.63
6.75	40.32	42.81	18.74
Remains	43.69	43.90	57.73

Table 4.1.6: Overall product upgrade compared to feed

Fluidisation rate (l/min)	Upgrade (%) relative to feed (Yield %)		
	6 channels (7A)	8 channels (8A)	12 channels (9A)
1.5	-21.02 (13.12)	-27.99 (10.67)	-2.12 (14.04)
3	6.86 (4.27)	1.26 (2.59)	18.05 (3.72)
4.75	15.17 (2.69)	4.84 (2.51)	54.73 (7.65)
6.75	12.41 (5.71)	7.11 (3.22)	58.89 (21.12)

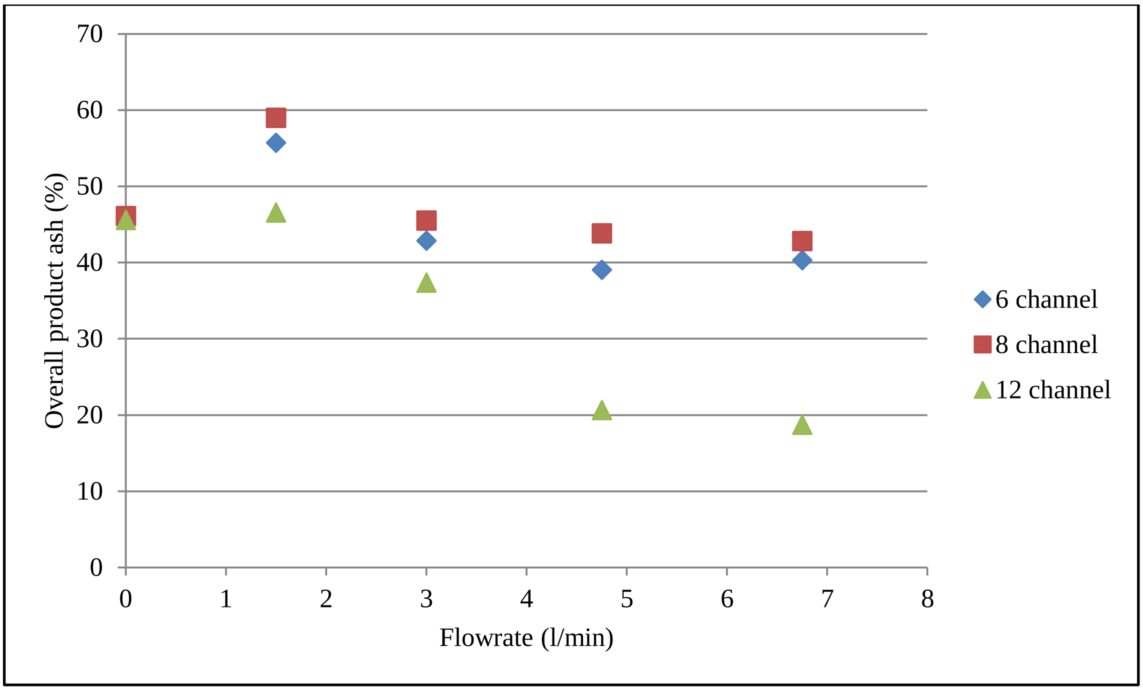

Figure 4.1.35 : Effect of fluidisation rate on the overall product ash (-500 micron feed)

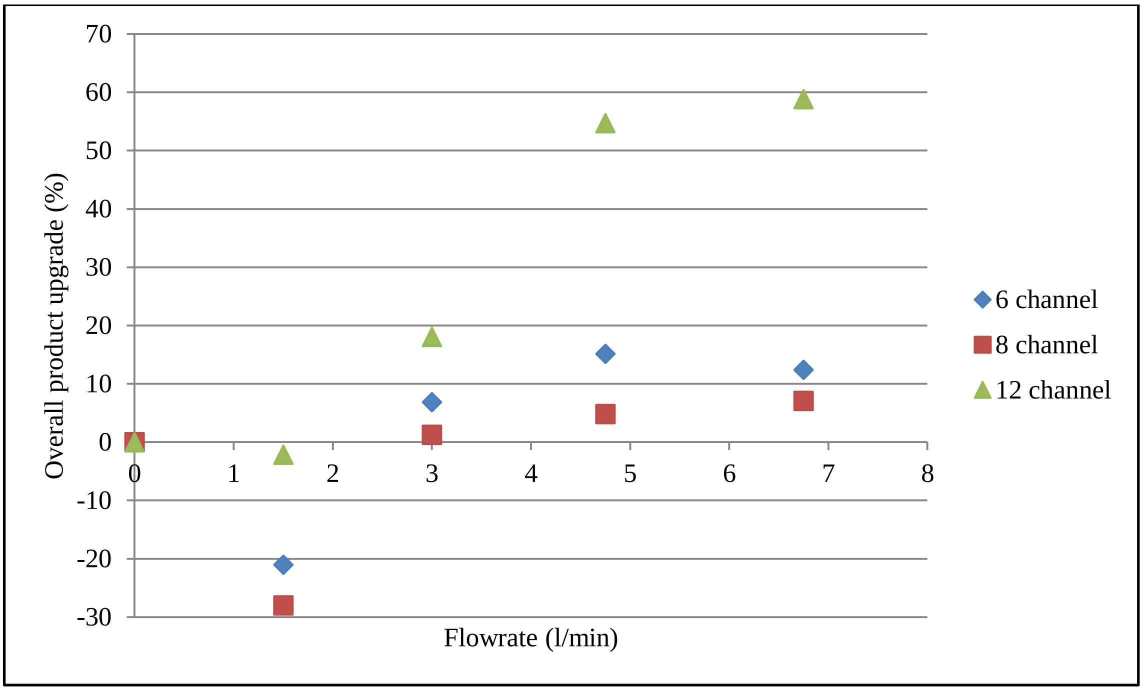

Figure 4.1.36: Effect of fluidisation rate on the overall product upgrade (-500 micron feed)

4.1.4 Tests 10A-12A: -355 µm Feed

Table 4.1.7: Overall product ash (feed ash shown at 0 l/min)

Fluidisation rate (l/min)	Ash (%)		
	6 channels (10A)	8 channels (11A)	12 channels (12A)
0	47.32	45.44	46.56
1.5	55.02	57.89	55.60
3	41.80	45.96	47.23
4.75	39.75	43.85	34.11
6.75	37.61	41.98	23.05
Remains	43.31	45.63	52.13

Table 4.1.8: Overall product upgrade compared to feed

Fluidisation rate (l/min)	Upgrade (%) relative to feed (Yield %)		
	6 channels (10A)	8 channels (11A)	12 channels (12A)
1.5	-16.26 (16.67)	-27.42 (12.54)	-19.41 (10.31)
3	11.67 (6.18)	-1.14 (4.24)	-1.43 (3.09)
4.75	16.01 (2.26)	3.49 (3.18)	26.74 (3.74)
6.75	20.54 (5.78)	7.61 (4.74)	50.50 (16.84)

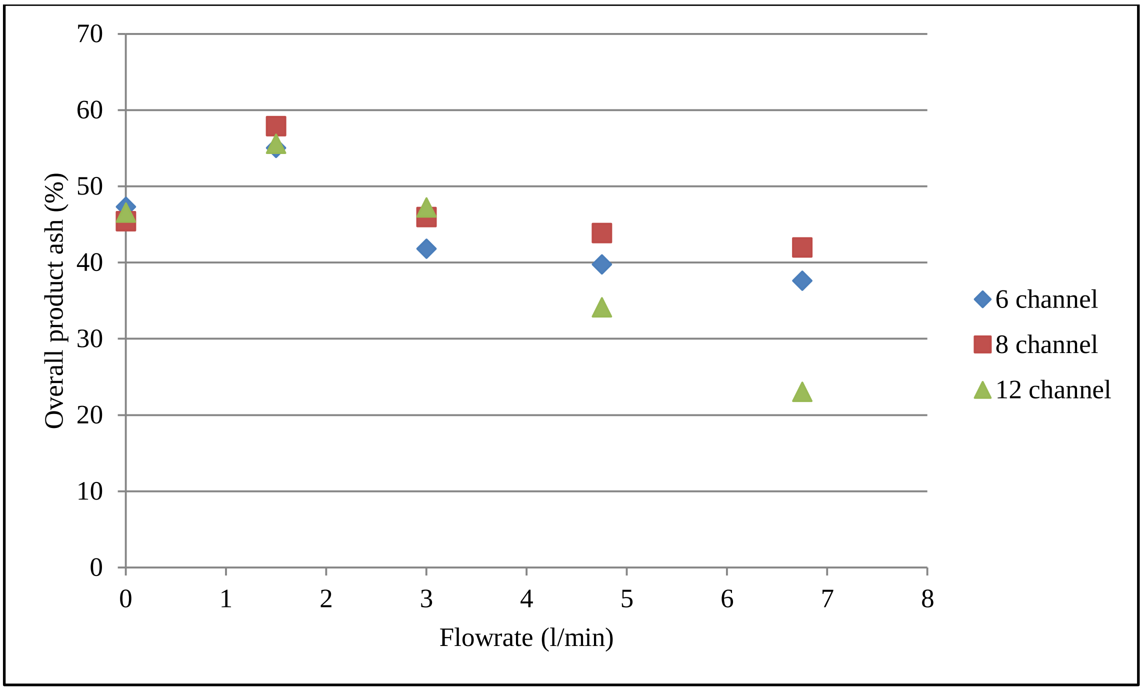

Figure 4.1.37: Effect of fluidisation rate on the overall product ash (-355 micron feed)

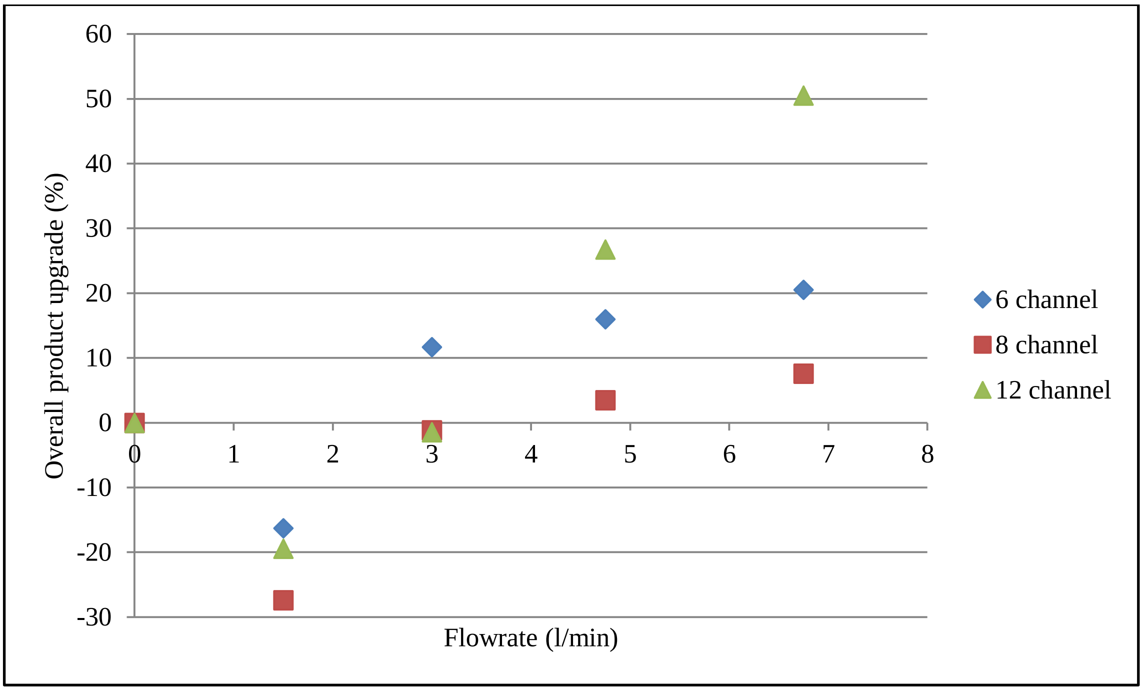

Figure 4.1.38: Effect of fluidisation rate on the overall product upgrade (-355 micron feed)

4.1.5 Tests 13A-15A: -212 µm Feed

Table 4.1.9: Overall product ash (feed ash shown at 0 l/min)

Fluidisation rate (l/min)	Ash (%)		
	6 channels (13A)	8 channels (14A)	12 channels (15A)
0	47.16	49.37	45.52
1.5	51.66	55.29	55.87
2.5	50.65	49.94	43.21
4	39.51	41.85	35.38
5.75	38.88	44.16	25.85
Remains	48.34	50.44	52.53

Table 4.1.10: Overall product upgrade compared to feed

Fluidisation rate (l/min)	Upgrade (%) relative to feed (Yield %)		
	6 channels (13A)	8 channels (14A)	12 channels (15A)
1.5	-9.54 (25.11)	-11.99 (14.52)	-22.76 (15.71)
2.5	-7.40 (4.83)	-1.15 (9.03)	5.08 (4.66)
4	16.23 (7.88)	15.23 (7.36)	22.27 (5.58)
5.75	17.55 (8.38)	10.56 (6.59)	43.21 (11.28)

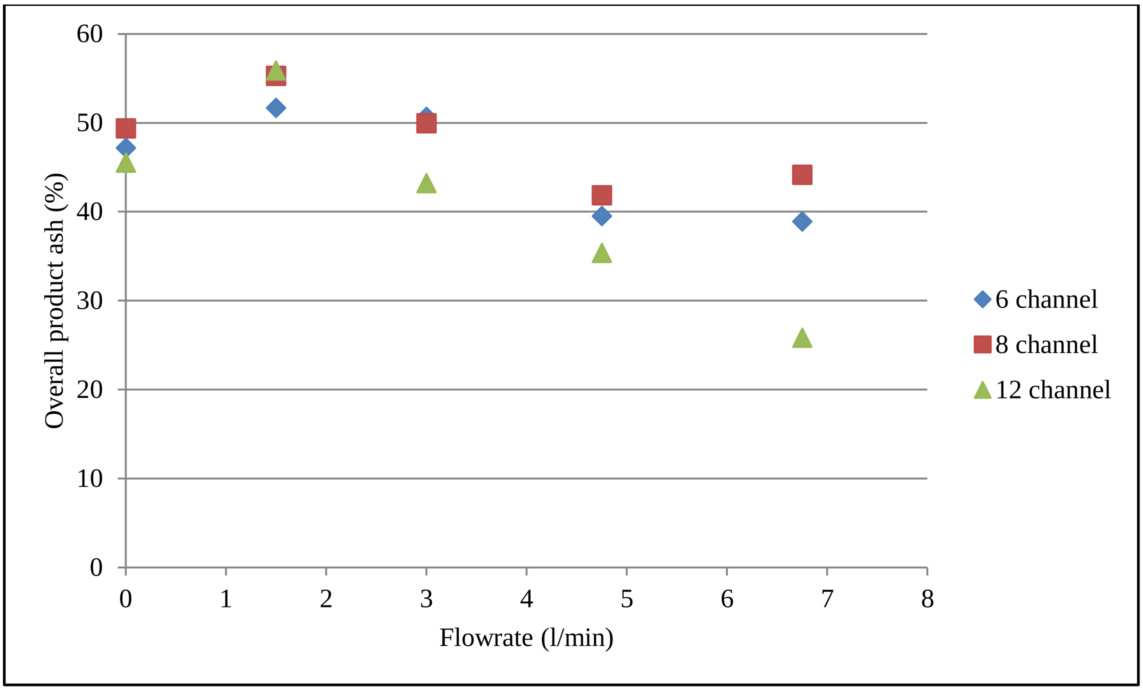

Figure 4.1.39: Effect of fluidisation rate on the overall product ash (-212 micron feed)

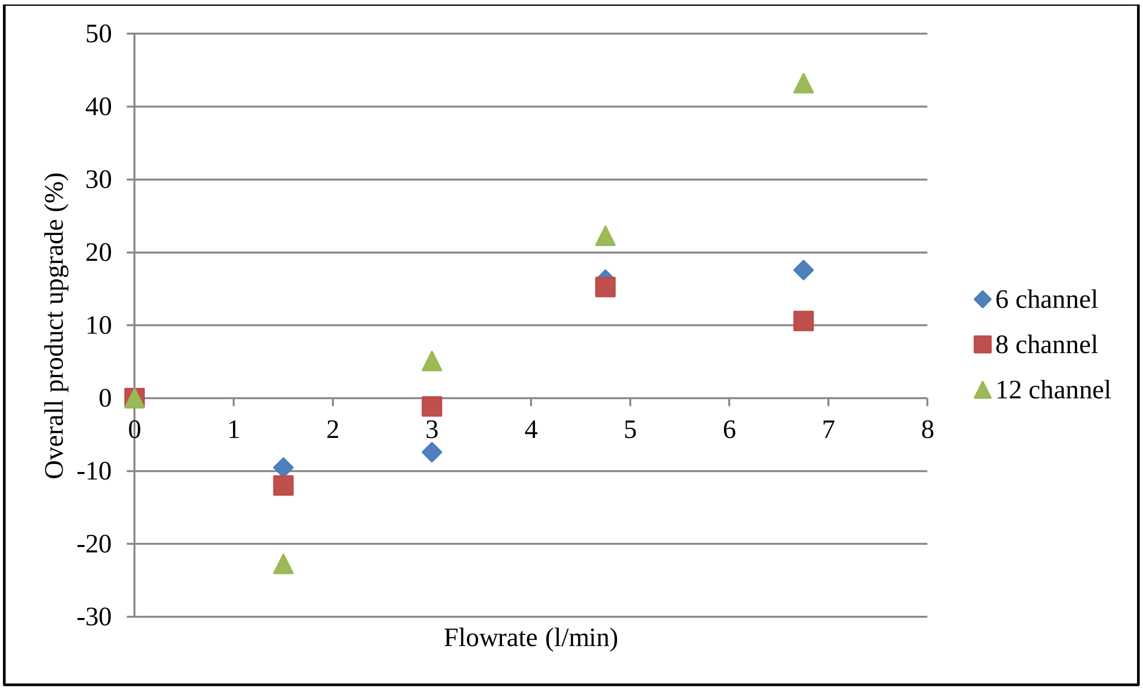

Figure 4.1.40: Effect of fluidisation rate on the overall product upgrade (-212 micron feed)

The effect of increased fines loading is evident in tables 4.1.5 to 4.1.10, in which the similarity in ash content of the remains and the product overflows in the 6 channel and 8 channel runs indicate that there was severe particle misplacement at the lower fluidisation rates. However, from tables A-1.1 to A-1.75 (of Appendix A-1), it can be inferred that both the 8 channel and 12 channel configurations are capable of producing a noticeable upgrade down to particle sizes below 75 μm if a sufficiently high fluidisation flowrate is used, such as in test 15 A, in which an upgrade of 33.33% was achieved in the -75μm fraction (see table A-1.74). Aside from revealing crucial details about the operational fluidisation rates and feed size ranges, the preliminary tests also demonstrated that, at higher flowrates (above 4.75 l/min), the 12 channel configuration showed marked reduction in ash contents of the product overflow throughout the entire size range. This result is of particular importance as it indicates that particles over a large size range are carried through the channels to the overflow by a common, and constant, channel velocity, attesting to density driven particle transport through the channels, with little dependence on particle size (Galvin et al., 2010c).

4.1.6 Summary of preliminary results

Overall, the results from the preliminary tests provided definitive evidence that the laboratory scale unit was indeed capable of producing noteworthy separation of fine, low quality coals with relatively high ash contents (as high as 60% feed ash). The 12 channel configuration, which translated to the narrowest channel spacing, resulted in a product with the lowest overall ash content. This result was expected and agreed with the findings of Laskovski et al. (2006), as well as various studies undertaken by Galvin (2006, 2009, 2010a, 2010b). The possibility of particle re-suspension behaviour in the narrowest channels, which was found to promote density-based separation in closely spaced channels in various studies conducted by Zhou et al. (2006), Galvin et al. (2009, 2010b) and Laskovski et al. (2006), was examined in greater detail during the main testing campaign. As stated earlier, a trial and error approach was adopted in the selection of the fluidisation rates by arbitrarily increasing the flowrate and observing the degree of elutriation of the feed. The lower ash content of the products attained at higher flowrates indicated that the feed material was comprised of a high proportion of low density coarse coal particles. A significant result of the preliminary campaign was that the 12 channel configuration, characterised by the narrowest channel width, was capable of producing an upgrade in the overflow product across the entire size range, even with a continuously increasing proportion of fine material in each subsequent test.

4.2 Primary batch separation tests

The preliminary findings revealed that consistent, and significant, reductions in product ash content were attained when fluidisation rates higher than 3 l/min were used. Furthermore, it was found that the reflux classifier was indeed capable of producing a distinct upgrade throughout the entire size range (-1000 μm), particularly when the 8 channel and 12 channel configurations were used. These promising results encouraged further batch tests using flowrates of 3, 6, 9 and 12 l/min. Each configuration was again tested independently with the same feed mass of approximately 500 g, however, this scope of experiments utilised a constant fluidisation rate throughout the entire run as well as feed covering the full size range. The overflow product was collected over the duration of an hour, and the samples amassed in each 15 minute interval were then analysed separately. The feed size range along with the choice of sieve sizes was identical to the preliminary experiments.

Waterberg coal was again used as the feed; however, the course of preliminary tests depleted the amount of readily available material below 1000 μm. Consequently, a rigorous process of crushing, screening, blending and sub-sampling was undertaken to supply the appropriate feed for each run. The feed was analysed to have an average ash content of approximately 60%.

The fundamental purpose of these tests was to examine the effect of the channel spacing on the separation efficiency of the laboratory scale device over time and to determine the combination of fluidisation rate and channel spacing that resulted in the highest upgrade of the feed throughout the entire size range, with particular emphasis on the finer sizes (-212 μm). Consequently, the lowest possible particle size that could be efficiently separated using the device could be ascertained. The consistency of the separator performance was also of particular import, thus, each combination of channel spacing and fluidisation rate was tested in triplicate.

In a similar manner to that of the preliminary campaign, the ash content of each size fraction was analysed relative to flowrate, channel spacing and time. Additionally, yield-ash curves were generated for each size fraction as well as for the overall size range, so as to examine the recovery aptitude of each combination of channel spacing and fluidisation rate.

4.2.1 Performance at 3 l/min (Tests 1-9)

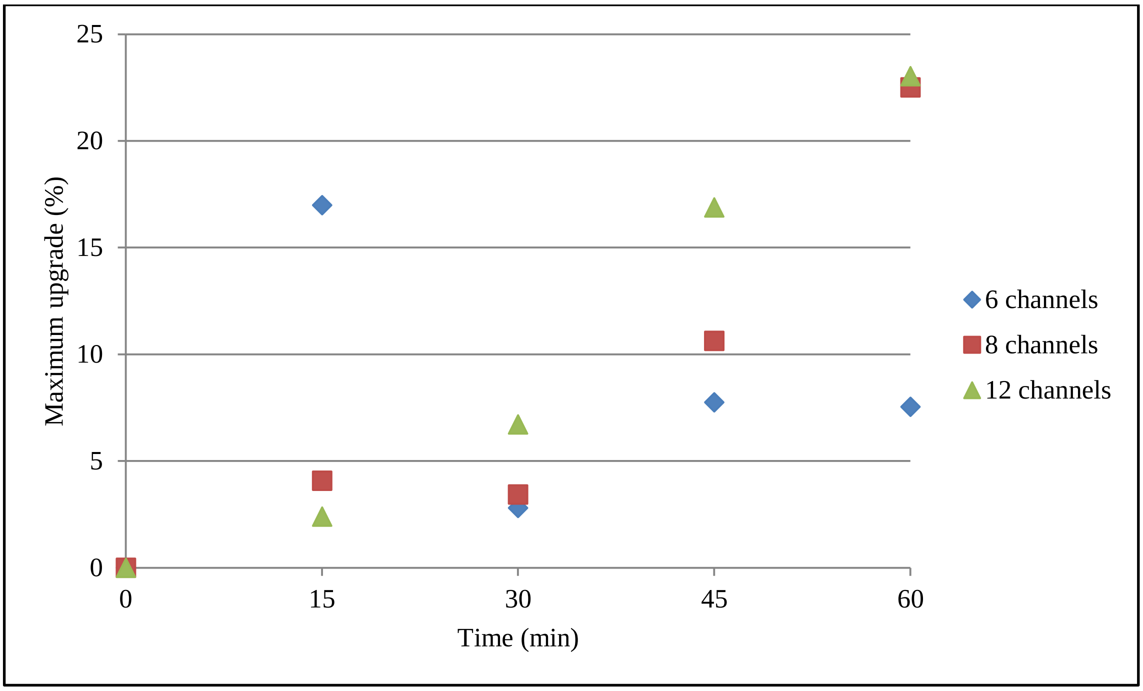

Figure 4.2.1: Maximum overall product upgrade (%) attained from triplicate runs over 60 minutes at 3 l/min

The first group of 9 tests were undertaken using the lowest fluidisation rate of 3 l/min and consisted of 3 repeated runs per channel configuration. Despite the poor separation attained at 3 l/min during the preliminary campaign, it was deemed necessary to incorporate it into the main scope of tests as both the head ash and size distribution of the feed was marginally different to that of earlier tests. Figure 4.2.1 above shows the highest product upgrades achieved out of the 3 repeated runs (The results of each individual test can be viewed in Appendix A-2). It can be seen that a reduction in product ash content was achieved throughout the duration of the test, with upgrades in the 8 channel and 12 channel runs rising steadily with time. The 6 channel run shows a relatively high upgrade immediately after 15 minutes. This upgrade, seen in test 1, may be attributed to the feed in this run consisting of a larger amount of fines (39.77% -150 µm material) at a slightly lower ash content compared to 31.79% in the 8 channel run (test 4) and 33.80% in the 12 channel run (test 7). Consequently, this material may have been elutriated immediately resulting in a high initial upgrade. Tables C-1.1 to C-1.8 (of Appendix C-1) shows the standard deviation in the upgrade across the triplicate of repeats over time. With 6 channels, the standard deviations range from 1.19-11.27 compared to 1.11-5.35 and 0.70-2.26 for 8 channels and 12 channels respectively. It is evident that the 12 channel configuration performs with greater repeatability and consistency, followed by the 8 channel configuration, and finally the 6 channel configuration. A closer examination of the product ash content achieved in each size fraction shows upgrades ranging from roughly 5% to 25% throughout the size range in the first 15 minutes. It is interesting to note that the widest channels (6 channel configuration) performed the best in the first 15 minutes of the run, however, in the latter 45 minutes of the test significant particle misplacement was observed in the 6 channel configuration in which the ash content of the product heavily exceeded that of the feed (details of which can be viewed in tables A-2.1 to A-2.15 of Appendix A-2). The 12 channel configuration achieved higher upgrades with time, especially in the coarser size range (-1000 + 500 µm), with upgrades reaching as high as 39% in the second half hour of the run.

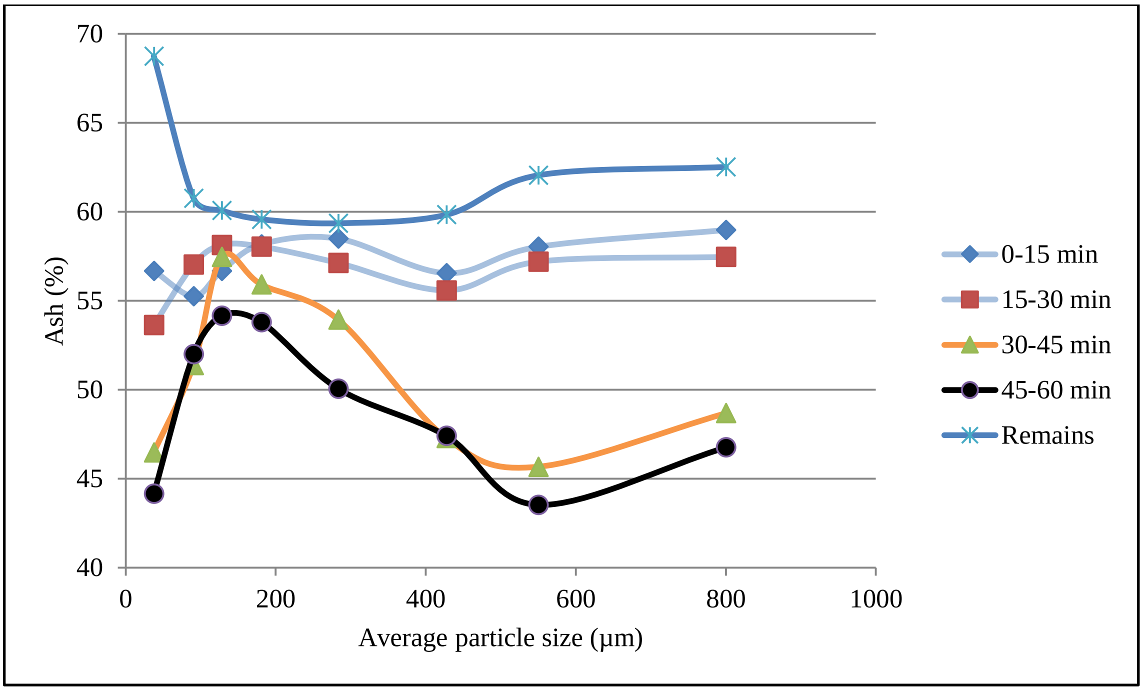

Figure 4.2.2: Ash % vs. average particle size for 12 channels at 3 l/min

Figure 4.2.2 above illustrates the variation in average product ash content as well as that of the remains (underflow) with the average particle size attained in Tests 7-9 when the closest channel spacing (12 channels with spacing equal to 2.10 mm) was utilised. The average particle size was determined by calculating the arithmetic mean of each size fraction. The average product ash content was taken over all 3 repeated runs at each respective time interval. It should be noted that the lines joining the data points in figure 4.2.2, as well as in all subsequent plots, is not meant to indicate a trend, but rather to assist in differentiating between the data sets. For the first 30 minutes of the test, it is apparent that the product ash content is somewhat independent of particle size, after which the results becomes irregular, which is likely due to the majority of the light material being removed in the first 30 minutes of test. Since the ash content within a particle size range is closely related to the density of the particles, it may be surmised that particles of various sizes are transported through the narrow channels based on density for the lower 2 tested flowrates, with some particle size involvement at higher flowrates. Thus, it is apparent that the capability of the narrow channels of the newly constructed device to enhance gravity separation is in accordance with the literature (Laskovski et al., 2006).

4.2.2 Performance at 6 l/min (Tests 10-18)

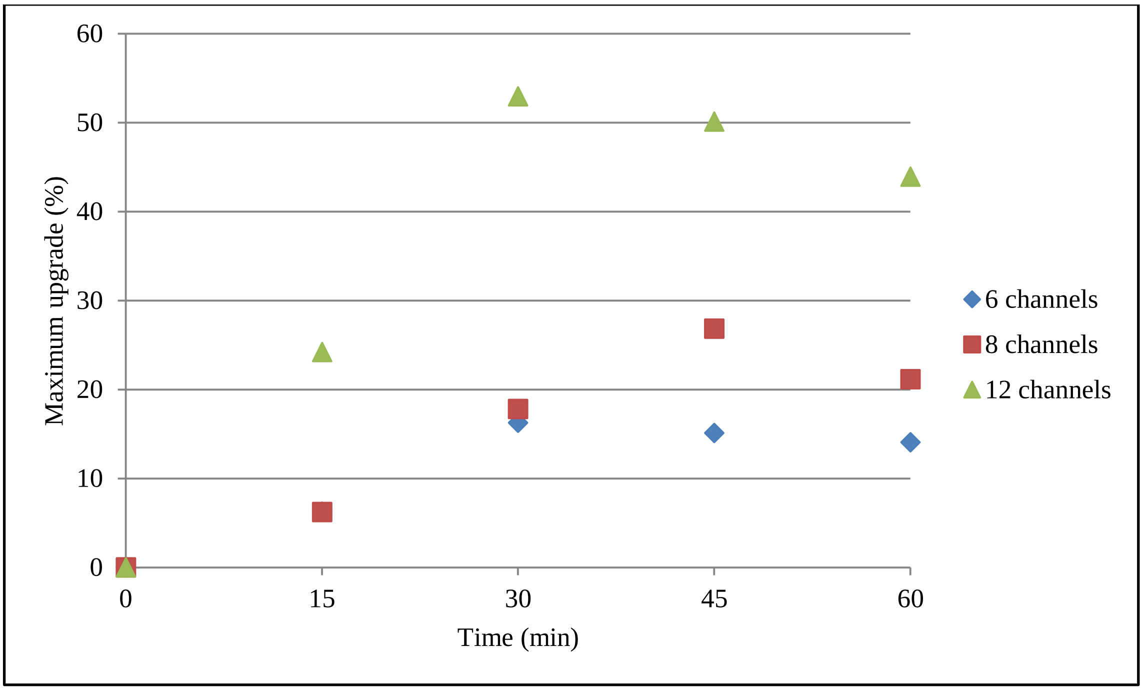

Figure 4.2.3: Maximum overall product upgrade (%) attained from triplicate runs over 60 minutes at 6 l/min

Figure 4.2.3 above summarises the results obtained during tests 10-18 in which the flowrate was set as 6 l/min. The 12 channel configuration produces significant upgrades throughout the duration of test. The upgrade generally tends to decrease after 30 to 45 minutes; however, as mentioned earlier, this is most likely a result of the clean coal reporting to the overflow in the first half of the test, in addition to finer material (-75 µm) being indiscriminately washed into the overflow. Furthermore, it can be clearly seen that all 3 configurations perform far better using 6 l/min compared to the previous runs which used 3 l/min. Individual fractional upgrades are presented in tables A-2.46 to A-2.90 (Appendix A-2) and it is evident that particle misplacement is less frequent in comparison with previous tests undertaken at 3 l/min.

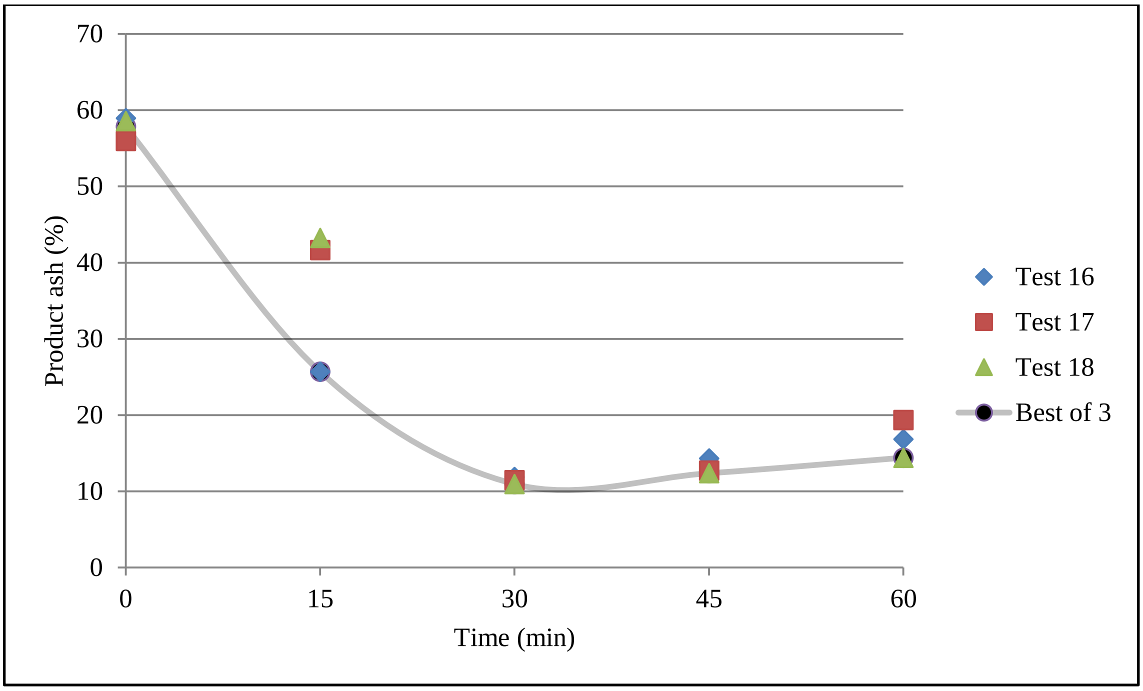

Figure 4.2.4: Product ash content over 60 minutes using 12 channels at 6 l/min (+212 microns)

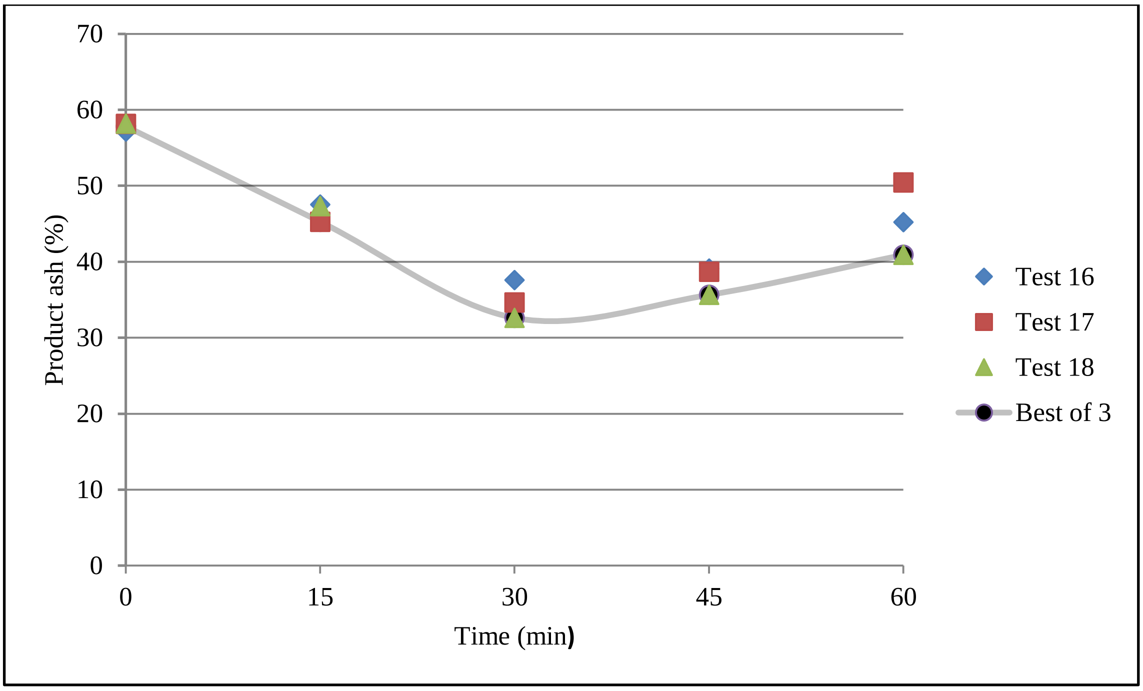

Figure 4.2.5: Product ash content over 60 minutes using 12 channels at 6 l/min (-212 microns)

Figures 4.2.4 and 4.2.5 above displays the results obtained for tests 16-18 (12 channels and 6 l/min) for material above and below 212 µm respectively. The results of all 3 runs are fairly consistent, with the standard deviation at each time interval below 2.01 at 30, 45 and 60 minutes for material above 212 µm (at 15 minutes the standard deviation in ash content was equal to 7.93). The standard deviation in ash content reaches a maximum of 3.90 at 60 minutes for the finer material (-212 µm) (Appendix C-1). In the size range -600 + 150 µm, upgrades ranging from roughly 20% (at the finest size) to 88% (at the coarsest size) can be observed for the 12 channel configuration and between 10% and 51% when 6 channels and 8 channels were used. In general, the upgrade is seen to peak in the first 30 minutes. In the size range -150 + 106 µm, the 12 channel configuration continued to perform impressively, producing a maximum upgrade of 25.14%, 56.56% and 61.49% at 15, 30 and 45 minutes. Thereafter, a faint decrease in upgrade was noted. At the finest size (-75 µm), a reasonable decrease in ash content from 57.37% to 45.74% was observed (The actual ash data can be viewed in Table A-2.76 to A-2.90).

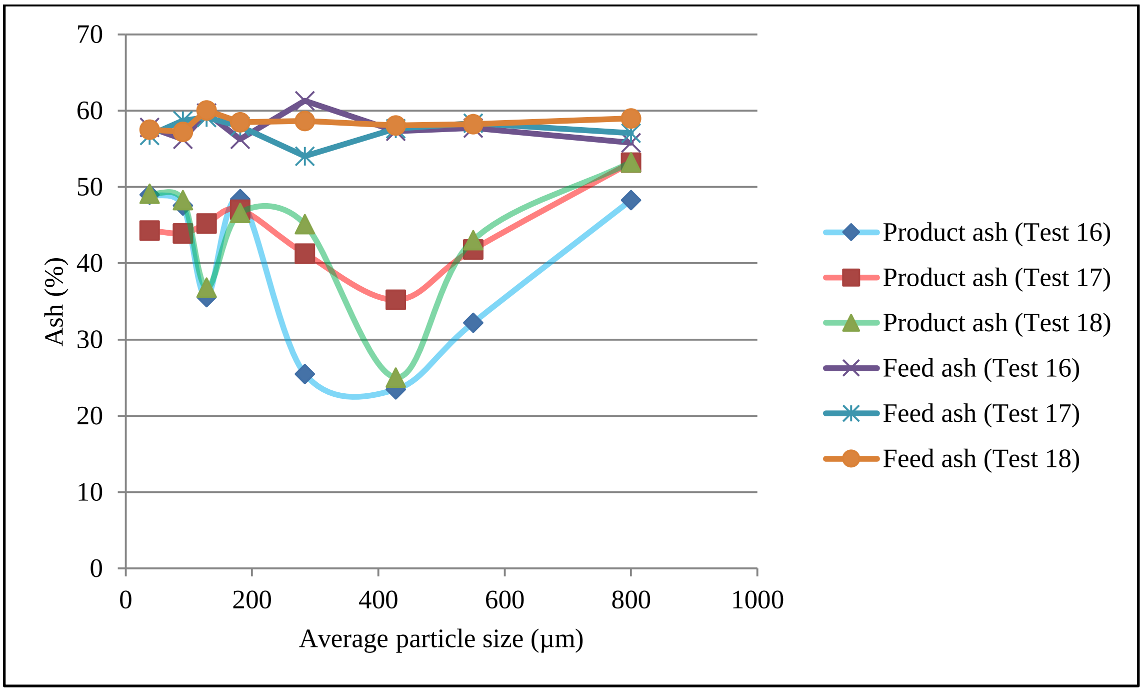

Figure 4.2.6: Product ash content vs. particle size for 12 channels at 6 l/min (0-15 minutes)

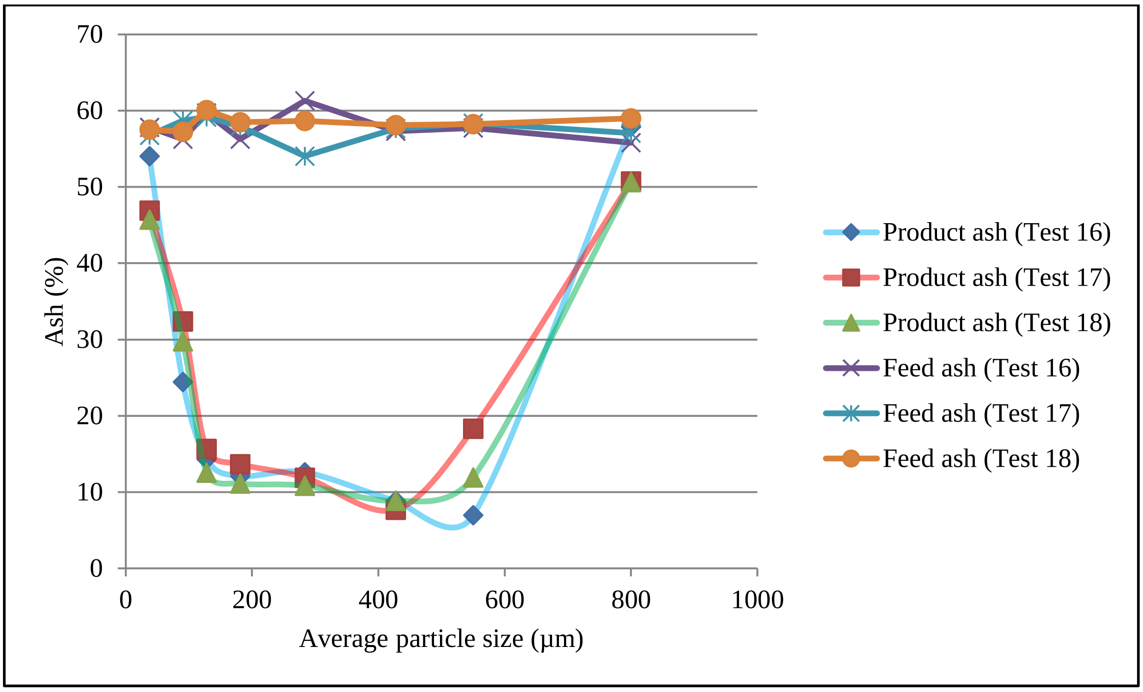

Figure 4.2.7: Product ash content vs. particle size for 12 channels at 6 l/min (15-30 minutes)

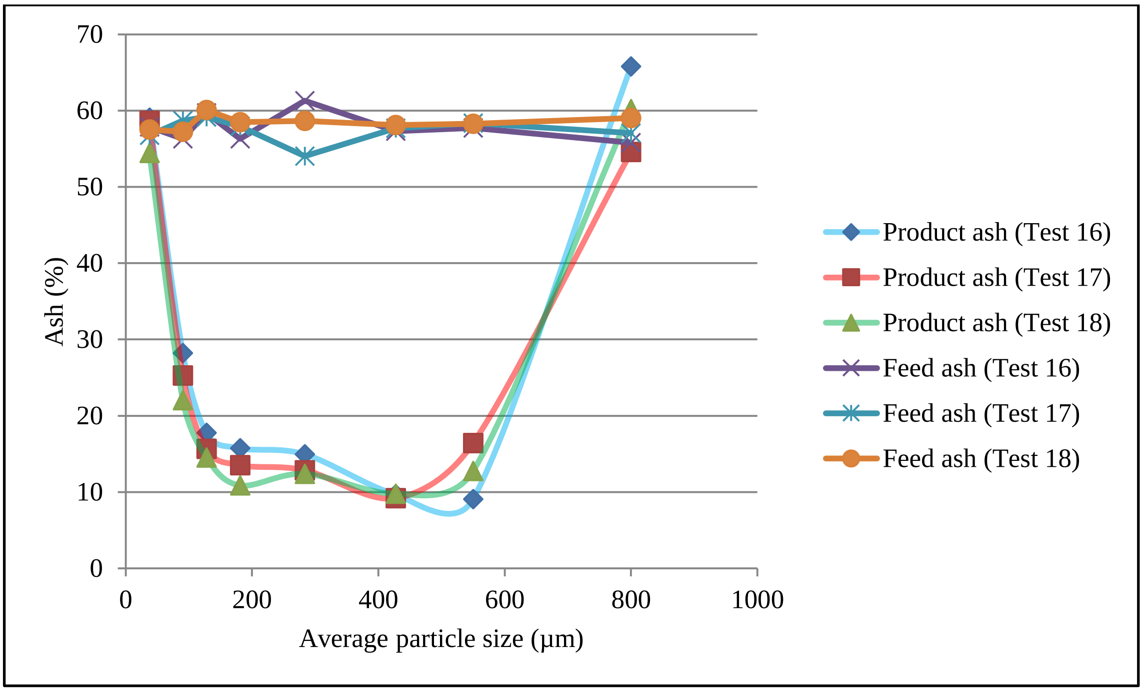

Figure 4.2.8: Product ash content vs. particle size for 12 channels at 6 l/min (30-45 minutes)

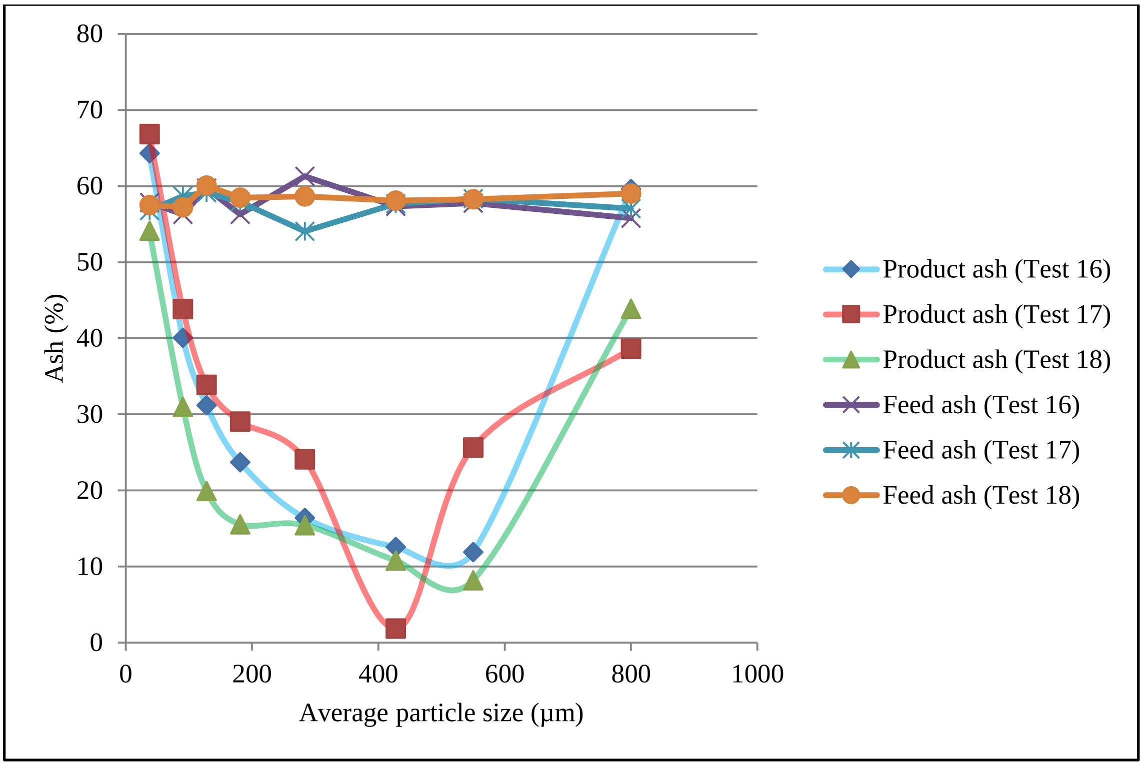

Figure 4.2.9: Product ash content vs. particle size for 12 channels at 6 l/min (45-60 minutes)

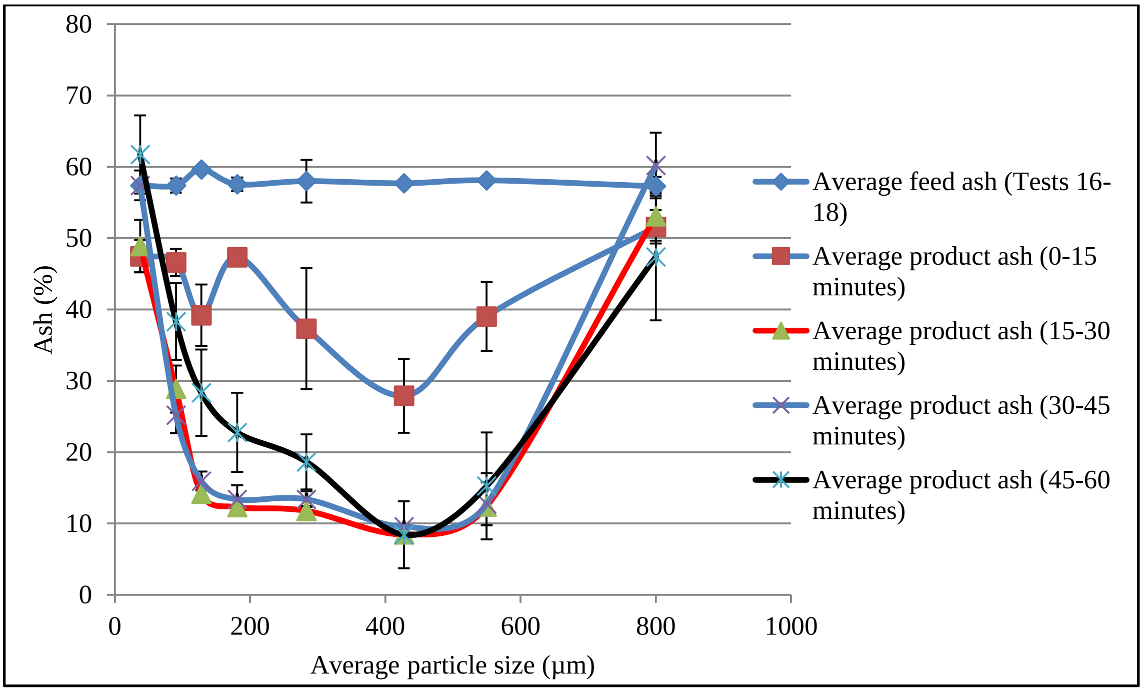

Figure 4.2.10: Average product ash vs. particle size for 12 channels at 6 l/min (Tests 16-18)

Figures 4.2.6-4.2.9 above focuses on the performance of the narrowest channels and illustrates the ash contents of both the product and feed for all 3 repeated runs (tests 16-18) achieved in each size fraction (arithmetic mean particle size in each fraction are plotted on the x-axis) for each 15 minute interval. Figure 4.2.10 illustrates the average product ash achieved over the duration of the 60 minute runs, as well as the associated standard deviations in ash (%) between the triplicate runs as error bands. Throughout the duration of the test, it is clear that significantly lower ash contents were achieved for particles in the -600 + 150 µm size range. Ash contents as low as 10% were attained between 15 and 45 minutes with reasonable consistency. It is evident that after the initial 15 minutes, in which distinct deviations in product ash attained between the repeated runs can be seen, the system began to stabilise and attain a steady-state (The data can be viewed in tables A-2.76 to A-2.90).

4.2.3 Performance at 9 l/min (Tests 19-27)

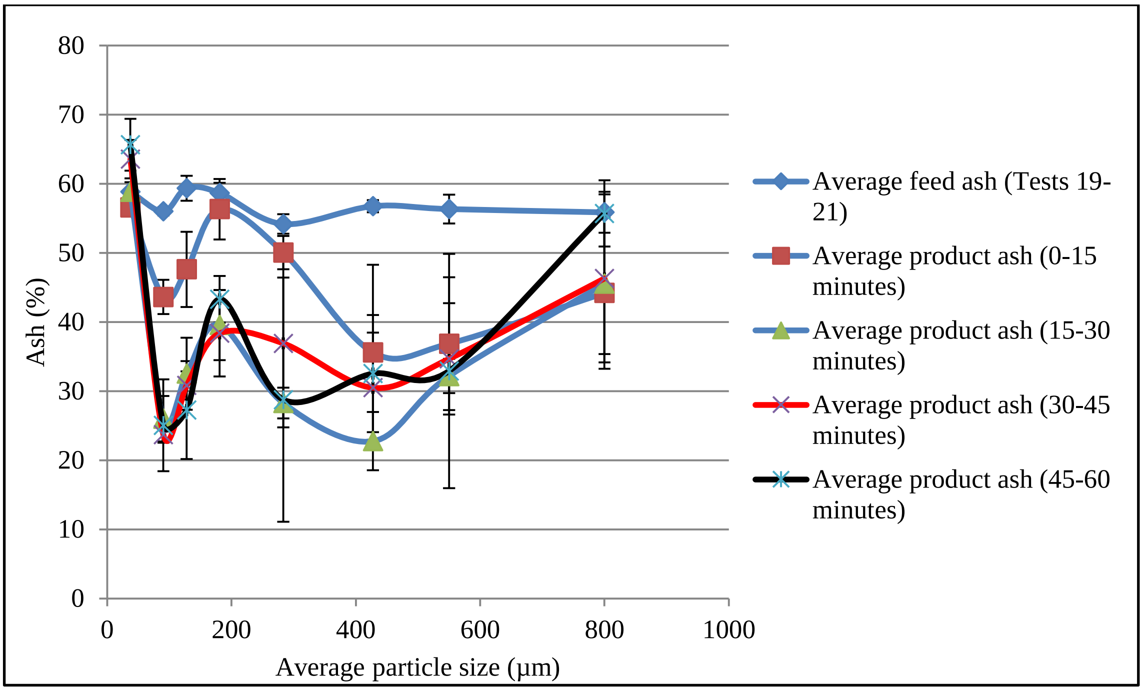

Figure 4.2.11: Average product ash vs. particle size for 6 channels at 9 l/min (Tests 19-21)

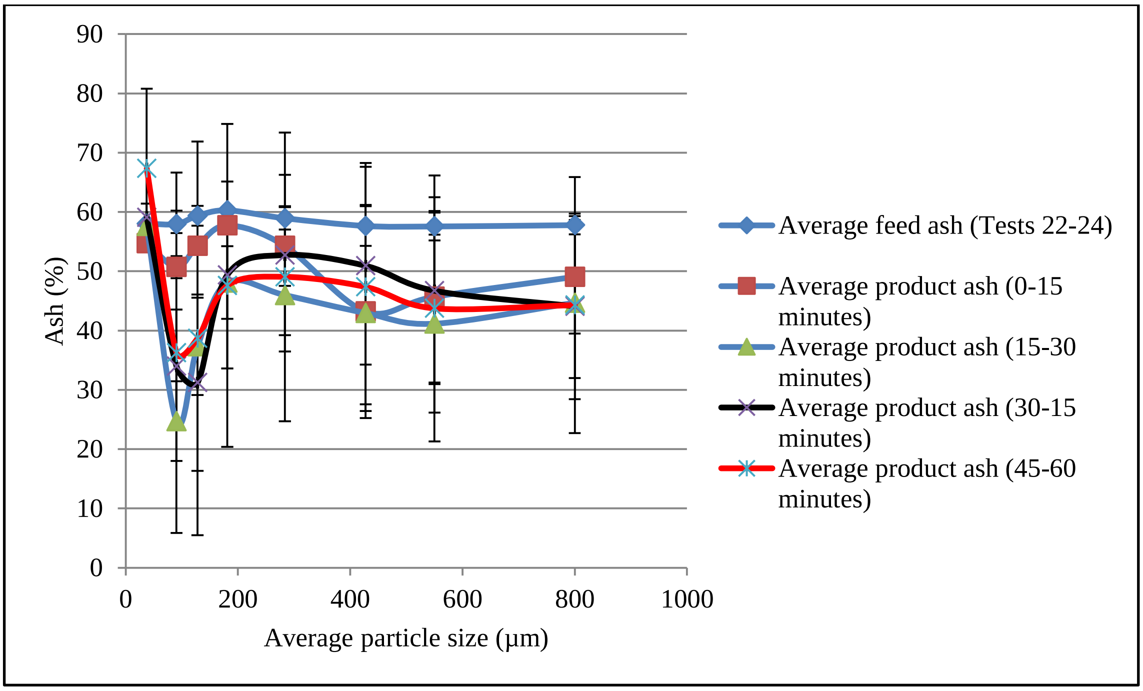

Figure 4.2.12: Average product ash vs. particle size for 8 channels at 9 l/min (Tests 22-24)

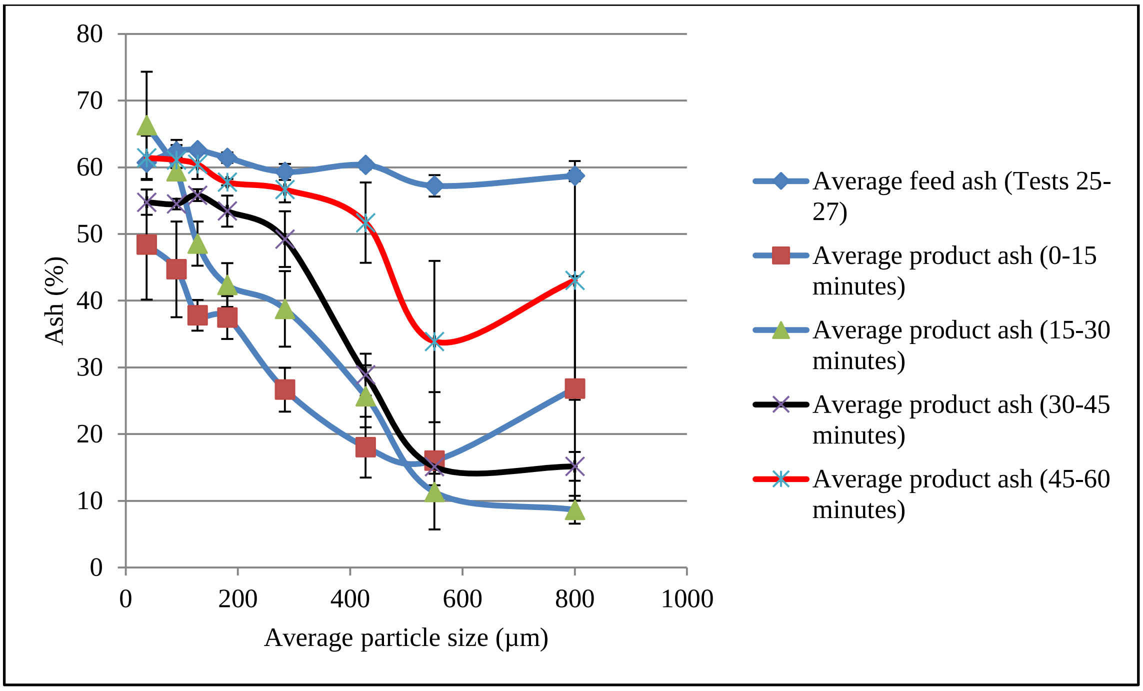

Figure 4.2.13: Average product ash vs. particle size for 12 channels at 9 l/min (Tests 25-27)

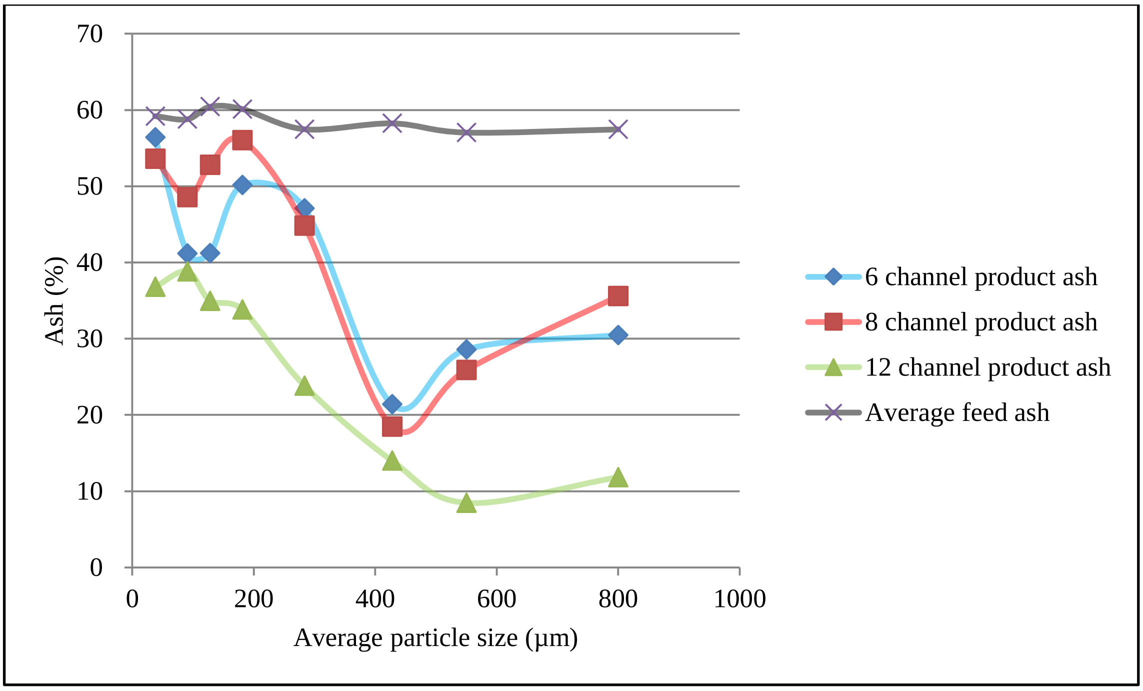

Figure 4.2.14: Variation of ash content with particle size at 9 l/min (0-15 min)

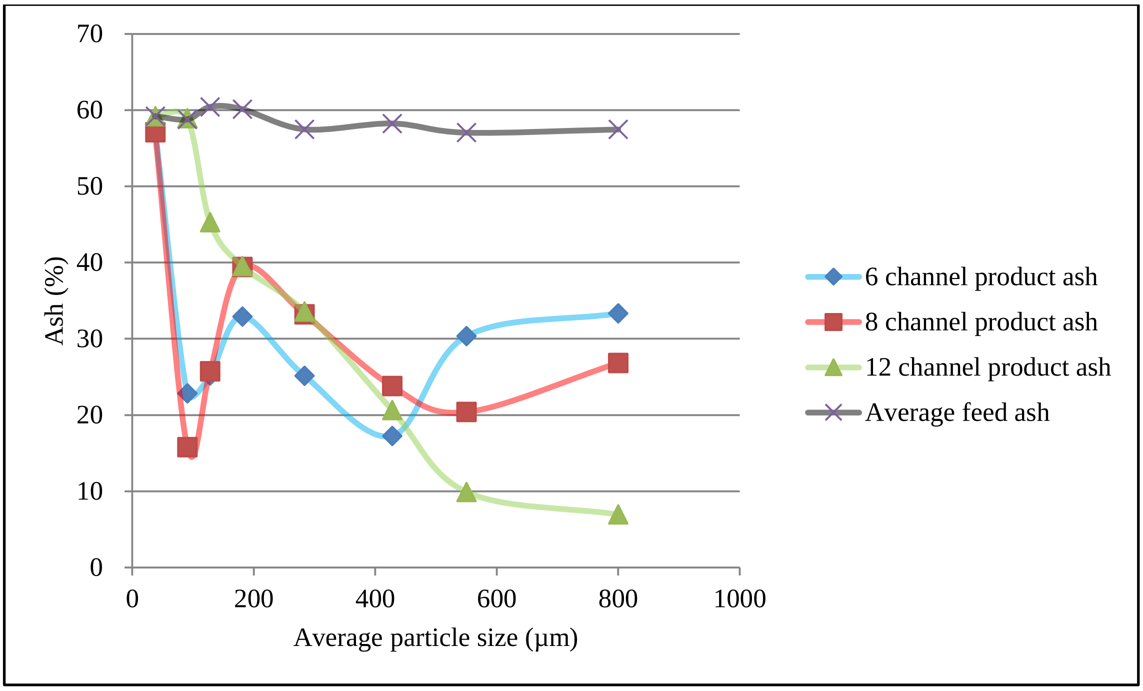

Figure 4.2.15: Variation of ash content with particle size at 9 l/min (15-30 min)

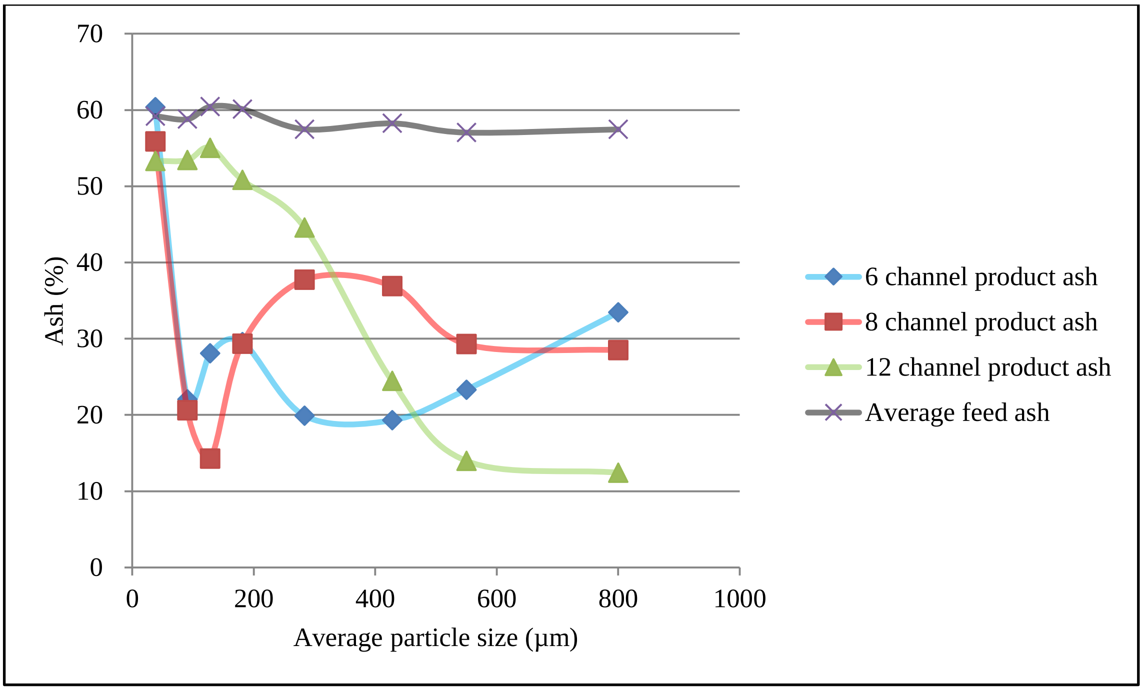

Figure 4.2.16: Variation of ash content with particle size at 9 l/min (30-45 min)

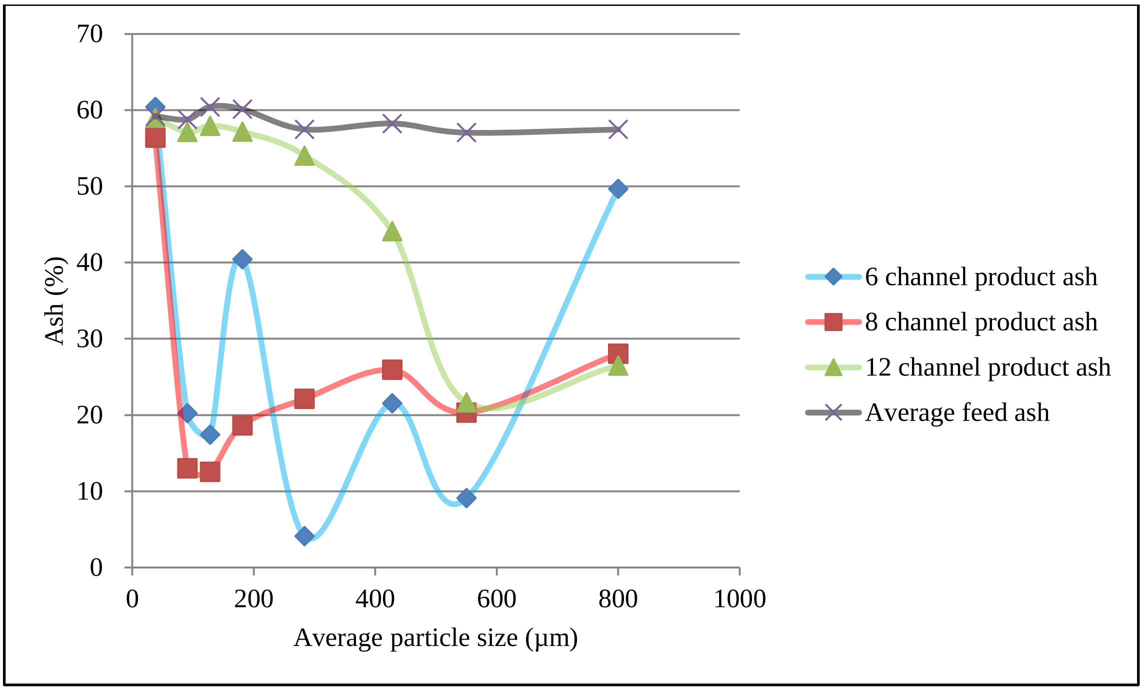

Figure 4.2.17: Variation of ash content with particle size at 9 l/min (45-60 min)

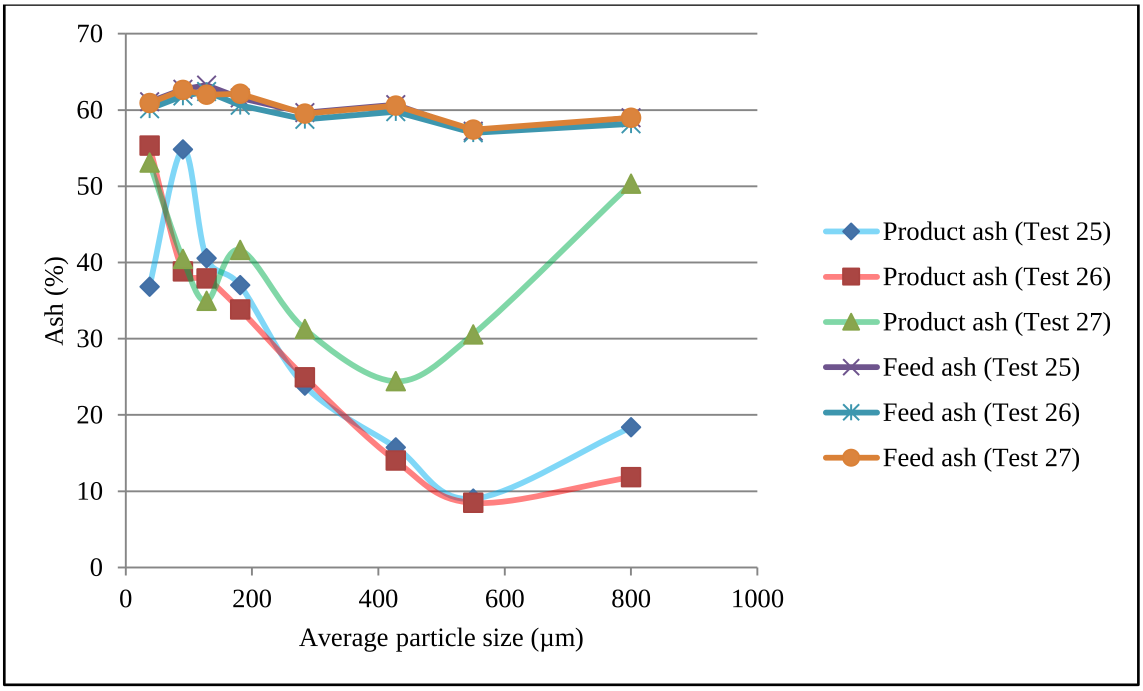

Figure 4.2.18: Product ash content vs. particle size for 12 channels at 9 l/min (0-15 minutes)

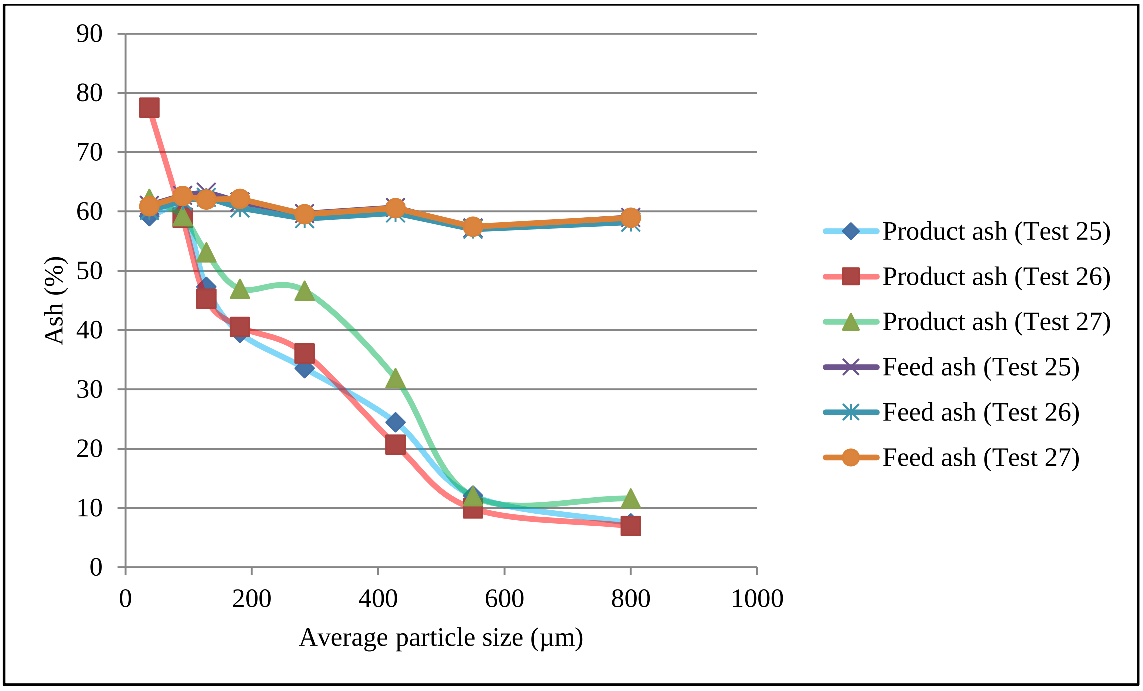

Figure 4.2.19: Product ash content vs. particle size for 12 channels at 9 l/min (15-30 minutes)

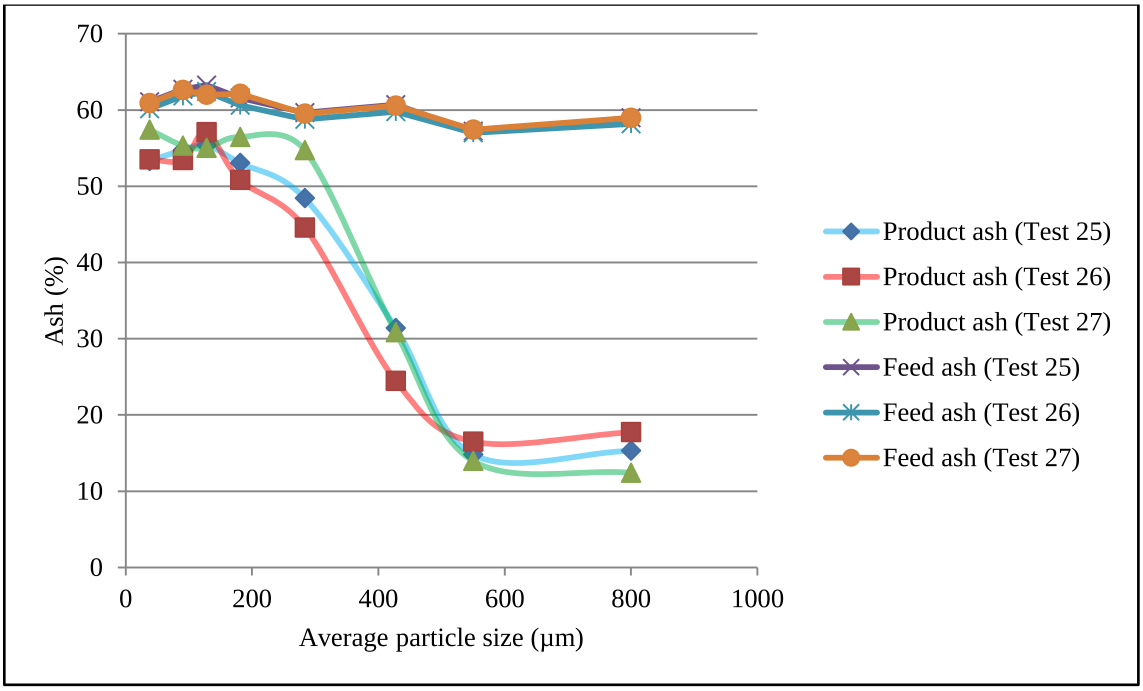

Figure 4.2.20: Product ash content vs. particle size for 12 channels at 9 l/min (30-45 minutes)

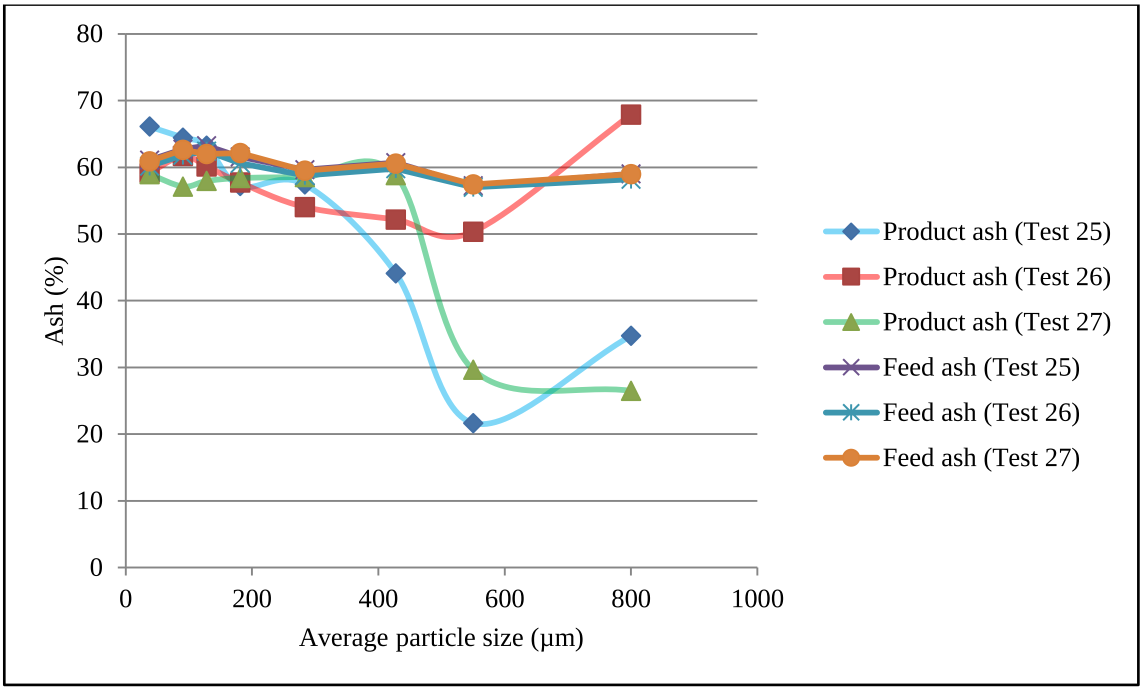

Figure 4.2.21: Product ash content vs. particle size for 12 channels at 9 l/min (45-60 minutes)

The lowest product ash contents attained using 9 l/min are shown in figures 4.2.14-4.2.17 for 6 channels (tests 19-21), 8 channels (tests 22-24) and 12 channels (tests 25-27) for each 15 minute interval over the duration of the run. The product ash content was examined in relation to the average feed ash, which was calculated by simply determining the arithmetic average of the ash content of the feed material used in tests 19-27 (average over 9 runs). The standard deviation in the feed ash content was suitably low, with the -106 + 75 µm fraction having the largest variance with a standard deviation of 2.67. From figure 4.2.14, it can be seen that all 3 configurations respond reasonably well at the 9 l/min in the first 15 minutes of the run, particularly for particles exceeding 355 µm. While the 6 channel and 8 channel configurations do indeed deliver a product with lower ash content (down to an ash content of approximately 18.50% from a head ash of approximately 59%), the separation is somewhat erratic. During the 15 minute interval between 30 and 45 minutes, the standard deviation in product ash content was as high as 10.17 in the 6 channel configuration and 12.16 in the 8 channel configuration for the coarsest size fraction, compared to a standard deviation of 2.17 for the identical size range when using 12 channels. Appendix C-1 shows the standard deviations associated with the product ash content and the upgrade, and the consistency of the 3 repeated runs is, for the most part, higher when using 12 channels. Similar to the results obtained using 12 channels and 6 l/min (figures 4.2.6-4.2.9), figures 4.2.19 and 4.2.20 shows a considerable reduction in product ash content over a large majority of the feed size range, as well as reasonable consistency across all 3 repeated runs. This observation was a contributing factor in extending the testing campaign to include semi-continuous tests, with the aim of consistently achieving similar product upgrades and repeatability seen in figures 4.2.19-4.2.20.

4.2.4 Performance at 12 l/min (Test 28-36)

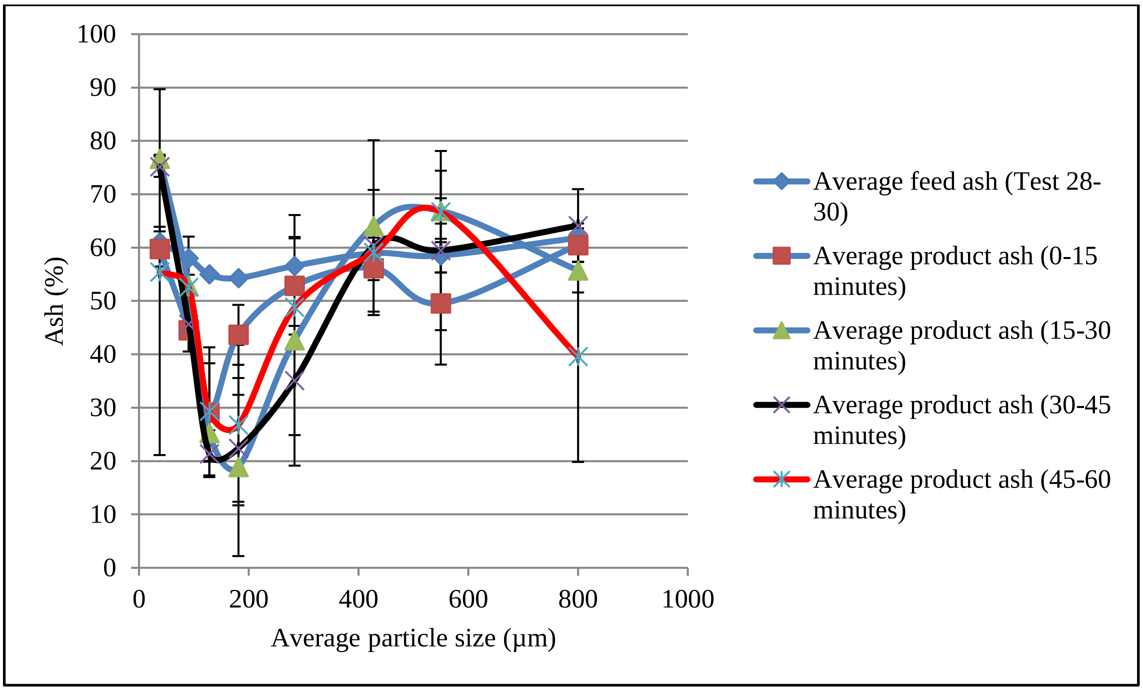

Figure 4.2.22: Average product ash vs. particle size for 6 channels at 12 l/min (Tests 28-30)

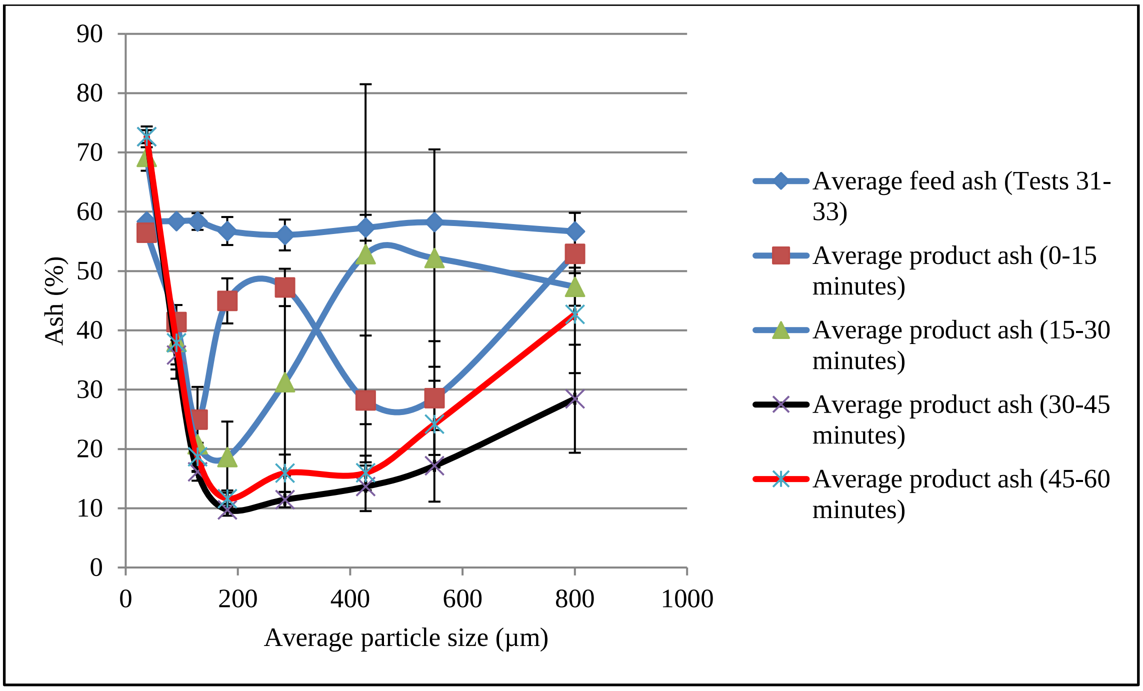

Figure 4.2.23: Average product ash vs. particle size for 8 channels at 12 l/min (Tests 31-33)

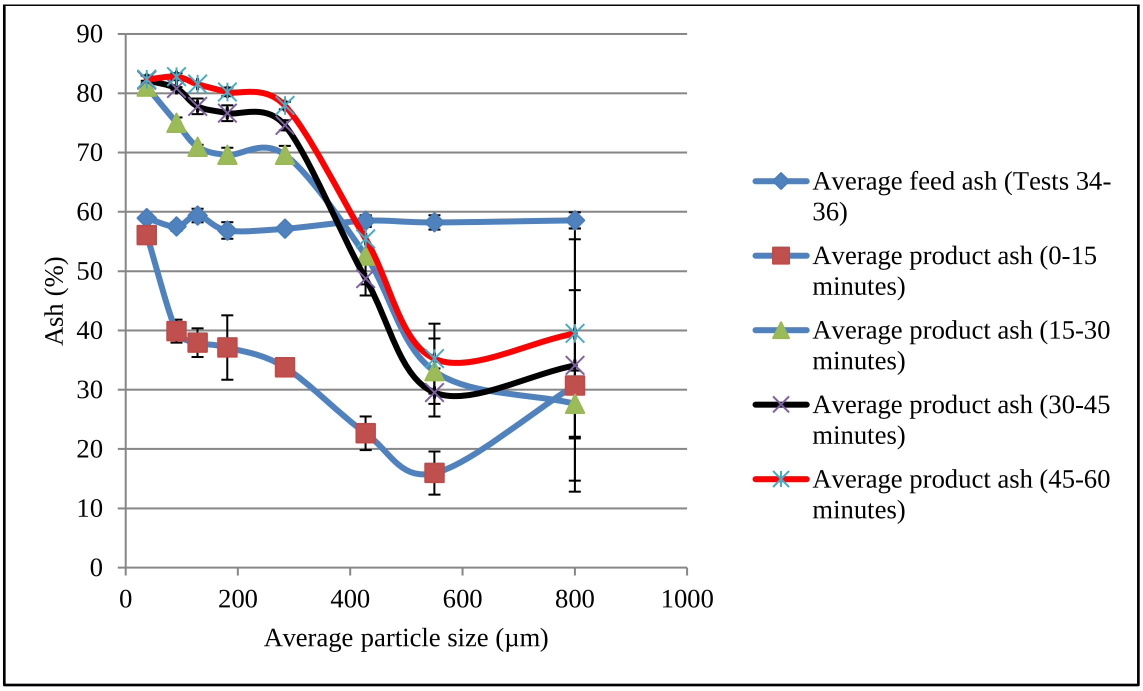

Figure 4.2.24: Average product ash vs. particle size for 12 channels at 12 l/min (Tests 34-36)

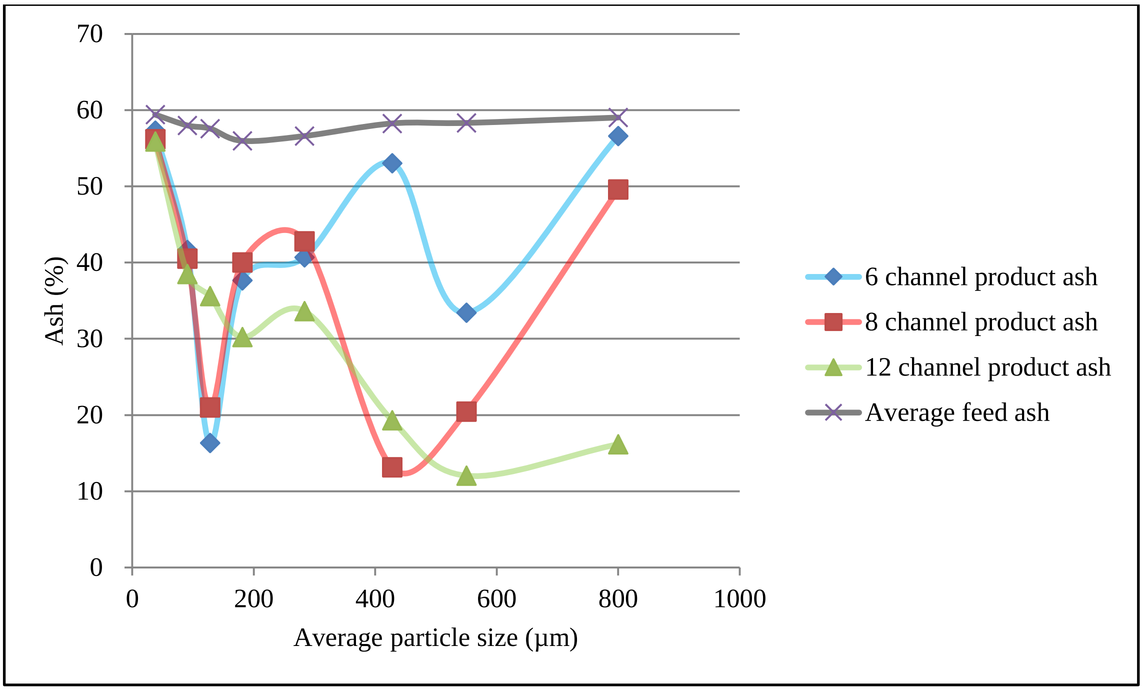

Figure 4.2.25: Variation of ash content with particle size at 12 l/min (0-15 min)

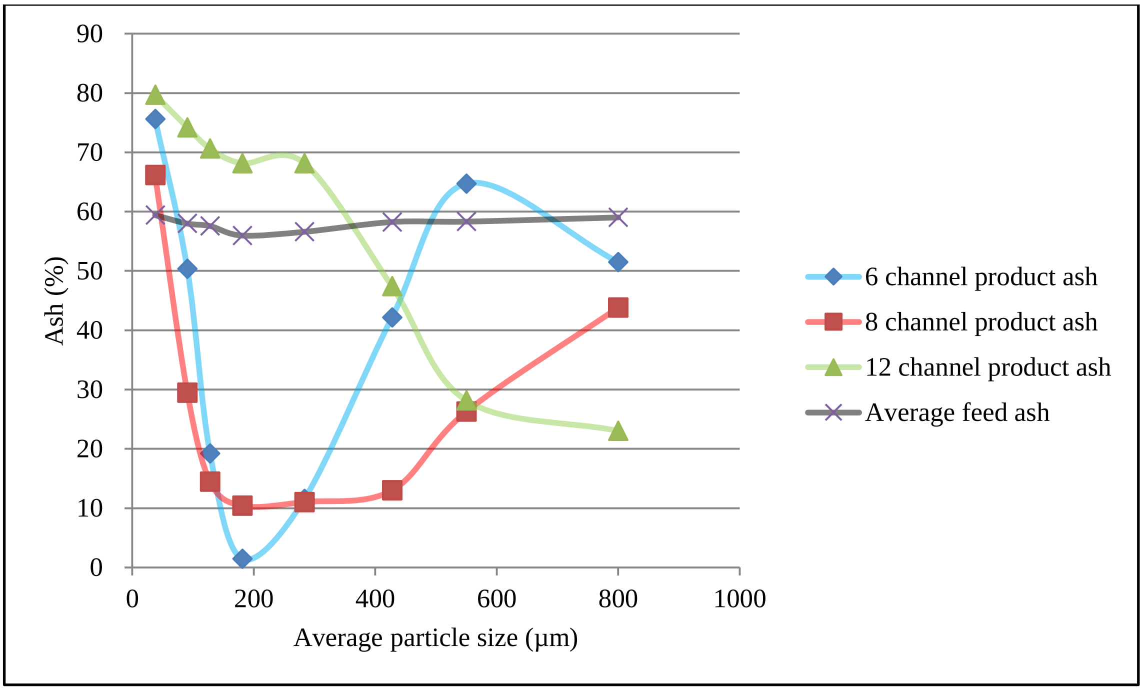

Figure 4.2.26: Variation of ash content with particle size at 12 l/min (15-30 min)

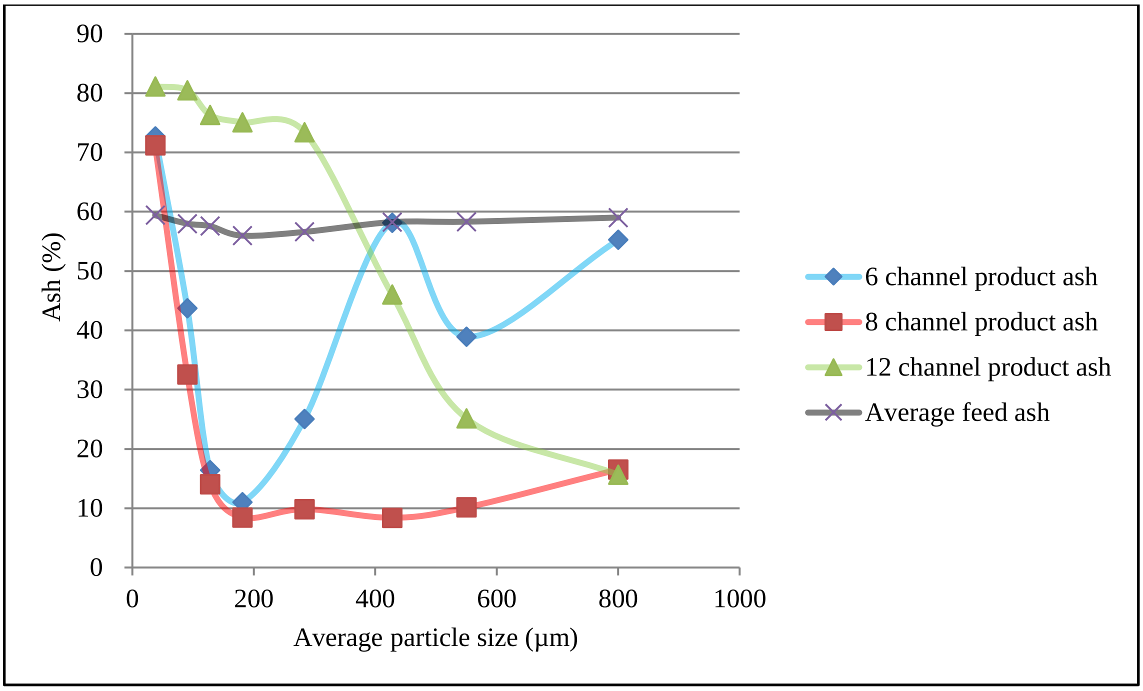

Figure 4.2.27: Variation of ash content with particle size at 12 l/min (30-45 min)

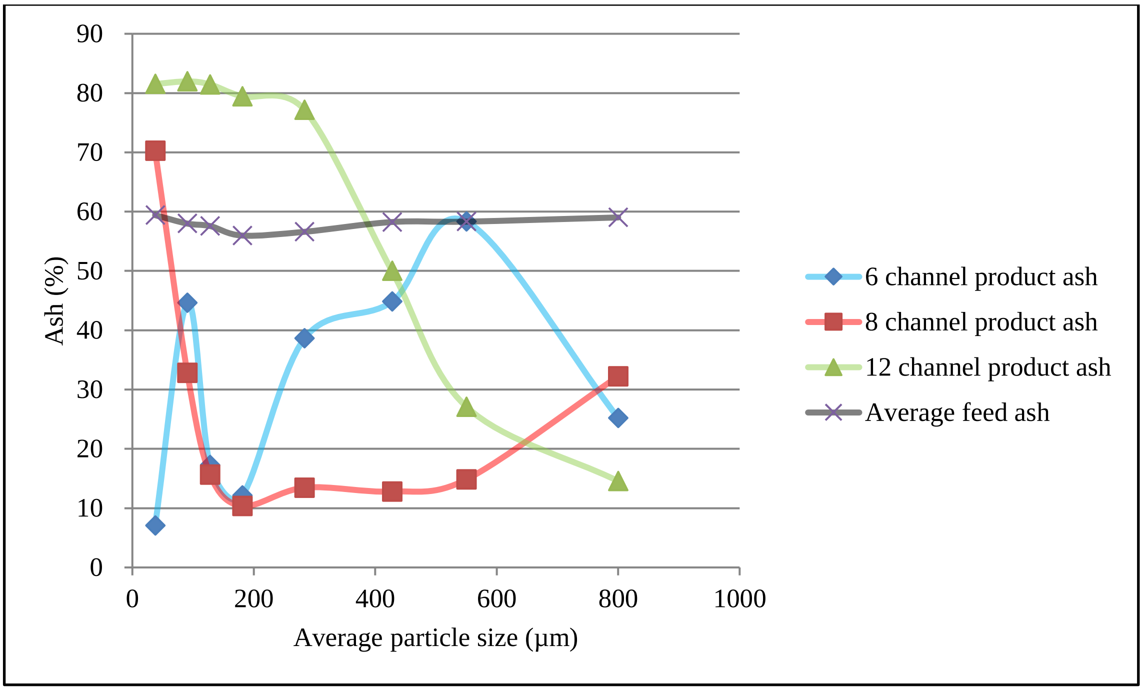

Figure 4.2.28: Variation of ash content with particle size at 12 l/min (45-60 min)

The performance of the reflux classifier at 9 l/min, especially that of the 12 channel configuration at finer particle sizes, supported a further set of experiments at a higher flowrate, namely 12 l/min, in order to ascertain if separation could be further improved or if a critical superficial velocity, beyond which turbulence in the channels hindered separation, had been reached. The most encouraging results achieved in tests 28-30 (6 channels), 31-33 (8 channels) and 34-36 (12 channels) are presented in figures 4.2.25-4.2.28. After roughly 15 minutes, which was observed in previous tests to be the time required for the system to stabilise under the higher flowrate, remarkable upgrades can be seen in the 8 channel set-up, especially at finer particle sizes (-355 + 106 μm), with a product of roughly 10% ash produced from feed with approximately 58% ash. The 12 channel configuration responded well to coarser particles (+500 μm), and the 6 channel configuration performed reasonably at finer sizes, albeit somewhat erratically. It should be noted that the 8 channel set-up performed best at 12 l/min for +106 μm particles compared to the previously lower flowrates, however, at the finest sizes (-106 μm), significant particle misplacement was common throughout all 3 configurations, with misplacement of particles as large as 300 μm occurring in the 12 channel set-up, evident from the overflow ash content exceeding the feed ash content. Moreover, the 12 channel set-up displayed a high degree of variance over the 3 repeated runs, mainly in the 2 coarsest size fractions, throughout the entire run. The 6 channel configuration also had relatively high standard deviation in the product ash content at the coarsest size, as well as below 212 μm, which became more pronounced after the first 15 minutes of the run. The poor performance of the closest channels (12 channel configuration) at the finer sizes was likely due to the higher flowrate translating to a channel velocity grossly exceeding the terminal velocity of the particles, resulting in indiscriminate elutriation of both clean and high-ash coal.

4.2.5 Overview of the synergistic effects of channel spacing and flowrate

4.2.5.1 Performance of 6 channels (spacing: 6.50 mm)

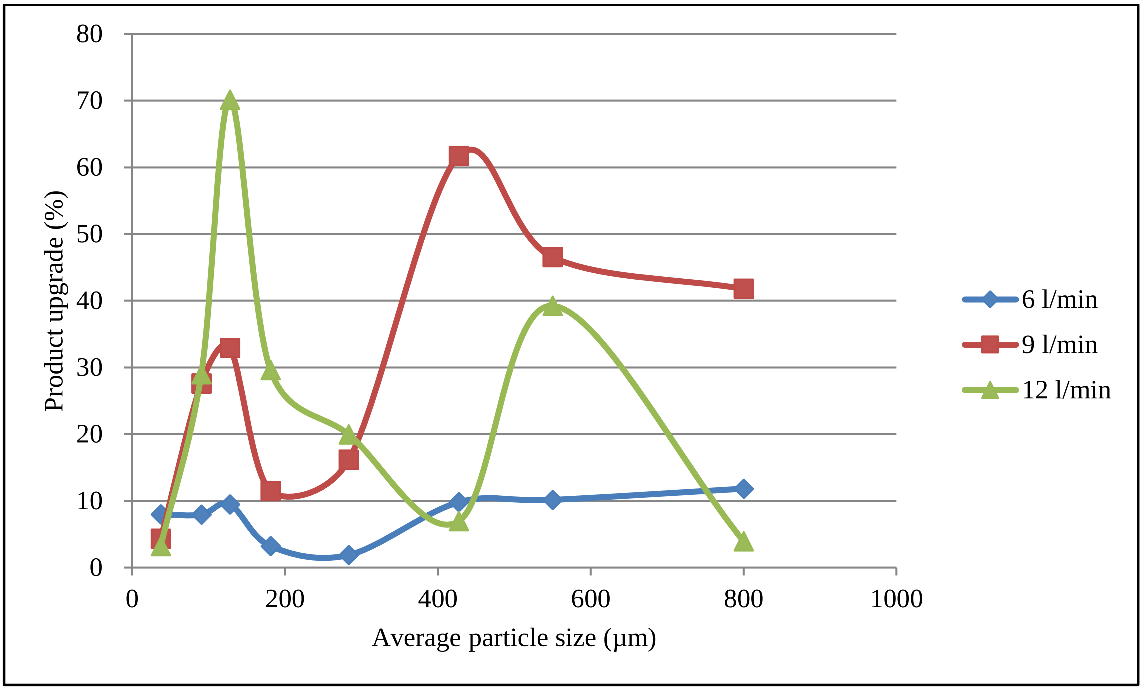

Figure 4.2.29: The effect of fluidisation rate on separation using 6 channels (0-15 minutes)

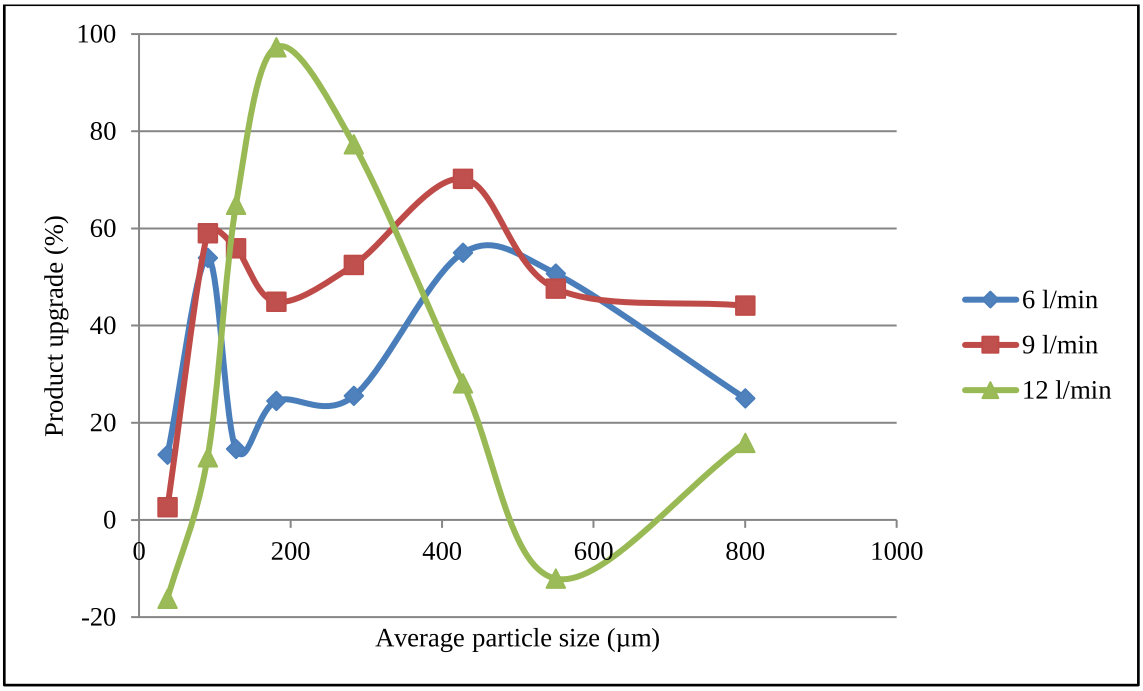

Figure 4.2.30: The effect of fluidisation rate on separation using 6 channels (15-30 minutes)

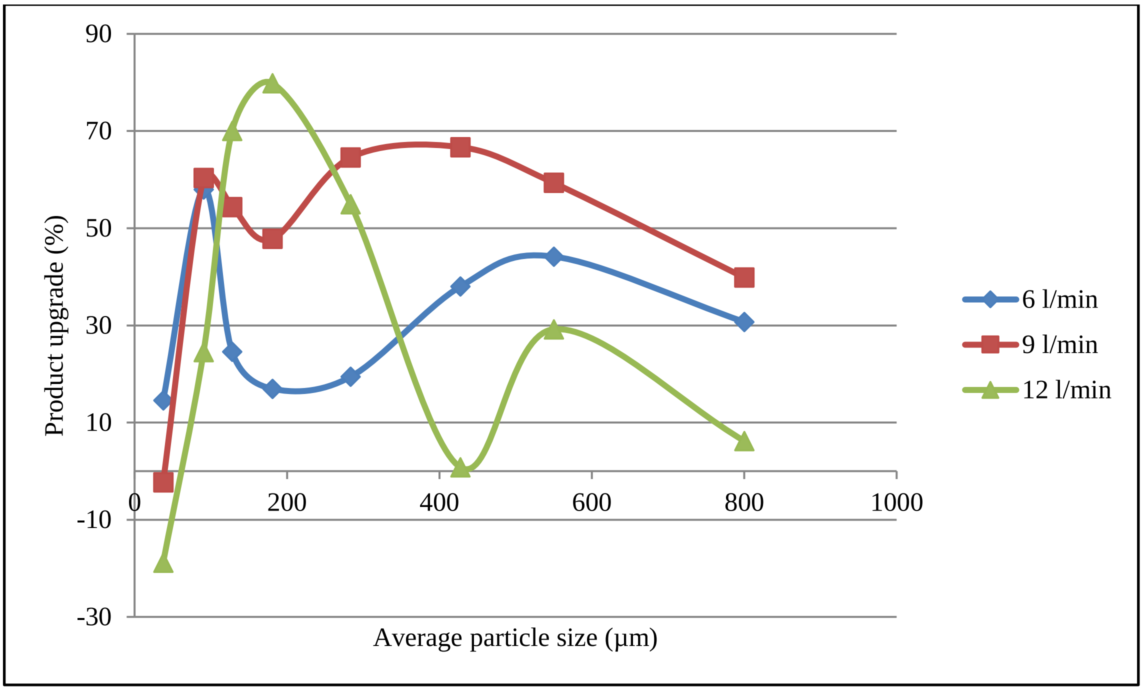

Figure 4.2.31: The effect of fluidisation rate on separation using 6 channels (30-45 minutes)

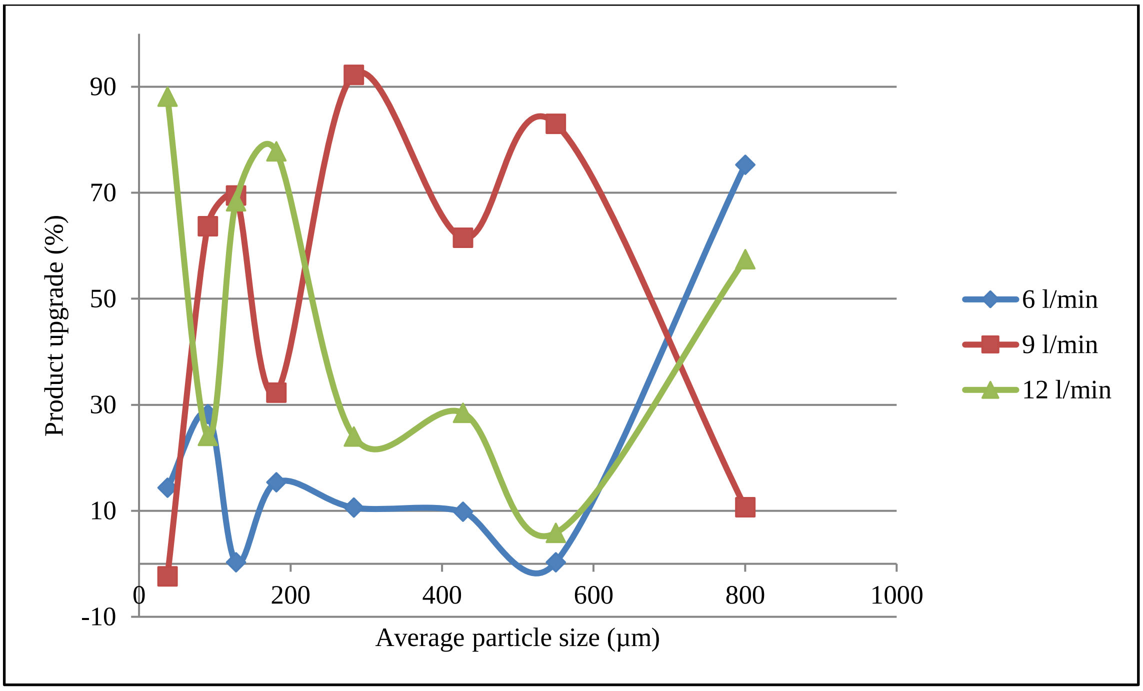

Figure 4.2.32: The effect of fluidisation rate on separation using 6 channels (45-60 minutes)

The impact of the fluidisation rate on separation using the widest channel gap (6 channels) is described in figures 4.2.29-4.2.32, in which the maximum upgrade (out of the 3 repeated runs) achieved at the 3 highest studied flowrates in each size fraction is shown. In general, a fluidisation rate of 9 l/min induces the most favourable response for the majority of the feed, beginning at +106µm up to the maximum particle size. After the first 15 minutes, consistent upgrades ranging from roughly 40% to 60% are seen for the following 30 minutes. In the final 15 minutes of the run, fairly reasonable upgrades are still observed for -600 + 106 µm particles, albeit with some variability. Improved upgrades was achieved in the finer sizes (-212 + 106 µm) with 12 l/min, however, separation is seen to decline rapidly at coarser sizes. Additionally, the high fluidisation rate appears to cause particles finer than 75 µm to wash over into the overflow indiscriminately, evidenced by the “negative upgrade” (product ash content exceeds that of the feed).

4.2.5.2 Performance of 8 channels (spacing: 4.50 mm)

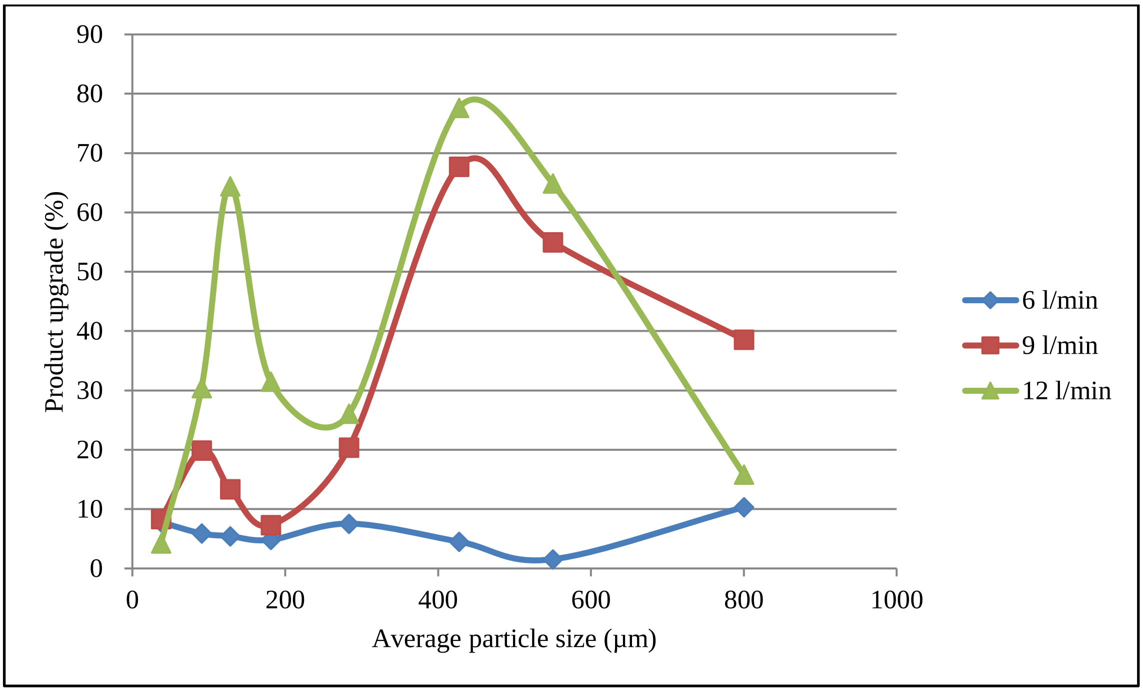

Figure 4.2.33: The effect of fluidisation rate on separation using 8 channels (0-15 minutes)

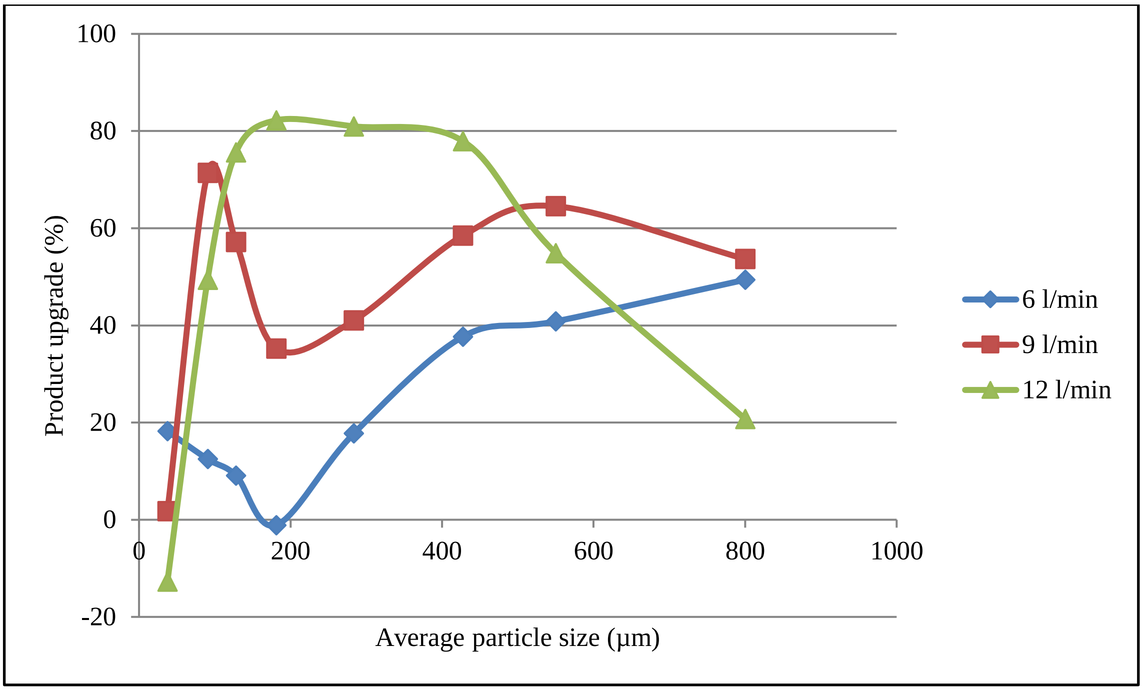

Figure 4.2.34: The effect of fluidisation rate on separation using 8 channels (15-30 minutes)

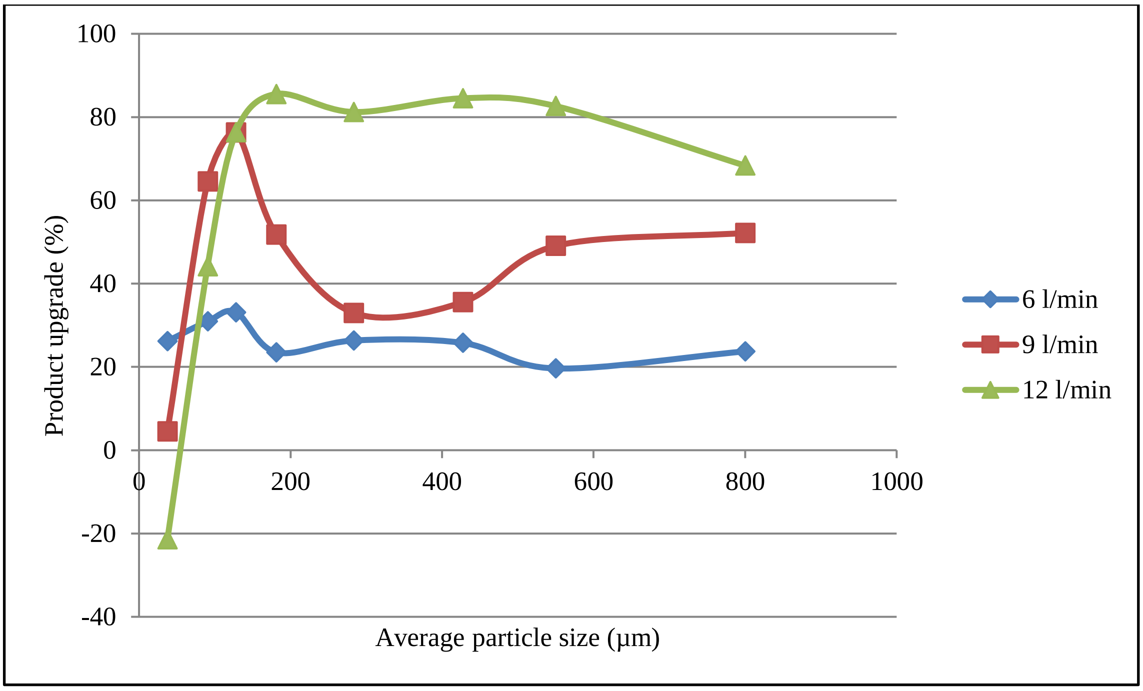

Figure 4.2.35: The effect of fluidisation rate on separation using 8 channels (30-45 minutes)

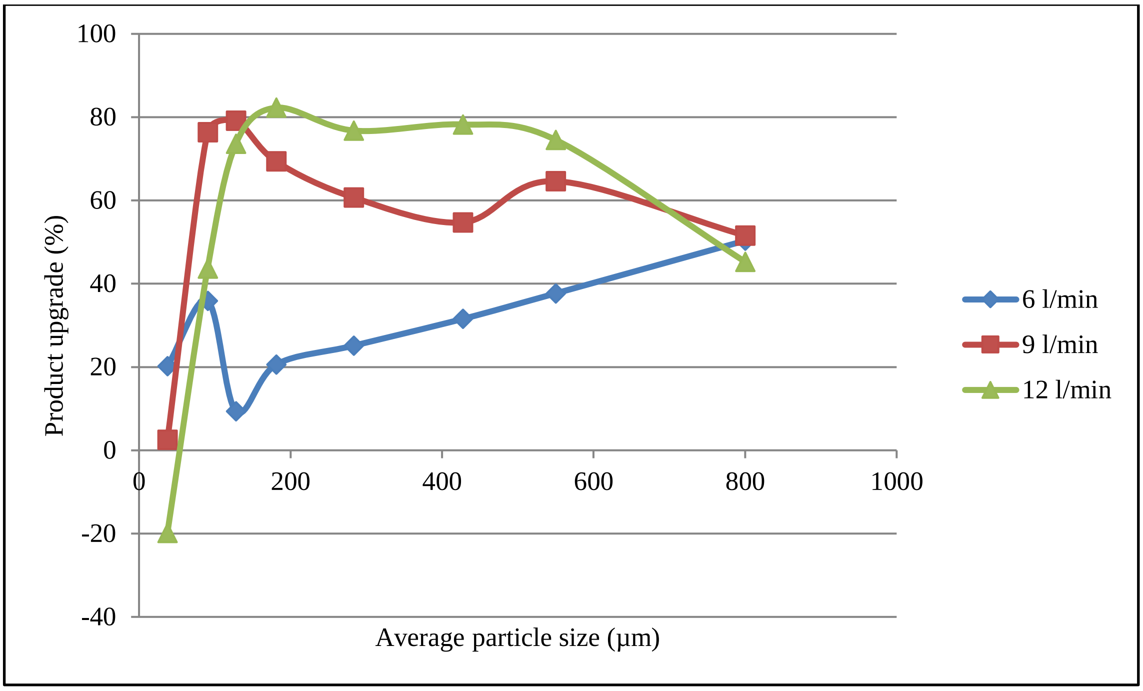

Figure 4.2.36: The effect of fluidisation rate on separation using 8 channels (45-60 minutes)

The 8 channel set-up, with a channel gap of 4.50 mm, responded remarkably well to the highest flowrate for +106 µm particles, as can be noted from figures 4.2.33-4.2.36 above. An interesting observation was the performance of the 8 channel configuration at 6 l/min which was the only combination of channel spacing and fluidisation rate thus far to produce a noticeable upgrade in the -75 µm fraction that was consistent over the duration of the entire run. The flowrate of 9 l/min was best suited to particles ranging from 75 µm to 106 µm although reasonable upgrades throughout the entire size range were also noticed, with little misplacement over the majority of the feed size range.

4.2.5.3 Performance of 12 channels (spacing: 2.10 mm)

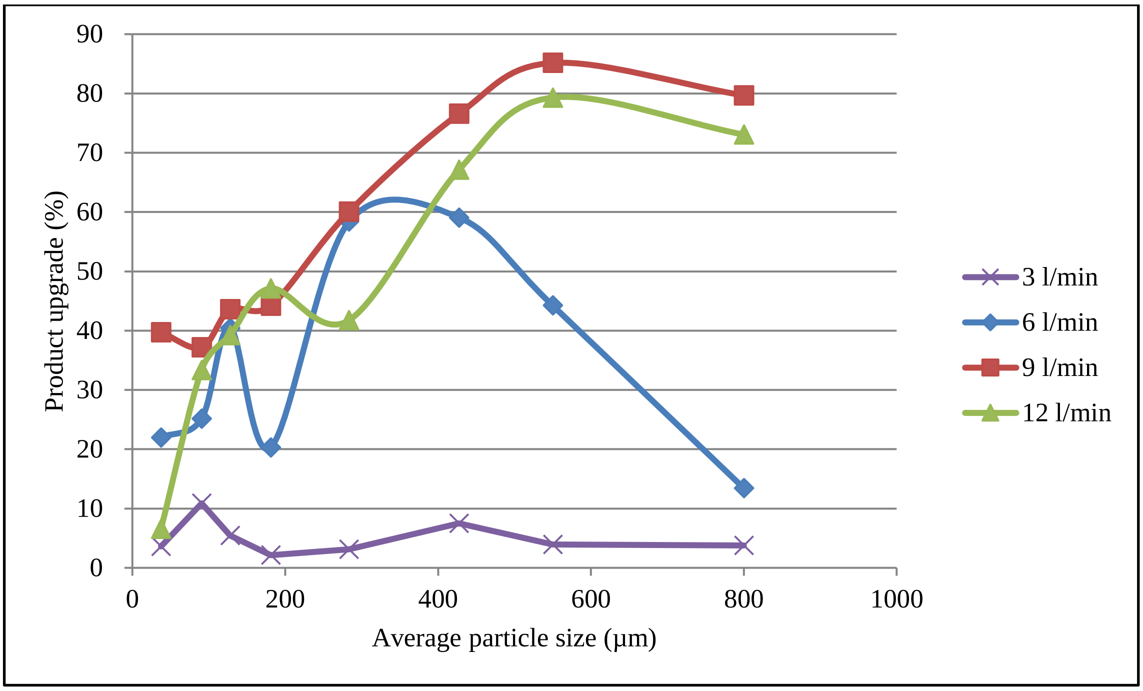

Figure 4.2.37: The effect of fluidisation rate on separation using 12 channels (0-15 minutes)

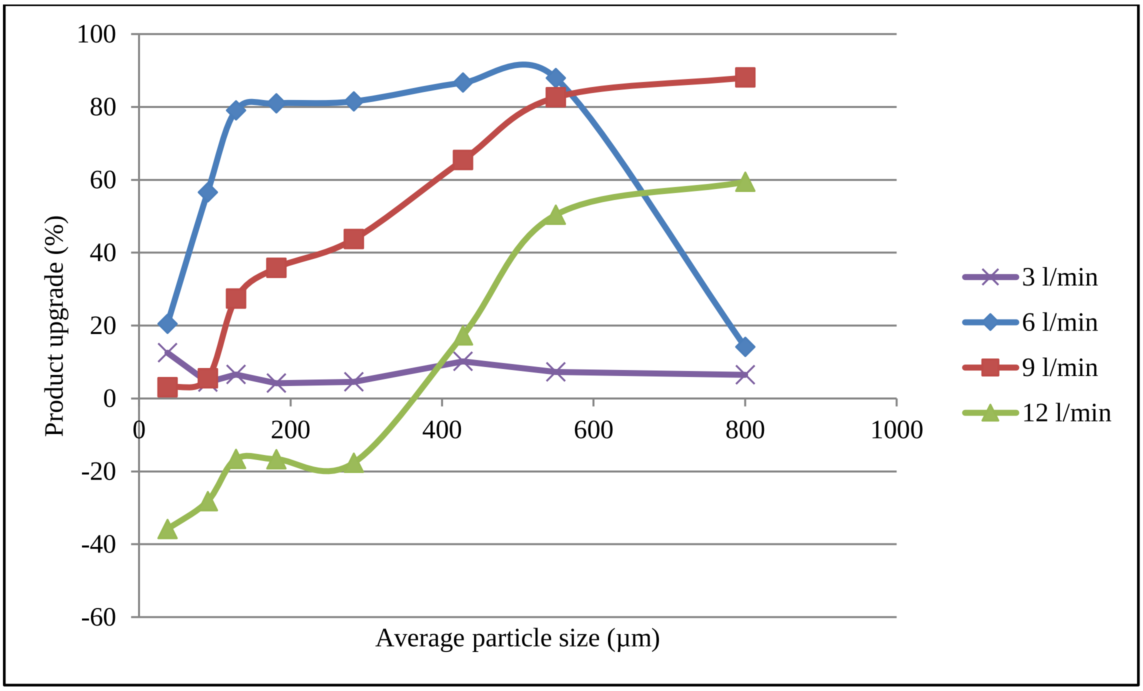

Figure 4.2.38: The effect of fluidisation rate on separation using 12 channels (15-30 minutes)

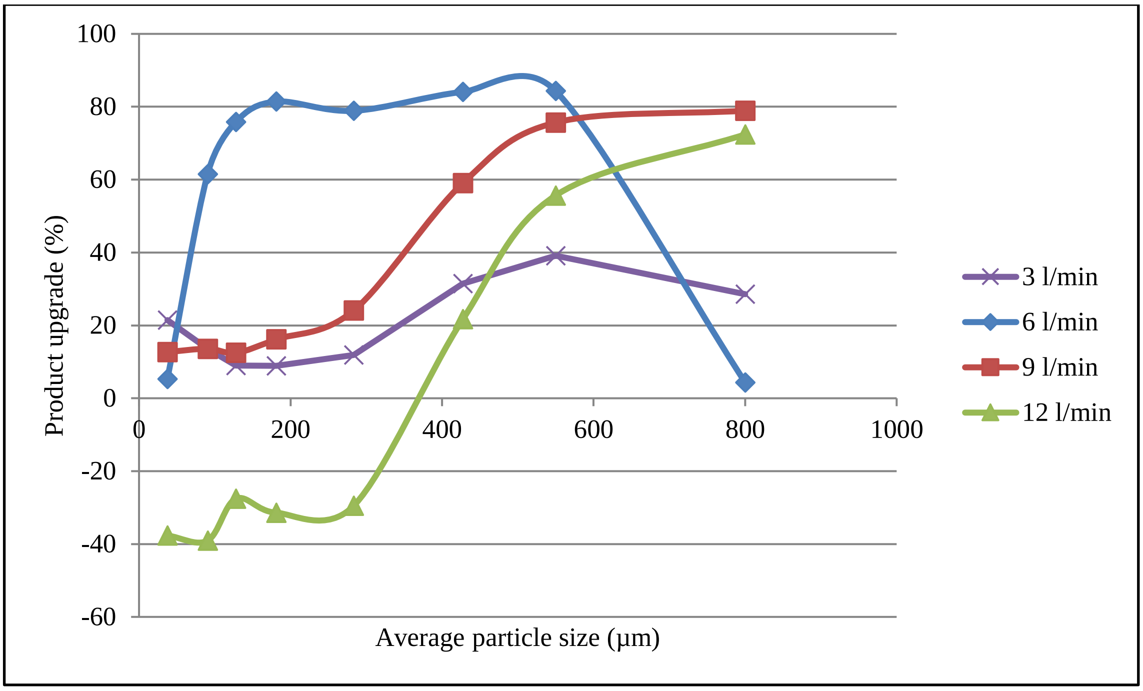

Figure 4.2.39: The effect of fluidisation rate on separation using 12 channels (30-45 minutes)

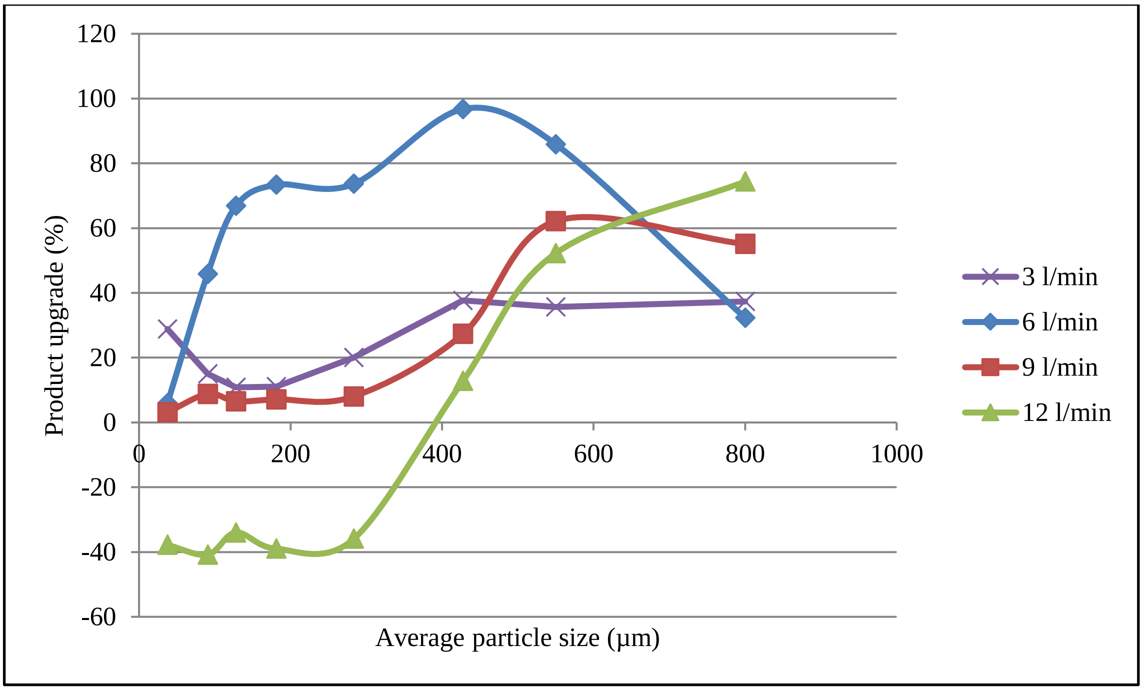

Figure 4.2.40: The effect of fluidisation rate on separation using 12 channels (45-60 minutes)

Figure 4.2.37 above shows that the flowrate of 9 l/min was extremely effective when coupled with the narrowest channel spacing (12 channel set-up) and significant upgrades can be seen within the first 15 minutes throughout the entire size range. Most notably, the finer particles (-106 µm), for which separation was problematic in previous tests, are seen to have upgraded considerably, with a reduction in ash content from 62.39% to 38.84% (-106 + 75 µm) and from 60.71% to 36.81% (-75 µm). Upgrades ranging from 60.05% to 79.66% were obtained for the coarser portion of the feed (+212 µm), and as high as 85.15% for the -600 + 500 µm interval which translates to a reduction in feed ash content from 57.22% to 8.47%. On average, a reduction in ash content from roughly 60% to 36% was noted for the -212 µm size range. The highest flowrate examined (12 l/min) performed favourably as well for particles larger than 106 µm, with upgrades marginally lower that those achieved at 9 l/min for coarser particles, however, considerable particle misplacement is noted after 15 minutes. Additionally, it can be seen that 6 l/min flowrate performs extremely well for particles ranging from 106 µm to 500 µm after a period of 15 minutes (figures 4.2.38-4.2.40).

4.2.6 Analysis of Yield-Ash curves

The analysis of the recovered mass and ash content in each size fraction enabled the construction of yield-ash curves, in which the cumulative yield is plotted against the cumulative ash, so as to quantify the maximum recoverable product at specific ash content.

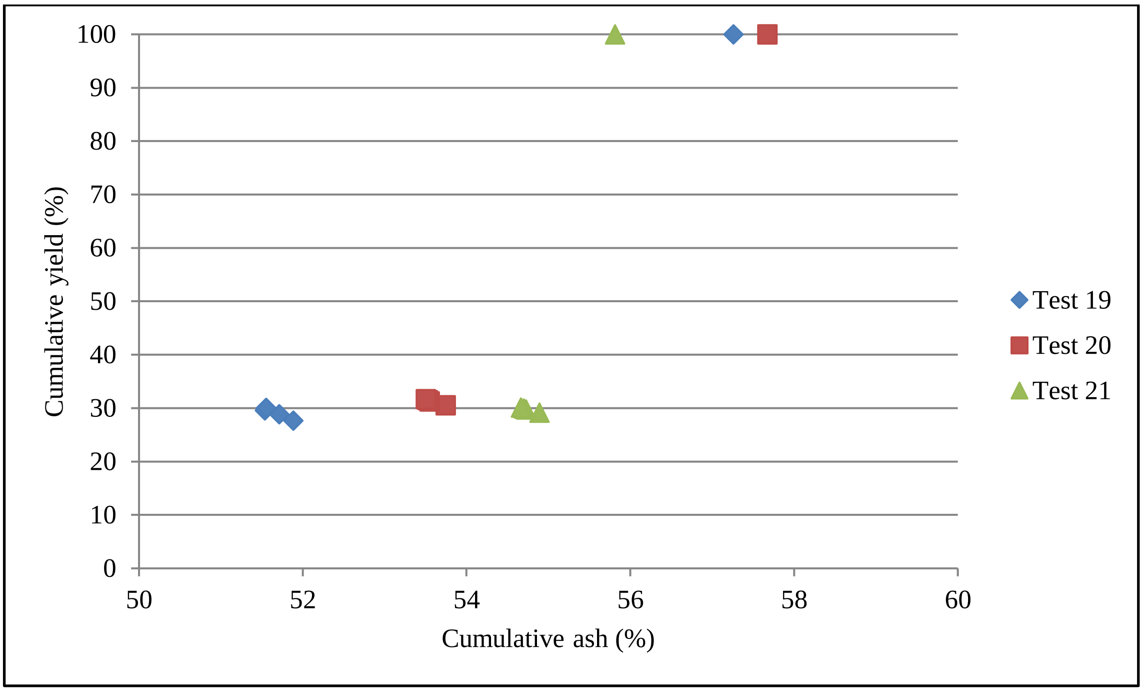

Figure 4.2.41: Yield-Ash curve for overall size range (6 channels, 9 l/min)

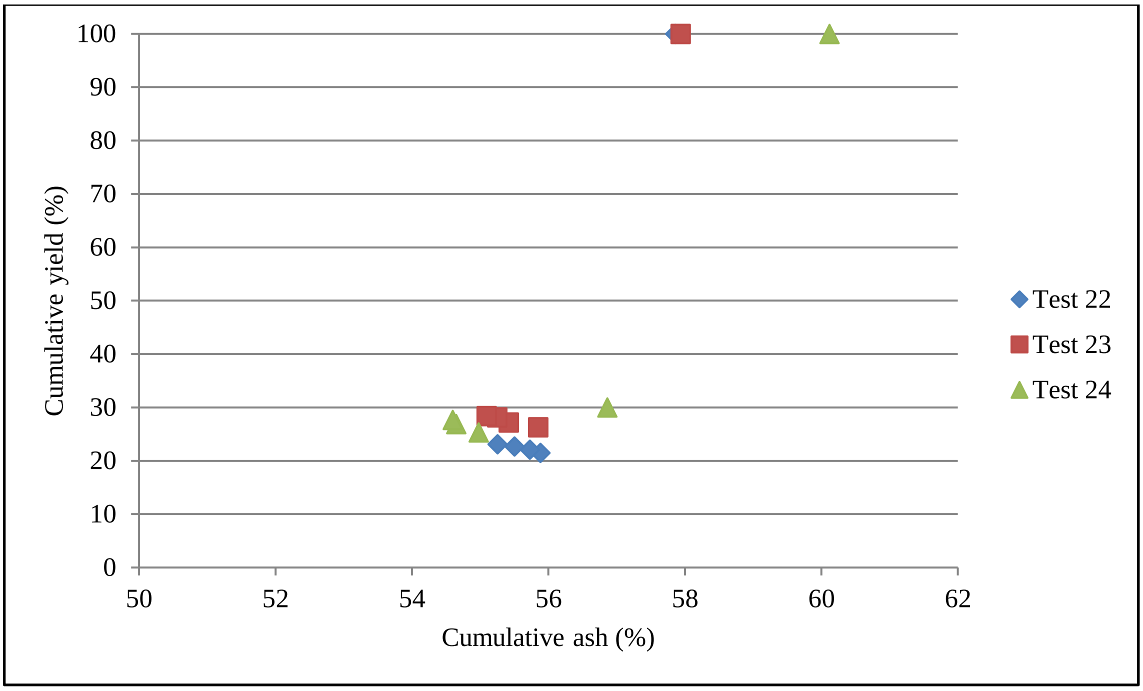

Figure 4.2.42: Yield-Ash curve for overall size range (8 channels, 9 l/min)

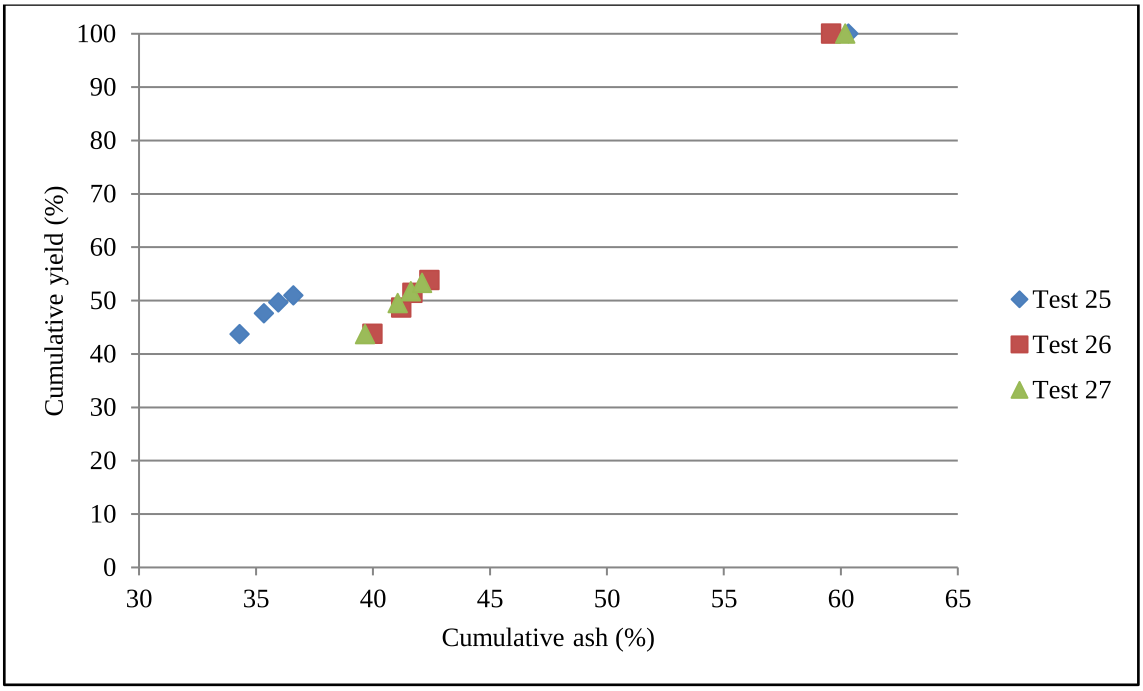

Figure 4.2.43: Yield-Ash curve for overall size range (12 channels, 9 l/min)

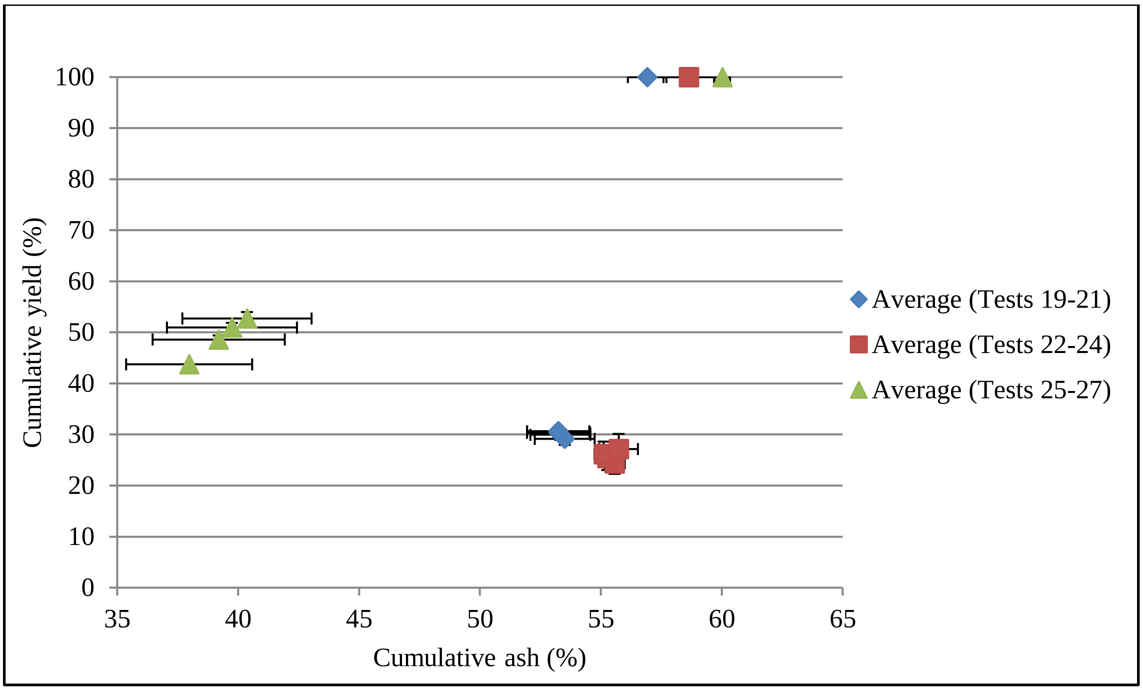

Figure 4.2.44: Yield-Ash (average) curve for overall size range

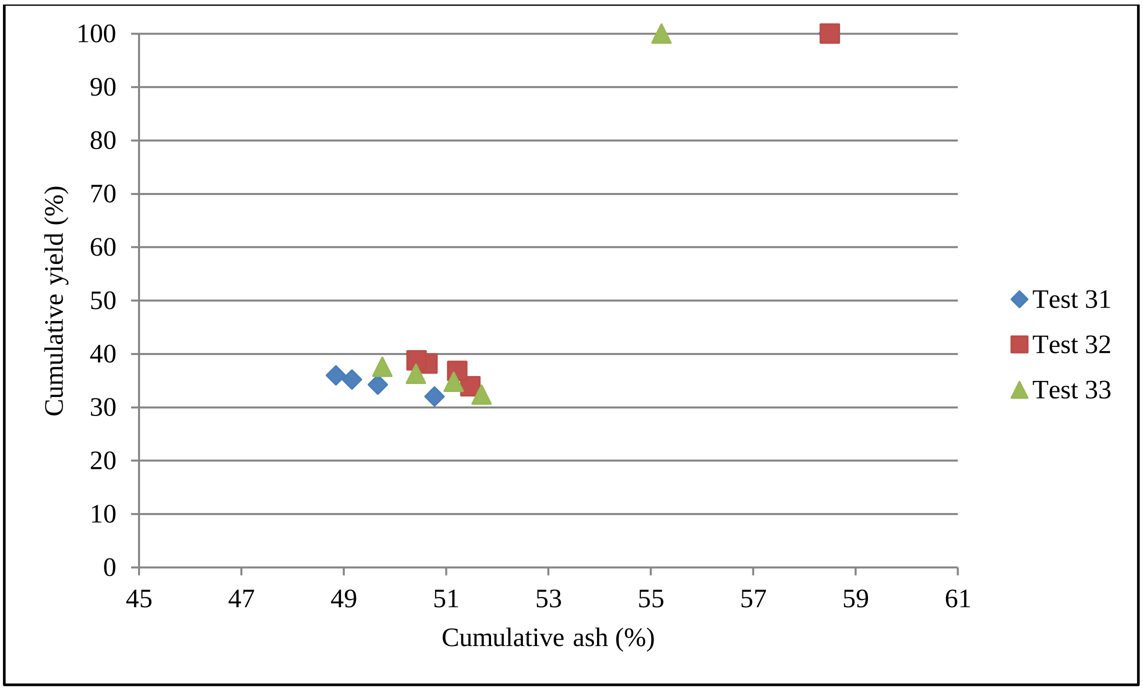

Figure 4.2.45: Yield-Ash curve for overall size range (8 channels, 12 l/min)

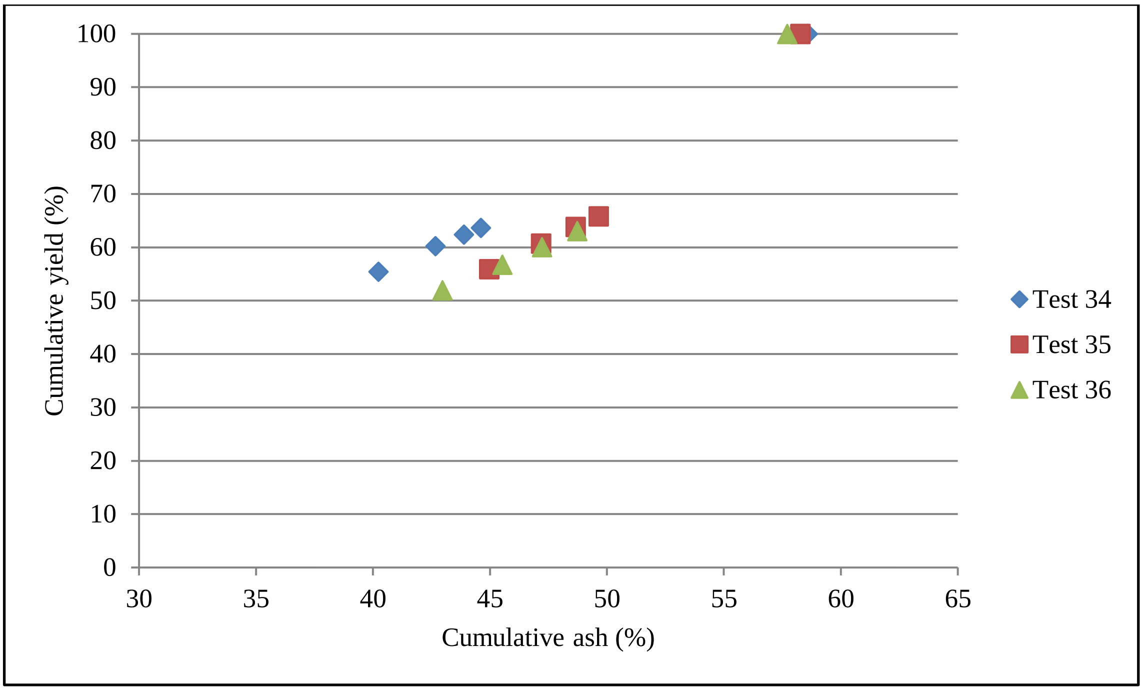

Figure 4.2.46: Yield-Ash curve for overall size range (12 channels, 12 l/min)

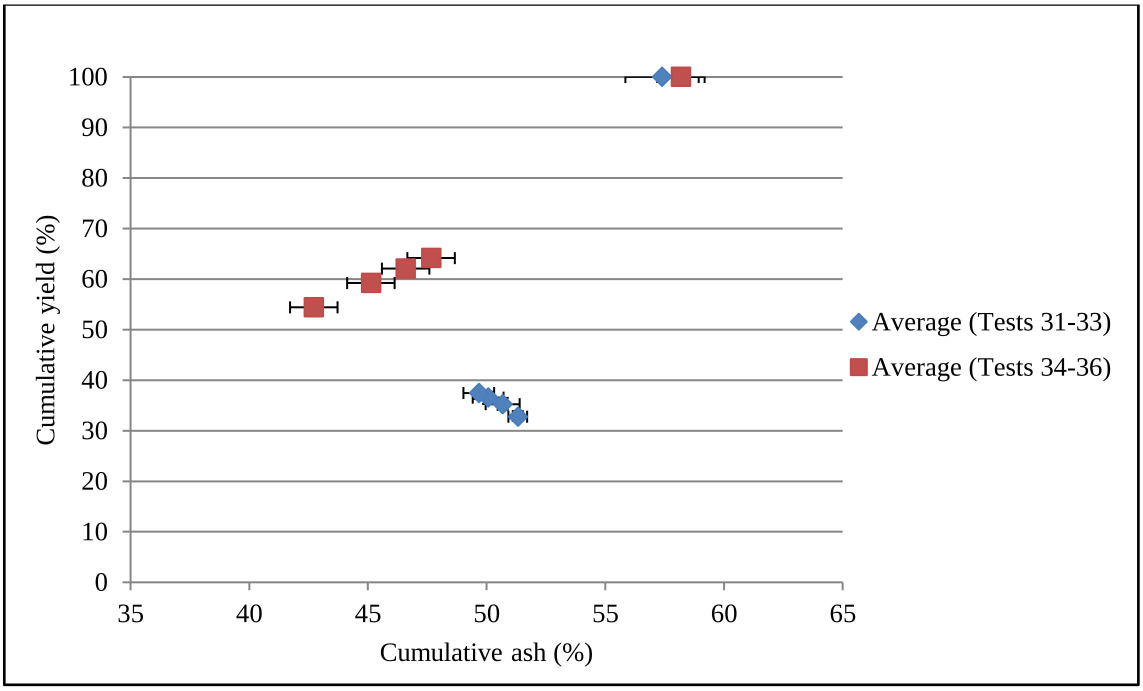

Figure 4.2.47: Yield-Ash (average) curve for overall size range

The yield-ash curves shown above were obtained by plotting the total cumulative yield over the entire size range obtained at each 15 minute interval against the corresponding total cumulative ash content, thus, each subsequent data point represents the yield and ash obtained after 15, 30, 45 and 60 minutes. The yield-ash produced for the tests that utilised 3 l/min showed very low recoveries, with a maximum of approximately 20% with a corresponding ash content ranging from 48%-58%. The curves produced for the 6 channel and 8 channel configurations at 6 l/min were similar to those constructed for 3 l/min, with a highest yield of only 25% containing 55%-58% ash. The 12 channel configuration gave slightly higher yields of around 30% with an ash content of approximately 40%. The overall yield-ash data, as well those obtained for each individual size fraction, can be found in Appendix B-1.

In the case of the 9 l/min fluidisation rate, it is evident that the narrowest channel spacing (12 channels) generated the highest yield with the lowest ash content. The first data point on figure 4.2.36, corresponding to a yield of 44% with an ash content of 34% attained after 15 minutes of run time, is considerably more favourable than the recovery attained using the wider channels (figures 4.2.41 and 4.2.42), and the subsequent data also shows higher yields with lower ash contents. Moreover, runs 2 (test 26) and 3 (test 27) of figure 4.2.43 displayed excellent agreement with each other. Using 12 channels, yields as high as 90%, with ash ranging from 36%-40%, were observed for particles finer than 75 μm. For material between 75 μm and 212 μm, recoveries ranging from 43% (at finest particle size) to 90% (at the coarsest particle size) were attained with corresponding ash content between 38%-43%.

Figure 4.2.46 illustrates the yield-ash data obtained for the narrowest channels at 12 l/min. In relation to figure 4.2.43, it can be seen that the yields obtained are marginally greater; however, the ash content of the recovered material is also suitably higher. The yield-ash curve obtained with 6 channels at 12 l/min is comparable to that of 6 channels at 9 l/min; however, the performance of the 8 channel configuration at 12 l/min is slightly better than its corresponding 9 l/min counterpart (figure 4.2.42), with yields roughly 40% with an associated ash content between 49% and 52%. In general, the highest yield with the lowest associated ash content for the overall feed was achieved using 12 channels with a flowrate of 9 l/min.

4.2.7 Summary

By and large, the flowrates ranging from 6 l/min to 12 l/min produced the greatest reduction in product ash content. With a flowrate of 3 l/min, the 6 channel set-up performed to some extent in the first 15 minutes, with an average reduction in ash content from roughly 58.74% to 47.36%, and a faint reduction in average ash content from 59.65% to 56.72% was seen when using 8 channels. Thereafter, significant misplacement was observed throughout the entire size range as well as higher variance between the repeated runs. The narrowest channel spacing was more adept at upgrading the coarser sizes with minimal particle misplacement, and also displayed proficiency at the finer sizes with a reduction in average ash content from 58.24% to 45.03% for particles finer than 106 µm.

At the flowrate of 6 l/min, some misplacement was observed when 6 channels and 8 channels were used; however, this only occurred after the initial 15 minutes of the runs and with less frequency compared to 3 l/min. The 12 channel configuration excelled in the size range of -600 + 75µm, with product ash contents as low as 22.04% after 45 minutes (relative to a feed ash content of 57.40%).

In a similar manner as above, separation continued to improve with both flowrate and channel proximity. With an operating flowrate of 9 l/min, consistently high upgrades were seen throughout the entire size range in the 12 channel configuration, and for all particle sizes aside from the -75 µm range in the other 2 configurations. In general, the upgrades ranged from 40% to 80% in the -1000 + 75 µm size range for all channel spacings tested. In the first 15 minutes, a reduction in ash content from 60.71% to 36.81% was attained in the -75 µm size fraction with 12 channels, which translated to an upgrade of 39.72%, the highest achieved in this fraction (with the least variance between the 3 runs) for any combination of flowrate and channel spacing. The upgrades achieved at 12 l/min were reasonably high for particles larger than 75 µm, and comparable with those attained at 9 l/min for the first 15 minutes, however, significant particle misplacement occurred in all 3 configurations after the initial 15 minutes, and continued for the rest of duration of the runs.

4.2.8 Partition curves

The favourable results obtained using the flowrates of 9 l/min (tests 19-27) and 12 l/min (tests 28-36) spurred further analysis of the separation achieved, thus, partition curves were constructed for the aforementioned groups of tests. The objective of these curves was to examine and quantify the performance of each permutation of channel spacing and flowrate in terms of separation size (d_{50}). Additionally, it enabled the identification of possible buoyancy-driven effects and re-suspension behaviour in the narrower channels and the ramifications of such behaviour on the separation size achieved, as noted by Laskovski et al. (2006).

The partition curves were generated by determining the proportion of material within each of the studied size fractions which remained in the unit upon completion of the test, relative to the amount of material in the corresponding size fractions that was introduced into the sysem in the feed prior to the test. These percentages, referred to as the partition numbers, were then plotted against the average particle size of each of the size fractions. The separation size (d_{50}), which characterises the particle size that has an equal likelihood of either remaining in the unit or being elutriated into the overflow, corresponds to a partition number of 50%.

Table 4.2.1: Separation size achieved for various channel gaps

Flowrate (l/min)	**Separation size (µm)**								
	6 channels ($z = 6.50$ mm)			**8 channels ($z = 4.50$ mm)**			**12 channels ($z = 2.10$ mm)**		
	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3	Run 1	Run 2	Run 3
6	43,74	42,67	46,15	-	-	-	65,00	50,83	-
9	80,50	85,82	92,50	64,67	69,00	66,00	264,17	255,76	301,33
12	97,00	99,95	105,50	96,75	108,00	113,51	379,04	341,11	359,81

The separation size (d_{50}) achieved for each of the channel spacings in the investigation is shown in table 4.2.1 above. It should be noted that at 3 l/min, the results obtained were too erratic to establish a definite separation size. This was also true for the experiments undertaken at 6 l/min using 8 channels, and for the final repeat run using 12 channels.

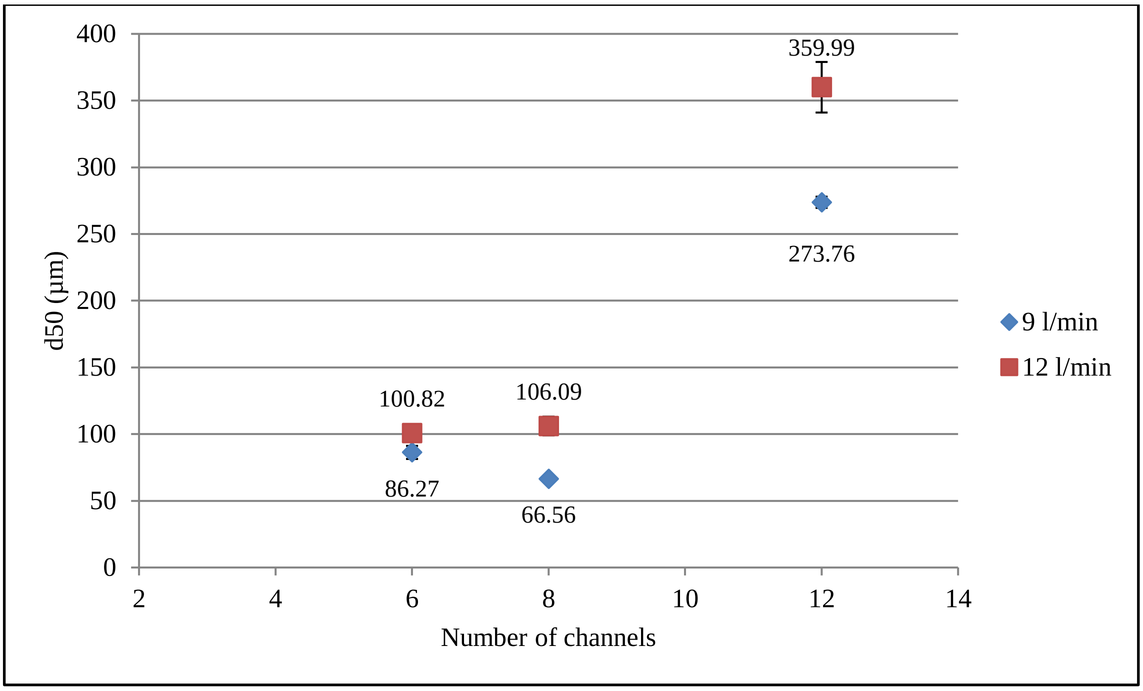

Figure 4.2.48: The effect of channel gap on the average separation size

The effect of the number of channels, which dictates the perpendicular channel gap (z), on the particle separation size (d_{50}) obtained at the 2 highest flowrates is presented in figure 4.2.39 above. The separation size (d_{50}) plotted is the arithmetic mean over the 3 runs. It is evident that the separation size increases with flowrate, and this trend was also noted in previous works (Doroodchi et al., 2004 and Laskovski et al., 2006). Furthermore, it can be seen that the separation size decreases as the channel gap narrows from 6.50 mm (6 channels) to 4.50 mm (8 channels) and therafter increases sharply. Laskovski et al. (2006) conducted numerous experiments with various channel gaps and noted that an increase in aspect ratio of the lamella section, which is dictated by the length and gap of the channels, resulted in a subsequent decrease in separation size to an extent. The reduction in separation size can be attributed to a larger effective segregation area as the aspect ratio increases, as detailed by kinematic analysis referred to as the PNK theory jointly developed by Ponder (1925) and Nakamura and Kuroda (1937) (see Section 2.3.2: The Boycott effect). Beyond a critical aspect ratio, dependent on the properties of the feed, operating conditions and device dimensions, the separation size tends to increase. This sudden increase in equilibrium separation size is due to an increase in shear rate within the channel as a result of the narrow gap (Zhou et al., 2006). This in turn gives rise to shear-induced lift force and buoyancy driven convective flow, which contributes to particle re-suspension of lighter particles and amplifies density based separation at higher aspect ratios, as seen with the 12 channel configuration, which has an aspect ratio of approximately 453. This phenomenon is elaborated on in detail in section 2.4.6.

4.3 Semi-continuous separation tests

The notable separation achieved in the batch campaign aided the selection of an optimum combination of channel spacing and fluidisation rate, and further testing using the narrowest channels (2.10 mm) at a flowrate of 9 l/min was subsequently undertaken. A semi-continuous mode of testing was established, in which an initial feed mass of approximately 500 g of Waterberg coal was added to the device, with an additional 250 g of coal added every 15 minutes over the course of 2 hours. Thus, fresh feed, identical to that used in the previous batch tests, was added after 15, 30, 45, 60, 75, 90 and 105 minutes and product was collected after each 15 minute interval. The experiment was repeated 3 times (tests 37-39) and intended to simulate a continuous system. The duration of time between feed additions was chosen based on the performance of the unit in tests 25-27, in which significant reduction in ash content was seen in the first 15 minutes of the run. Consequently, the parameters of this current scope of tests were selected in order to replicate the upgrades seen previously, as well as to examine the effect of enhanced hindered settling due to the emergence of an autogenous dense media within the fluidised bed zone as the material accumulated.

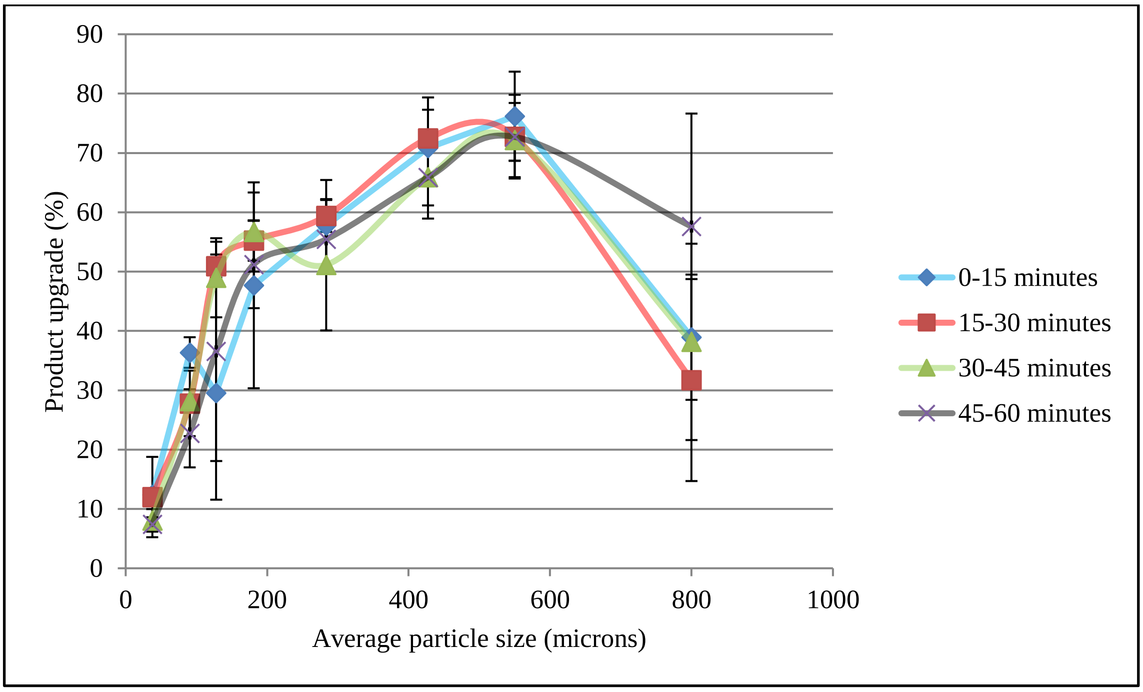

Figure 4.3.1: Average product upgrade achieved over the first hour

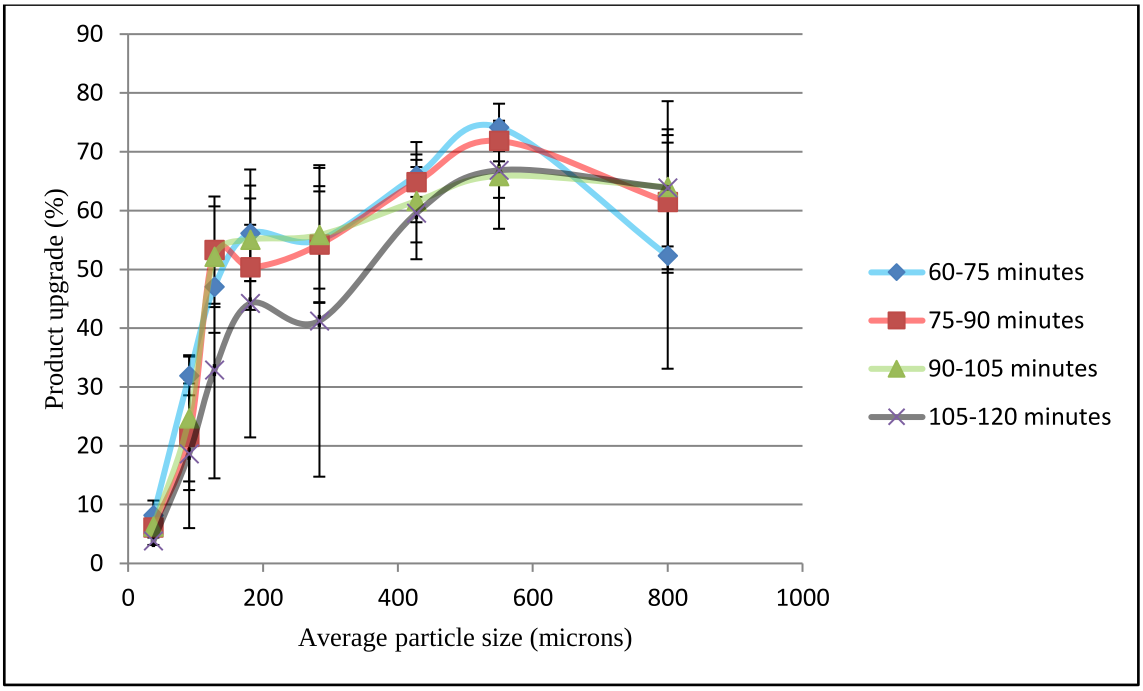

Figure 4.3.2: Average product upgrade achieved over the second hour

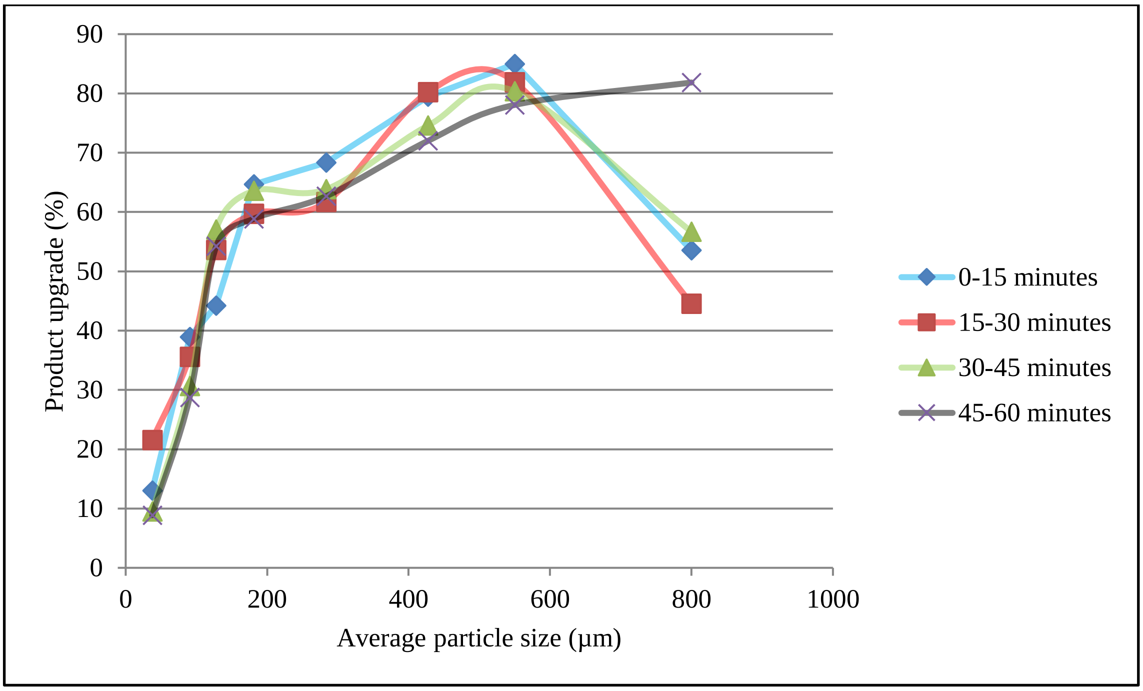

Figure 4.3.3: Upgrade (%) achieved for various particle sizes over the first hour

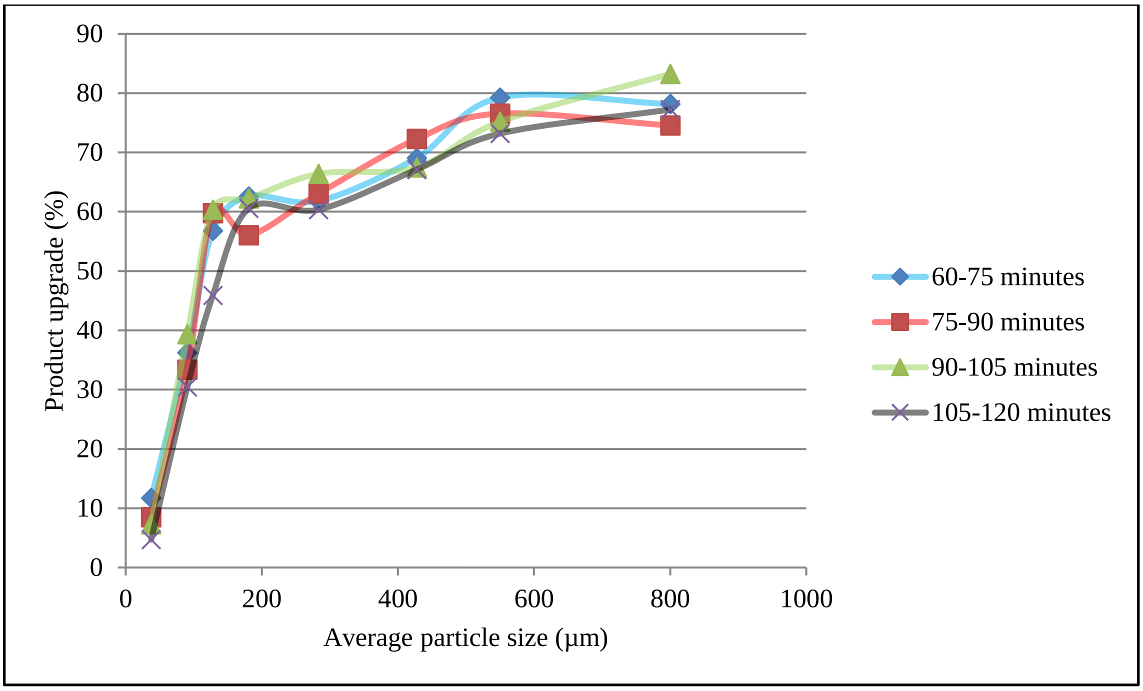

Figure 4.3.4: Upgrade (%) achieved for various particle sizes over the second hour

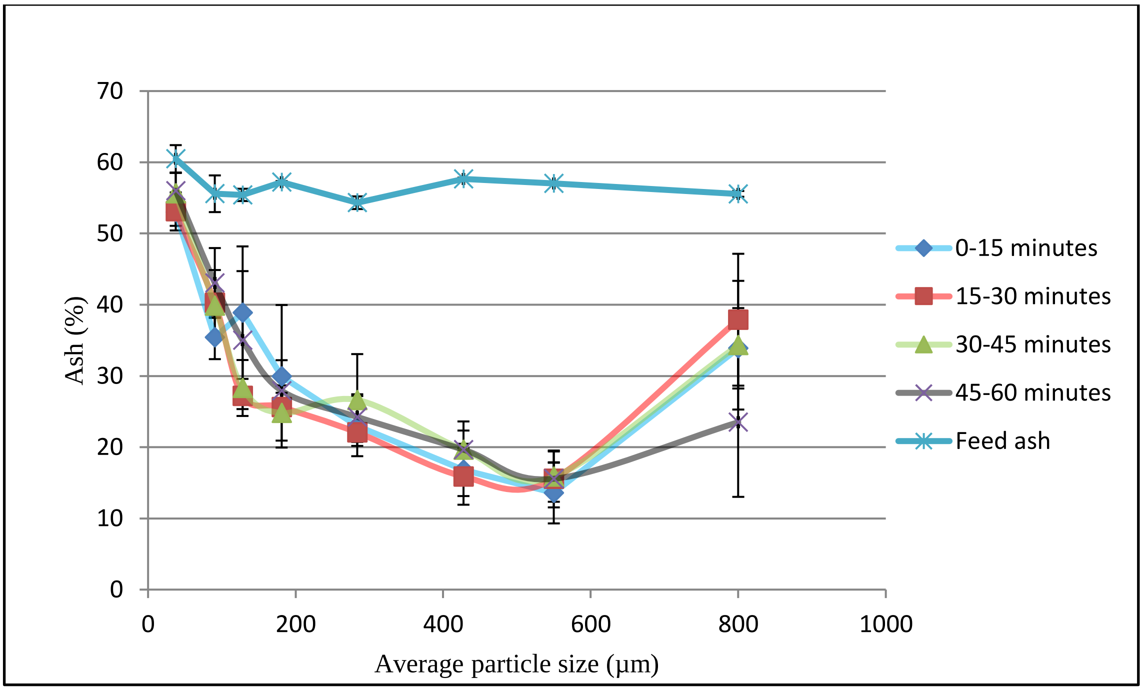

Figure 4.3.5: Average product ash (%) compared to feed ash (%) achieved over the first hour

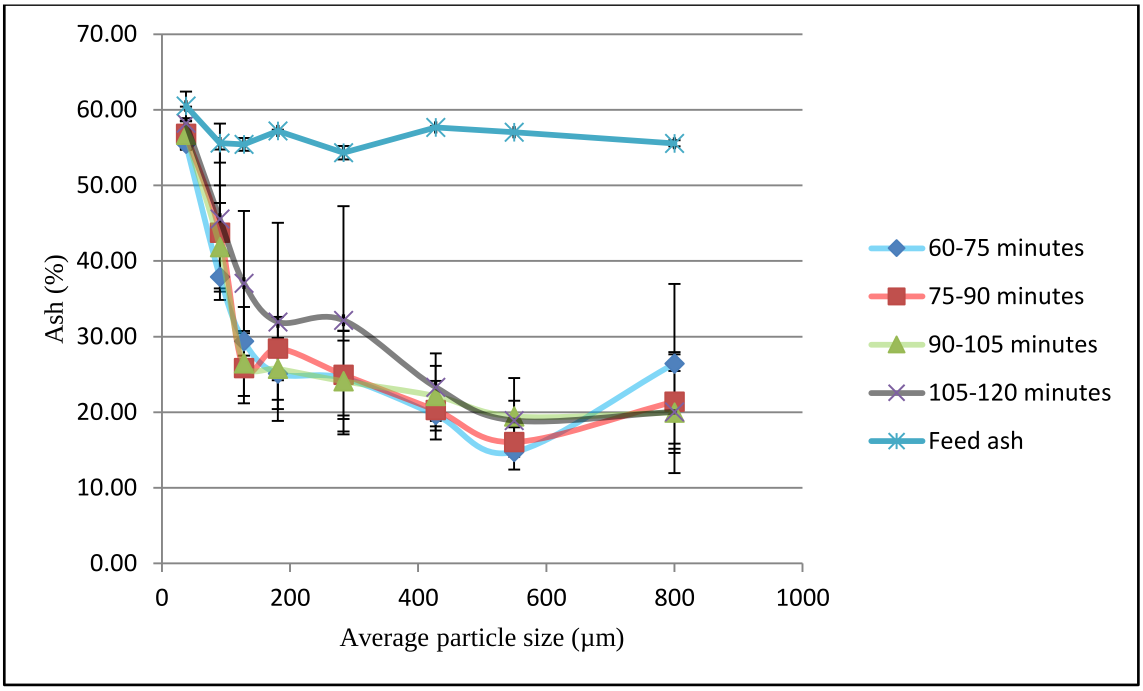

Figure 4.3.6: Average product ash (%) compared to feed ash (%) achieved over the second hour

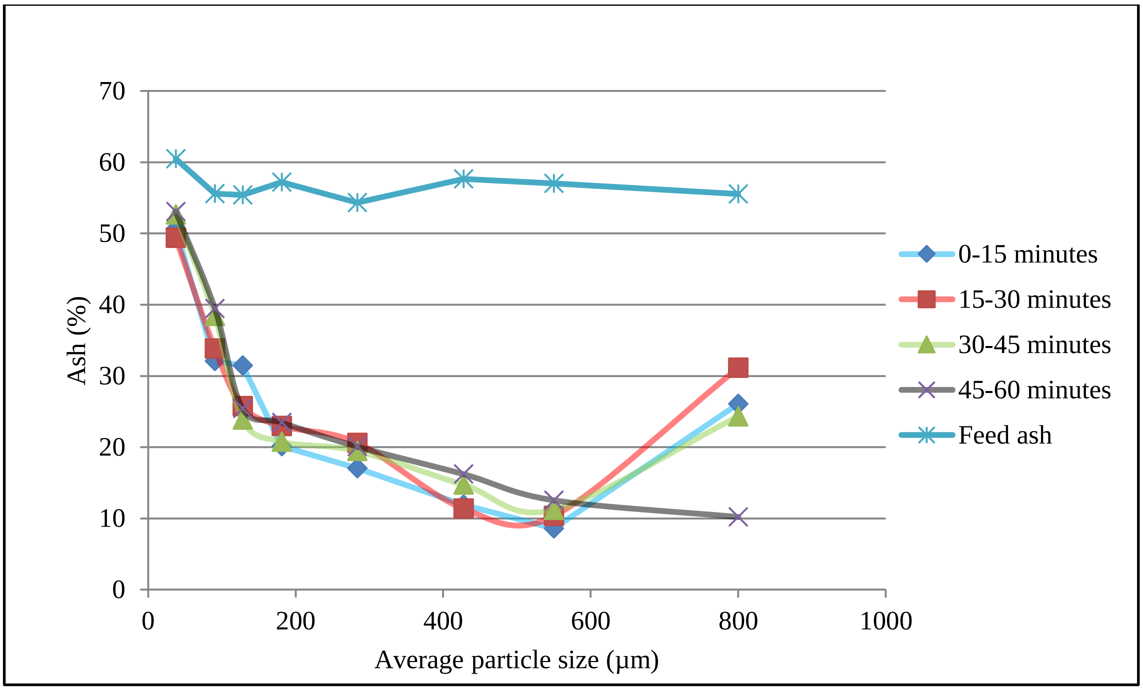

Figure 4.3.7: Product ash (%) compared to feed ash (%) achieved over the first hour

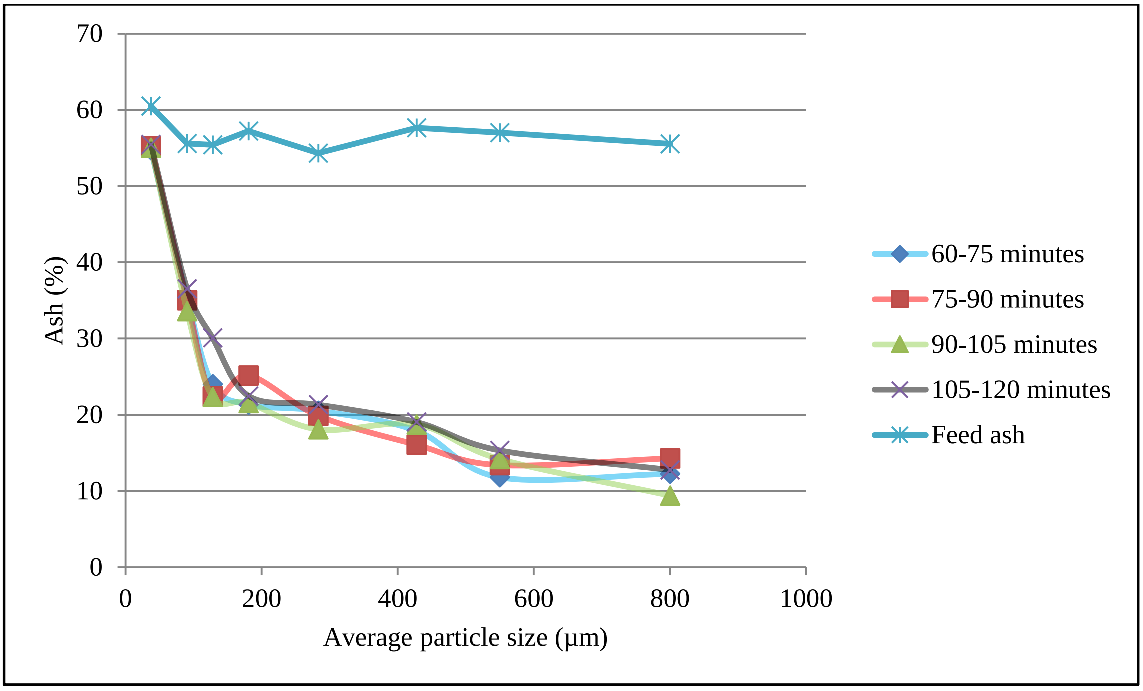

Figure 4.3.8: Product ash (%) compared to feed ash (%) achieved over the second hour

The maximum upgrades achieved in tests 37-39 are presented in figures 4.3.3 and 4.3.4. The average upgrade (calculated as the arithmetic average) is illustrated in figures 4.3.1 and 4.3.2 together with the error bands (standard deviation). It is evident that fairly consistent upgrades were achieved over time. In figure 4.3.3, it can be seen that for the first 45 minutes, the coarsest size range was upgraded the least. However, this size fraction thereafter attained the lowest ash content over the subsequent 75 minutes indicated by upgrades as high as 83%, with a reduction in average ash content from 55.56% to approximately 11%. This improvement over time attests to the enhanced gravity separation brought about by greater hindered settling as the material within the fluidised bed zone accumulated over time. Significant reductions in ash content were seen in the intermediate to fine size ranges as well, with a reduction in average ash content from 55.63% to 27.61% for particles in the -355 + 75 µm size range. In comparison to the first 15 minutes of tests 25-27 (figure 4.2.37), on which these semi-continuous tests were based, it is clear that similar reductions in ash content were attained consistently for the entire duration of the experiment for particles larger than 106 µm.

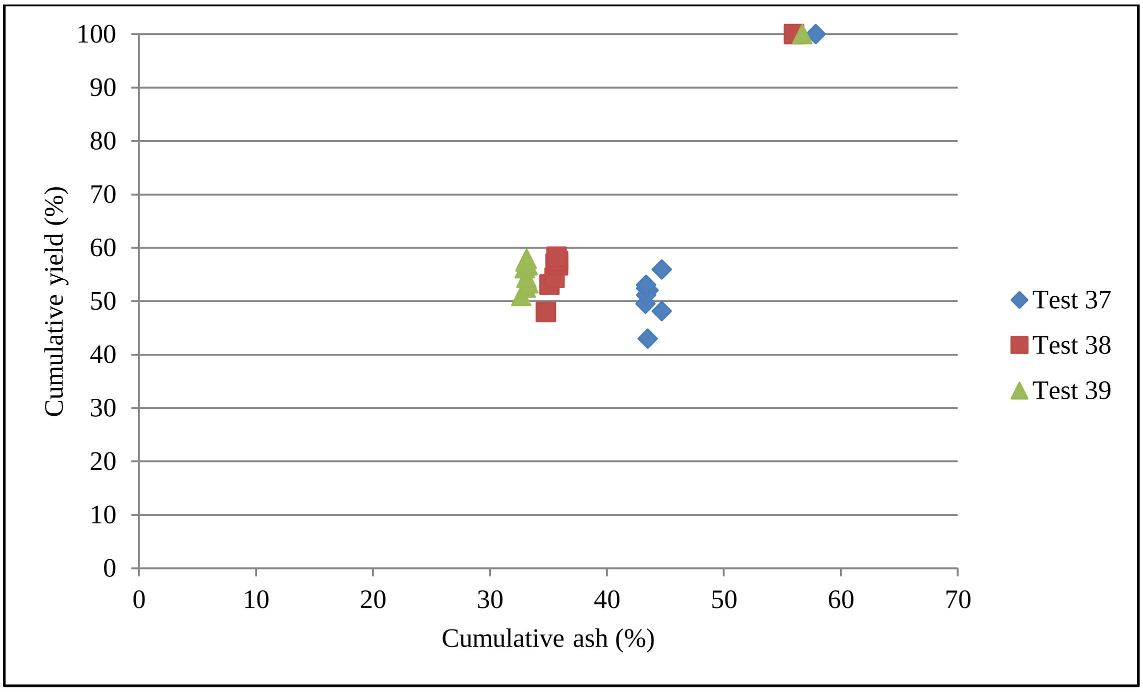

Figure 4.3.9: Yield-ash curve for overall size range of the semi-continuous tests (12 channels, 9 l/min)

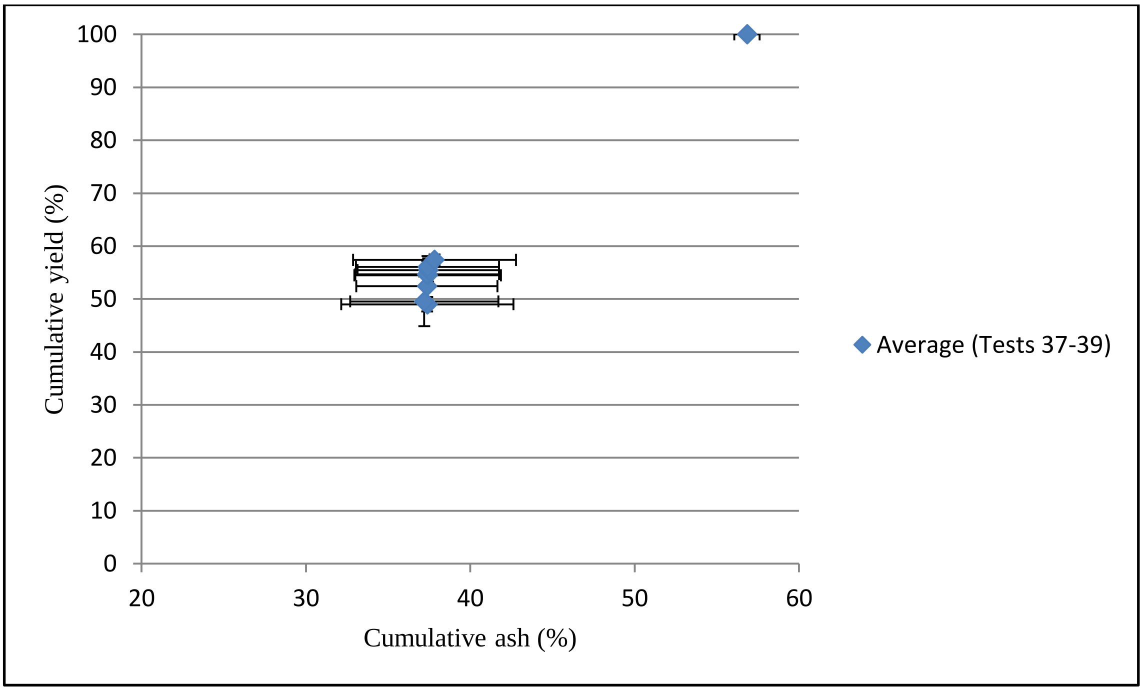

Figure 4.3.10: Yield-ash curve (average) for overall size range of the semi-continuous tests (12 channels, 9 l/min)

Figure 4.3.9 displays a plot of the overall yield recovered after each 15 minute interval and its corresponding ash content. In runs 2 and 3 (tests 38 and 39), overall yields ranging from 48%-57% with an ash content of approximately 35% were achieved. These yields are higher, with overall lower ash contents over time, compared to the corresponding batch tests using 12 channels and 9 l/min (see figure 4.2.43). The higher yields were expected due to influx of fresh feed over the course of the experiment. Fairly reasonable yields were also achieved at the lower sizes, such as for particles in the -106 + 75 μm fraction, in which yields ranging from 57%-69% were seen with corresponding ash contents between 32%-40%. In the coarser size ranges, between 355 μm and 600 μm, yields ranging from 38%-53% were attained, with remarkably low ash contents (8%-24%). Additionally, the semi-continuous tests indicate that initial fine material separation (as seen during the primary batch tests) followed by stabilisation of the bed (with the additional feed) are occurring. This suggests that a continuous system could achieve effective coal cleaning above 106 μm up to the 1 mm top-size.

4.4 Significance of results

Present-day coal cleaning practises rely heavily on physical separation, as it is more economical compared to biological and chemical processes. More often than not, gravity concentration is employed to clean coarser sizes, while spirals and froth flotation are favoured for finer coal. In theory, the reduction in particle size would enable better liberation between the coal and the associated gangue material (Demir et al., n.d). Consequently, advanced coal cleaning methods, which aim to build upon and enhance techniques for fine coal treatment, have been an area of focus in recent years. Moreover, as underlined in Chapter 2 (section 2.1.2), the ever increasing demand for mined resources inevitably result in the depletion of its reserves and quality, further necessitating research and development into fine coal cleaning.

As mentioned earlier, froth flotation is typically used for coal finer than 500 μm. A study conducted on Illinois coal assessed the efficacy of froth flotation in cleaning fine coal (- 250 μm size range) with relatively low ash content under laboratory conditions. The feed coal consisted of 8 samples that had previously undergone various physical cleaning processes, with ash contents ranging from 7-16.10%. An upgrade, again defined by the percentage reduction in product ash content relative to the feed, in the range of 24-69% was achieved.

The credibility of the findings was further examined by comparing it to a full washability analysis of the feed, which revealed that upgrades between 47-75% were achievable (Demir et al., n.d). In a separate study, a pilot plant set-up consisting of a 2-stage Jameson Cell flotation circuit was used to clean coal from the Hunter Valley Coalfield located in New South Wales, Australia. The feed coal, consisting of material finer than 500 μm, had an ash content of roughly 60% and was cleaned to a product with 15-16% ash content (Mercuri et al., 2014). These results are comparable with those achieved using the narrowest channels in the present investigation, particularly during the semi-continuous tests, in which upgrades as high as 68% were noted for particles finer than 300 μm (see figures 4.3.3 and 4.3.4). Furthermore, the current investigation tested feed material with high ash contents and, using the narrowest channel spacing, was able to clean the material to produce a product with ash content ranging from 8.59-25.71% in the –600 + 150 μm size range. From a commercial perspective, thermal coal utilised by Eskom for power generation has an ash content ranging from 25-33%, with coal containing more than 35% being rejected as viable material. Additionally, Sasol, which uses coal for most of its gasification feedstock in the Secunda plant rejects coal with an ash content exceeding 29.7% (Steyn and Minnitt, 2010). Thus, it is possible to utilise the reflux classifier to produce a saleable product from low quality feedstock (coal with ash exceeding 55% ash). Moreover, the prospect of an economical technology capable of producing clean product on par with froth flotation is a significant development in the area of advanced coal cleaning.

The results presented in this thesis provide a unique insight into the capability of the reflux classifier in cleaning high ash coal. Due to the novel nature of the technology, previous studies focused primarily on developing the theory that governs the separation characteristics, and in investigations involving coal, feedstock with relatively low ash content was utilised. Galvin et al. (2009) conducted an investigation of a similar nature in which closely spaced channels were employed to minimise the impact of particle size on separation. A series of batch separation tests on -250 + 38 μm coal were conducted in a laboratory scale unit which incorporated 1.77 mm wide channels. An interesting result was that a common fluidisation rate was capable of conveying particles covering a broad size range to the overflow, which was also noted in this investigation. In terms of ash content, a reduction from 12.2% (feed ash) to roughly 4% in the product was achieved while still maintaining a high yield. A thorough study on the applicability of the reflux classifier to coarser materials was undertaken and reported in Galvin et al. (2010c). The investigation included both pilot and laboratory scale batch testing of coal with a top-size of 8 mm. A fairly wide channel spacing of 18 mm was utilised in the laboratory-scale unit. On average, the feed coal finer than 1 mm with an ash content of approximately 17.41% was cleaned to produce a product with 9.12% ash, which translated to an upgrade of 47.63%. In another batch-wise study reported in Galvin (2009b), coal with a top size of 4 mm was cleaned in a laboratory scale reflux classifier. For material finer than 1 mm, a reduction in ash content from roughly 20% (feed ash) to 7% in the product was noted. In one particular investigation which resembled the test conditions laid out in this thesis, coal finer than 500 μm was cleaned using 1.77 mm wide channels in a batch-wise campaign. A reduction in the overall feed ash content from 63.2% in the feed to product ash content of 25.3% was noted in one of the tests (Galvin et al., 2010b). The results of this investigation, particularly the semi-continuous tests, compare well with the above results. In test 39 (which was the third run of the semi-continuous triplicate of tests), a reduction in feed ash from 56.66% to a product containing 23.04% ash was achieved in the -500 μm size range. Thus, in terms of the relative upgrade of coal that can be achieved using the reflux classifier, the findings reported in this thesis are indeed comparable, and furthermore, the results provides evidence that the reflux classifier is adept at cleaning low quality coals finer than 1 mm, which covers the size range normally processed using spirals and flotation.

CHAPTER 5: CONCLUSIONS

- The preliminary batch separation tests, conducted using the double fractionation technique, demonstrated that considerable reduction in the product ash content was attainable at flowrates ranging from 5 l/min to 10 l/min.
- Furthermore, more enhanced density-based separation, evidenced by the lower product ash contents, was promoted in the narrower channels.
- In the main batch tests conducted over 60 minutes, significant reductions in product ash content were observed throughout the entire size range when using the narrowest channels (2.10 mm width) with flowrates of 9 l/min and 12 l/min. The use of 9 l/min achieved product ash contents as low as 36.11% in the -75 μm size fraction compared to the average feed ash content of 60.71% in the corresponding size range.
- The batch tests revealed that the yield of coal increased as the fluidisation rate increased. Furthermore, the ash content of the recovered product generally decreased at higher flowrates, and this response became more profound as the channel width decreased.
- Using 6 channels (6.50 mm channel width), the overall ash content of the product for the 60 minute runs was reduced progressively from 55.55% ash (20.05 % yield) to 54.64% ash (33.86% yield) as the fluidisation rate was increased from 3 l/min in stages up to 12 l/min.
- Using 8 channels (4.50 mm channel width), the overall ash content of the product for the 60 minute runs was reduced progressively from 57.78% ash (16.74 % yield) to 49.67% ash (38.17% yield) as the fluidisation rate was increased from 3 l/min in stages up to 12 l/min.
- Using 12 channels (2.10 mm channel width), the overall ash content of the product for the 60 minute runs was reduced progressively from 56.24% ash (13.92 % yield) to 40.37% ash (52.73% yield) as the fluidisation rate was increased from 3 l/min in stages up to 12 l/min.
- The cleaner product achieved at higher flowrates indicated that the feed consisted of a large proportion of light coarse material.
- The semi-continuous tests conducted over 120 minutes using the narrowest channels generated an average yield of 57.40% with an ash content of 37.82%. The continuous addition of fresh feed gave rise to more pronounced hindered settling conditions due to the development of an autogenous dense medium through the accumulation of

material within the fluidisation zone. This is evident from the overall product ash content of 37.82% mentioned above, which was the lowest achieved in any of the runs.

- Particle re-suspension behaviour induced by high aspect ratios, which heavily promotes density-driven separation, was also noted in the 12 channel configuration.
- The relative upgrade achieved using the narrowest channels were comparable with previous studies on the reflux classifier, as well as with those achieved using laboratory-scale froth flotation.
- The reduction in ash content achieved in the semi-continuous trials indicates that the reflux classifier can be used to clean low quality coals to produce a saleable product.
- Considerable cleaning of the coal down to particles in the -75 μm fraction was attainable when using the narrowest channels.
- In comparison to the cost of flotation, this is an attractive alternative method of processing very fine coal.

CHAPTER 6: RECOMMENDATIONS

- It is recommended that a full washability analysis using the sink-float technique be performed to determine the density distribution of the feed. Thus, the degree of similarity between the cumulative yield% and cumulative ash% obtained in the laboratory scale unit and those obtained using the widely accepted sink-float method can be deduced.
- The semi-continuous campaign should be extended to cover the 6 channel and 8 channel configurations to ascertain the effect of an autogenous dense medium on separation compared to the relatively low solids volume fractions tested in the current scope.
- Continuous testing over more limited size ranges should be undertaken to determine whether enhanced separations can be achieved with more closely sized feed.

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APPENDIX A: RAW DATA

A-1: Preliminary batch tests data

Table A-1.1: Test 1 A, Flow fraction 1 at 1.5 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 1 (Elutriation time: 33.35 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	74,84	18,44	43,49	0,69	1,26	1,26	35,82	17,63
- 600 + 500	29,23	7,20	43,13	0,75	1,37	2,63	36,00	16,53
- 500 + 355	58,02	14,30	43,07	2,08	3,80	6,43	35,64	17,24
- 355 + 212	86,20	21,24	41,01	10,35	18,89	25,32	41,18	-0,41
- 212 + 150	31,70	7,81	44,21	4,59	8,38	33,70	46,08	-4,23
- 150 + 106	26,42	6,51	46,18	3,55	6,48	40,18	46,08	0,22
- 106 + 75	28,48	7,02	46,89	4,40	8,03	48,21	49,51	-5,60
-75	70,92	17,48	51,23	28,37	51,79	100,00	51,96	-1,43
Total	405,82	100		54,780	100,000			

Table A-1.2: Test 1 A, Flow fraction 2 at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 2 (Elutriation time: 5.38 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	74,84	18,44	43,49	0,14	1,77	1,77	61,54	-41,50
- 600 + 500	29,23	7,20	43,13	0,25	3,17	4,94	39,13	9,27
- 500 + 355	58,02	14,30	43,07	0,38	4,82	9,76	44,74	-3,87
- 355 + 212	86,20	21,24	41,01	1,13	14,32	24,08	37,25	9,16
- 212 + 150	31,70	7,81	44,21	0,88	11,15	35,23	43,68	1,20
- 150 + 106	26,42	6,51	46,18	0,53	6,72	41,95	47,17	-2,14
- 106 + 75	28,48	7,02	46,89	0,54	6,84	48,80	23,08	50,78
-75	70,92	17,48	51,23	4,04	51,20	100,00	50,98	0,49
Total	405,82	100		7,890	100,000			

Table A-1.3: Test 1 A, Flow fraction 3 at 5.75 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 3 (Elutriation time: 4.17 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	74,84	18,44	43,49	0,39	4,31	4,31	71,79	-65,08
- 600 + 500	29,23	7,20	43,13	0,16	1,77	6,08	37,50	13,05
- 500 + 355	58,02	14,30	43,07	0,14	1,55	7,62	42,86	0,49
- 355 + 212	86,20	21,24	41,01	0,29	3,20	10,83	39,29	4,20
- 212 + 150	31,70	7,81	44,21	0,22	2,43	13,26	36,36	17,75
- 150 + 106	26,42	6,51	46,18	0,31	3,43	16,69	48,39	-4,78
- 106 + 75	28,48	7,02	46,89	0,50	5,52	22,21	42,86	8,60
-75	70,92	17,48	51,23	7,04	77,79	100,00	50,49	1,45
Total	405,82	100		9,050	100,000			

Table A-1.4: Test 1 A, Flow fraction 4 at 9.75 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 4 (Elutriation time: 3.47 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	74,84	18,44	43,49	0,29	1,62	1,62	78,26	-79,95
- 600 + 500	29,23	7,20	43,13	0,03	0,17	1,79	50,00	-15,93
- 500 + 355	58,02	14,30	43,07	0,13	0,73	2,51	27,27	36,68
- 355 + 212	86,20	21,24	41,01	0,42	2,34	4,85	42,50	-3,63
- 212 + 150	31,70	7,81	44,21	0,24	1,34	6,19	42,86	3,06
- 150 + 106	26,42	6,51	46,18	0,46	2,57	8,76	20,45	55,71
- 106 + 75	28,48	7,02	46,89	3,25	18,14	26,90	14,42	69,24
-75	70,92	17,48	51,23	13,10	73,10	100,00	33,98	33,67
Total	405,82	100		17,920	100,000			

Table A-1.5: Test 1 A, Underflow

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	74,84	18,44	43,49	54,80	18,99	18,99	39,05	-10,21
- 600 + 500	29,23	7,20	43,13	25,39	8,80	27,78	41,75	-3,21
- 500 + 355	58,02	14,30	43,07	47,52	16,46	44,25	44,12	2,43
- 355 + 212	86,20	21,24	41,01	74,67	25,87	70,12	41,18	0,41
- 212 + 150	31,70	7,81	44,21	25,98	9,00	79,12	44,76	1,25
- 150 + 106	26,42	6,51	46,18	19,57	6,78	85,90	42,86	-7,20
- 106 + 75	28,48	7,02	46,89	21,27	7,37	93,26	53,40	13,88
-75	70,92	17,48	51,23	19,44	6,74	100,00	72,55	41,61
Total	405,82	100		288,640	100,000			

Table A-1.6: Test 2 A, Flow fraction 1 at 1.5 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 1 (Elutriation time: 40 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	72,67	17,82	41,18	0,94	2,65	2,65	60,00	-45,71
- 600 + 500	30,42	7,46	42,31	1,56	4,39	7,04	52,94	-25,13
- 500 + 355	62,62	15,35	45,19	3,55	9,99	17,03	53,40	-18,16
- 355 + 212	87,42	21,43	42,31	13,94	39,23	56,26	50,00	-18,18
- 212 + 150	32,78	8,04	43,00	5,75	16,18	72,45	51,46	-19,67
- 150 + 106	27,01	6,62	37,25	5,55	15,62	88,07	54,90	-47,37
- 106 + 75	27,92	6,85	48,51	3,52	9,91	97,97	53,40	-10,07
-75	67,04	16,44	55,88	0,72	2,03	100,00	53,52	4,23
Total	407,88	100,00		35,53	100,00			

Table A-1.7: Test 2 A, Flow fraction 2 at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 2 (Elutriation time: 5.95 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	72,67	17,82	41,18	0,12	1,51	1,51	16,67	59,52
- 600 + 500	30,42	7,46	42,31	0,03	0,38	1,88	33,33	21,21
- 500 + 355	62,62	15,35	45,19	0,15	1,88	3,77	26,67	40,99
- 355 + 212	87,42	21,43	42,31	1,05	13,19	16,96	38,10	9,96
- 212 + 150	32,78	8,04	43,00	0,56	7,04	23,99	48,21	-12,13
- 150 + 106	27,01	6,62	37,25	0,43	5,40	29,40	39,53	-6,12
- 106 + 75	27,92	6,85	48,51	0,60	7,54	36,93	41,67	14,12
-75	67,04	16,44	55,88	5,02	63,07	100,00	45,54	18,50
Total	407,88	100,00		7,96	100,00			

Table A-1.8: Test 2 A, Flow fraction 3 at 5.75 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 3 (Elutriation time: 4.00 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	72,67	17,82	41,18	0,25	2,78	2,78	24,00	41,71
- 600 + 500	30,42	7,46	42,31	0,05	0,56	3,33	20,00	52,73
- 500 + 355	62,62	15,35	45,19	0,11	1,22	4,56	27,27	39,65
- 355 + 212	87,42	21,43	42,31	0,54	6,00	10,56	38,89	8,08
- 212 + 150	32,78	8,04	43,00	0,38	4,22	14,78	44,74	-4,04
- 150 + 106	27,01	6,62	37,25	0,36	4,00	18,78	38,89	-4,39
- 106 + 75	27,92	6,85	48,51	0,53	5,89	24,67	43,40	10,55
-75	67,04	16,44	55,88	6,78	75,33	100,00	46,08	17,54
Total	407,88	100,00		9,00	100,00			

Table A-1.9: Test 2 A, Flow fraction 4 at 9.75 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 4 (Elutriation time: 2.50 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	72,67	17,82	41,18	0,31	1,45	1,45	51,61	-25,35
- 600 + 500	30,42	7,46	42,31	0,29	1,36	2,81	51,72	-22,26
- 500 + 355	62,62	15,35	45,19	0,40	1,88	4,69	35,00	22,55
- 355 + 212	87,42	21,43	42,31	3,39	15,89	20,58	39,81	5,91
- 212 + 150	32,78	8,04	43,00	0,85	3,98	24,57	41,18	4,24
- 150 + 106	27,01	6,62	37,25	1,35	6,33	30,90	34,31	7,89
- 106 + 75	27,92	6,85	48,51	6,46	30,29	61,18	37,62	22,45
-75	67,04	16,44	55,88	8,28	38,82	100,00	50,00	10,53
Total	407,88	100,00		21,33	100,00			

Table A-1.10: Test 2 A, Underflow

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	72,67	17,82	41,18	65,39	22,49	22,49	44,12	7,14
- 600 + 500	30,42	7,46	42,31	23,25	8,00	30,49	47,06	11,23
- 500 + 355	62,62	15,35	45,19	44,43	15,28	45,77	41,58	-7,98
- 355 + 212	87,42	21,43	42,31	74,87	25,75	71,53	43,56	2,97
- 212 + 150	32,78	8,04	43,00	35,40	12,18	83,71	44,12	2,60
- 150 + 106	27,01	6,62	37,25	15,26	5,25	88,95	47,52	27,57
- 106 + 75	27,92	6,85	48,51	17,34	5,96	94,92	49,02	1,04
-75	67,04	16,44	55,88	14,77	5,08	100,00	66,34	18,71
Total	407,88	100,00		290,71	100,00			

Table A-1.11: Test 3 A, Flow fraction 1 at 1.5 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 1 (Elutriation time: 66.00 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	77,82	19,07	45,54	4,90	12,27	12,27	57,43	-26,09
- 600 + 500	28,36	6,95	43,69	2,34	5,86	18,14	52,43	-20,00
- 500 + 355	54,03	13,24	42,45	3,67	9,19	27,33	49,51	-16,63
- 355 + 212	85,92	21,05	46,15	8,56	21,44	48,77	44,76	3,02
- 212 + 150	30,97	7,59	40,00	3,51	8,79	57,57	44,55	-11,39
- 150 + 106	26,11	6,40	34,00	5,18	12,98	70,54	46,53	-36,87
- 106 + 75	29,35	7,19	54,90	8,22	20,59	91,13	45,63	16,89
-75	75,57	18,52	56,44	3,54	8,87	100,00	44,12	21,83
Total	408,13	100		39,92	100			

Table A-1.12 Test 3 A, Flow fraction 2 at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 2 (Elutriation time: 8.00 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	77,82	19,07	45,54	0,00	0,00	0,00	0,00	-
- 600 + 500	28,36	6,95	43,69	0,06	0,86	0,86	33,33	23,70
- 500 + 355	54,03	13,24	42,45	0,14	2,01	2,87	28,57	32,70
- 355 + 212	85,92	21,05	46,15	0,86	12,34	15,21	38,37	16,86
- 212 + 150	30,97	7,59	40,00	0,51	7,32	22,53	39,22	1,96
- 150 + 106	26,11	6,40	34,00	0,42	6,03	28,55	35,71	-5,04
- 106 + 75	29,35	7,19	54,90	0,48	6,89	35,44	33,33	39,29
-75	75,57	18,52	56,44	4,50	64,56	100,00	39,60	29,82
Total	408,13	100		6,97	100			

Table A-1.13: Test 3 A, Flow fraction 3 at 5.75 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 3 (Elutriation time: 4.00 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	77,82	19,07	45,54	0,45	1,85	1,85	53,33	-17,10
- 600 + 500	28,36	6,95	43,69	0,44	1,81	3,65	47,73	-9,24
- 500 + 355	54,03	13,24	42,45	1,60	6,57	10,22	25,49	39,96
- 355 + 212	85,92	21,05	46,15	7,82	32,10	42,32	13,73	70,26
- 212 + 150	30,97	7,59	40,00	2,50	10,26	52,59	18,63	53,43
- 150 + 106	26,11	6,40	34,00	1,55	6,36	58,95	14,85	56,32
- 106 + 75	29,35	7,19	54,90	2,38	9,77	68,72	13,73	75,00
-75	75,57	18,52	56,44	7,62	31,28	100,00	36,63	35,09
Total	408,13	100		24,36	100			

Table A-1.14: Test 3 A, Flow fraction 4 at 9.75 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 4 (Elutriation time: 2.25 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	77,82	19,07	45,54	1,28	1,22	1,22	13,73	69,86
- 600 + 500	28,36	6,95	43,69	5,20	4,95	6,17	8,00	81,69
- 500 + 355	54,03	13,24	42,45	17,71	16,87	23,04	11,00	74,09
- 355 + 212	85,92	21,05	46,15	55,97	53,32	76,36	18,63	59,64
- 212 + 150	30,97	7,59	40,00	5,15	4,91	81,27	15,84	60,40
- 150 + 106	26,11	6,40	34,00	6,16	5,87	87,14	16,67	50,98
- 106 + 75	29,35	7,19	54,90	6,39	6,09	93,23	18,63	66,07
-75	75,57	18,52	56,44	7,11	6,77	100,00	42,72	24,31
Total	408,13	100		104,97	100			

Table A-1.15: Test 3 A, Underflow

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	77,82	19,07	45,54	55,87	21,70	21,70	43,00	-5,59
- 600 + 500	28,36	6,95	43,69	21,95	8,53	30,23	51,49	17,84
- 500 + 355	54,03	13,24	42,45	45,05	17,50	47,73	64,08	50,94
- 355 + 212	85,92	21,05	46,15	80,33	31,20	78,93	68,00	47,33
- 212 + 150	30,97	7,59	40,00	11,27	4,38	83,31	67,65	69,12
- 150 + 106	26,11	6,40	34,00	12,07	4,69	88,00	65,35	92,20
- 106 + 75	29,35	7,19	54,90	14,00	5,44	93,44	70,00	27,50
-75	75,57	18,52	56,44	16,89	6,56	100,00	77,67	37,63
Total	408,13	100		257,43	100			

Table A-1.16: Test 4 A, Flow fraction 1 at 1.5 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 1 (Elutriation time: 48.23 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 600 + 500	59,66	11,19	46,15	1,25	1,54	1,54	53,92	-16,83
- 500 + 355	79,77	14,96	46,60	5,70	7,01	8,55	49,50	-6,23
- 355 + 212	130,22	24,42	41,18	58,05	71,42	79,97	53,00	-28,71
- 212 + 150	47,25	8,86	37,62	9,61	11,82	91,79	53,00	-40,87
- 150 + 106	38,20	7,16	36,89	1,61	1,98	93,77	53,47	-44,92
- 106 + 75	58,60	10,99	47,52	2,57	3,16	96,94	52,00	-9,42
-75	119,64	22,43	57,84	2,49	3,06	100,00	52,48	9,28
Total`	533,34	100		81,28	100			

Table A-1.17: Test 4 A, Flow fraction 2 at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 2 (Elutriation time: 11.17 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 600 + 500	59,66	11,19	46,15	0,12	1,88	1,88	40,00	13,33
- 500 + 355	79,77	14,96	46,60	0,73	11,41	13,28	47,89	-2,76
- 355 + 212	130,22	24,42	41,18	1,96	30,63	43,91	48,00	-16,57
- 212 + 150	47,25	8,86	37,62	0,93	14,53	58,44	48,91	-30,01
- 150 + 106	38,20	7,16	36,89	0,56	8,75	67,19	43,64	-18,28
- 106 + 75	58,60	10,99	47,52	1,09	17,03	84,22	44,00	7,42
-75	119,64	22,43	57,84	1,01	15,78	100,00	42,57	26,40
Total`	533,34	100		6,4	100			

Table A-1.18: Test 4 A, Flow fraction 3 at 4.75 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 3 (Elutriation time: 5.17 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 600 + 500	59,66	11,19	46,15	0,60	2,84	2,84	55,17	-19,54
- 500 + 355	79,77	14,96	46,60	1,37	6,47	9,31	56,00	-20,17
- 355 + 212	130,22	24,42	41,18	1,89	8,93	18,24	61,39	-49,08
- 212 + 150	47,25	8,86	37,62	1,28	6,05	24,29	69,31	-84,21
- 150 + 106	38,20	7,16	36,89	1,52	7,18	31,47	73,53	-99,30
- 106 + 75	58,60	10,99	47,52	2,41	11,39	42,86	62,38	-31,25
-75	119,64	22,43	57,84	12,09	57,14	100,00	59,80	-3,39
Total`	533,34	100		21,16	100			

Table A-1.19: Test 4 A, Flow fraction 4 at 6.75 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 4 (Elutriation time: 2.75 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 600 + 500	59,66	11,19	46,15	0,10	0,47	0,47	10,00	78,33
- 500 + 355	79,77	14,96	46,60	0,12	0,56	1,03	16,67	64,24
- 355 + 212	130,22	24,42	41,18	0,53	2,49	3,53	41,51	-0,81
- 212 + 150	47,25	8,86	37,62	0,31	1,46	4,98	45,16	-20,03
- 150 + 106	38,20	7,16	36,89	0,91	4,28	9,26	34,07	7,66
- 106 + 75	58,60	10,99	47,52	4,30	20,22	29,48	20,00	57,92
-75	119,64	22,43	57,84	15,00	70,52	100,00	48,00	17,02
Total	533,34	100		21,27	100			

Table A-1.20: Test 4 A, Underflow

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Underflow				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
- 600 + 500	59,66	11,19	46,15	33,31	9,48	9,48	45,54	-1,32
- 500 + 355	79,77	14,96	46,60	76,83	21,87	31,35	40,00	-14,17
- 355 + 212	130,22	24,42	41,18	130,80	37,23	68,59	40,00	-2,86
- 212 + 150	47,25	8,86	37,62	36,98	10,53	79,11	41,00	8,97
- 150 + 106	38,20	7,16	36,89	26,70	7,60	86,71	40,00	8,42
- 106 + 75	58,60	10,99	47,52	26,34	7,50	94,21	48,51	2,08
-75	119,64	22,43	57,84	20,33	5,79	100,00	71,29	23,24
Total	533,34	100		351,29	100			

Table A-1.21: Test 5 A, Flow fraction 1 at 1.5 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 1 (Elutriation time: 58 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 600 + 500	33,02	5,89	63,37	0,31	0,56	0,56	58,06	8,37
- 500 + 355	99,51	17,76	57,14	8,95	16,10	16,66	59,00	-3,25
- 355 + 212	148,76	26,55	52,43	22,49	40,46	57,11	56,00	-6,81
- 212 + 150	46,76	8,35	53,92	8,84	15,90	73,02	55,00	-2,00
- 150 + 106	35,04	6,25	61,39	4,90	8,81	81,83	55,00	10,40
- 106 + 75	72,25	12,90	66,35	6,59	11,85	93,69	58,00	12,58
-75	124,95	22,30	62,00	3,51	6,31	100,00	55,00	11,29
Total	560,3	100		55,59	100			

Table A-1.22: Test 5 A, Flow fraction 2 at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 2 (Elutriation time: 11 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 600 + 500	33,02	5,89	63,37	0,11	0,61	0,61	36,36	42,61
- 500 + 355	99,51	17,76	57,14	1,56	8,68	9,29	45,54	20,30
- 355 + 212	148,76	26,55	52,43	2,83	15,75	25,04	40,59	22,57
- 212 + 150	46,76	8,35	53,92	1,09	6,07	31,11	41,58	22,88
- 150 + 106	35,04	6,25	61,39	0,61	3,39	34,50	38,98	36,50
- 106 + 75	72,25	12,90	66,35	0,75	4,17	38,68	42,47	35,99
-75	124,95	22,30	62,00	11,02	61,32	100,00	44,55	28,14
Total	560,3	100		17,97	100			

Table A-1.23: Test 5 A, Flow fraction 3 at 4.75 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 3 (Elutriation time: 6.38 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 600 + 500	33,02	5,89	63,37	0,23	2,00	2,00	56,52	10,80
- 500 + 355	99,51	17,76	57,14	0,87	7,57	9,57	42,53	25,57
- 355 + 212	148,76	26,55	52,43	1,17	10,17	19,74	37,00	29,43
- 212 + 150	46,76	8,35	53,92	0,50	4,35	24,09	36,00	33,24
- 150 + 106	35,04	6,25	61,39	0,42	3,65	27,74	35,71	41,82
- 106 + 75	72,25	12,90	66,35	0,53	4,61	32,35	37,74	43,12
-75	124,95	22,30	62,00	7,78	67,65	100,00	40,00	35,48
Total`	560,3	100		11,5	100			

Table A-1.24: Test 5 A, Flow fraction 4 at 6.75 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 4 (Elutriation time: 3.20 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 600 + 500	33,02	5,89	63,37	0,06	0,35	0,35	50,00	21,09
- 500 + 355	99,51	17,76	57,14	0,33	1,90	2,25	42,42	25,76
- 355 + 212	148,76	26,55	52,43	1,71	9,85	12,10	41,00	21,80
- 212 + 150	46,76	8,35	53,92	0,90	5,18	17,28	44,44	17,58
- 150 + 106	35,04	6,25	61,39	0,65	3,74	21,03	30,77	49,88
- 106 + 75	72,25	12,90	66,35	1,39	8,01	29,03	32,00	51,77
-75	124,95	22,30	62,00	12,32	70,97	100,00	49,00	20,97
Total`	560,3	100		17,36	100			

Table A-1.25: Test 5 A, Underflow

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
- 600 + 500	33,02	5,89	63,37	23,95	7,88	7,88	64,71	2,11
- 500 + 355	99,51	17,76	57,14	68,18	22,44	30,32	56,00	-2,00
- 355 + 212	148,76	26,55	52,43	94,23	31,02	61,34	52,48	0,09
- 212 + 150	46,76	8,35	53,92	28,48	9,37	70,72	56,86	5,45
- 150 + 106	35,04	6,25	61,39	20,09	6,61	77,33	61,76	0,62
- 106 + 75	72,25	12,90	66,35	29,56	9,73	87,06	66,67	0,48
-75	124,95	22,30	62,00	39,32	12,94	100,00	76,47	23,34
Total	560,3	100		303,81	100			

Table A-1.26: Test 6 A, Flow fraction 1 at 1.5 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 1 (Elutriation time: 47.50 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 600 + 500	42,79	8,54	48,13	0,66	1,47	1,47	51,52	-7,03
- 500 + 355	81,96	16,36	48,07	5,54	12,34	13,81	48,00	0,15
- 355 + 212	127,68	25,48	46,01	16,76	37,34	51,16	44,00	4,37
- 212 + 150	43,10	8,60	49,21	7,43	16,56	67,71	46,00	6,52
- 150 + 106	33,61	6,71	51,18	2,92	6,51	74,22	41,00	19,89
- 106 + 75	59,83	11,94	51,89	3,96	8,82	83,04	46,00	11,35
-75	112,06	22,37	56,23	7,61	16,96	100,00	52,00	7,52
Total	501,03	100		44,88	100			

Table A-1.27: Test 6 A, Flow fraction 2 at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 2 (Elutriation time: 14.25 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 600 + 500	42,79	8,54	48,13	0,04	0,25	0,25	25,00	48,06
- 500 + 355	81,96	16,36	48,07	0,13	0,82	1,08	30,77	35,99
- 355 + 212	127,68	25,48	46,01	0,60	3,80	4,88	40,00	13,06
- 212 + 150	43,10	8,60	49,21	0,61	3,86	8,74	45,90	6,72
- 150 + 106	33,61	6,71	51,18	0,83	5,26	14,00	45,78	10,54
- 106 + 75	59,83	11,94	51,89	1,19	7,54	21,53	46,08	11,20
-75	112,06	22,37	56,23	12,39	78,47	100,00	44,00	21,75
Total	501,03	100		15,79	100			

Table A-1.28: Test 6 A, Flow fraction 3 at 4.75 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 3 (Elutriation time: 10.45 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 600 + 500	42,79	8,54	48,13	0,07	0,29	0,29	57,14	-18,73
- 500 + 355	81,96	16,36	48,07	0,86	3,57	3,86	13,95	70,97
- 355 + 212	127,68	25,48	46,01	2,94	12,19	16,04	10,68	76,79
- 212 + 150	43,10	8,60	49,21	0,83	3,44	19,49	21,69	55,93
- 150 + 106	33,61	6,71	51,18	1,04	4,31	23,80	31,73	38,00
- 106 + 75	59,83	11,94	51,89	1,65	6,84	30,64	28,43	45,21
-75	112,06	22,37	56,23	16,73	69,36	100,00	34,65	38,37
Total	501,03	100		24,12	100			

Table A-1.29: Test 6 A, Flow fraction 4 at 6.75 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 4 (Elutriation time: 9.00 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 600 + 500	42,79	8,54	48,13	1,74	1,88	1,88	12,87	73,26
- 500 + 355	81,96	16,36	48,07	15,01	16,20	18,07	9,09	81,09
- 355 + 212	127,68	25,48	46,01	26,55	28,65	46,72	9,90	78,48
- 212 + 150	43,10	8,60	49,21	9,22	9,95	56,67	8,91	81,89
- 150 + 106	33,61	6,71	51,18	8,12	8,76	65,44	9,80	80,84
- 106 + 75	59,83	11,94	51,89	7,03	7,59	73,02	10,89	79,01
-75	112,06	22,37	56,23	25,00	26,98	100,00	37,62	33,09
Total	501,03	100		92,67	100			

Table A-1.30: Test 6 A, Underflow

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
- 600 + 500	42,79	8,54	48,13	33,19	11,19	11,19	47,00	-2,35
- 500 + 355	81,96	16,36	48,07	57,53	19,40	30,59	50,00	4,01
- 355 + 212	127,68	25,48	46,01	81,85	27,60	58,19	55,00	19,54
- 212 + 150	43,10	8,60	49,21	26,20	8,83	67,02	56,73	15,28
- 150 + 106	33,61	6,71	51,18	26,28	8,86	75,88	53,47	4,47
- 106 + 75	59,83	11,94	51,89	21,27	7,17	83,06	57,14	10,12
-75	112,06	22,37	56,23	50,25	16,94	100,00	71,00	26,27
Total	501,03	100		296,57	100			

Table A-1.31: Test 7 A, Flow fraction 1 at 1.5 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 1 (Elutriation time: 49.40 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 500 + 355	92,21	18,29	46,53	0,81	1,22	1,22	40,74	12,45
- 355 + 212	138,18	27,41	41,18	8,38	12,67	13,89	53,00	-28,71
- 212 + 150	45,33	8,99	41,58	5,63	8,51	22,40	53,00	-27,45
- 150 + 106	55,72	11,05	38,00	17,39	26,29	48,69	58,00	-52,63
- 106 + 75	55,15	10,94	40,59	8,07	12,20	60,89	56,00	-37,95
-75	117,51	23,31	59,41	25,87	39,11	100,00	56,00	5,73
Total	504,10	100,00		66,15	100,00			

Table A-1.32: Test 7 A, Flow fraction 2 at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 2 (Elutriation time: 9.30 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 500 + 355	92,21	18,29	46,53	0,15	0,70	0,70	13,33	71,35
- 355 + 212	138,18	27,41	41,18	0,69	3,20	3,90	21,74	47,20
- 212 + 150	45,33	8,99	41,58	0,89	4,13	8,03	37,08	10,83
- 150 + 106	55,72	11,05	38,00	0,77	3,57	11,60	37,66	0,89
- 106 + 75	55,15	10,94	40,59	2,21	10,26	21,86	47,00	-15,78
-75	117,51	23,31	59,41	16,84	78,14	100,00	44,00	25,93
Total	504,10	100,00		21,55	100,00			

Table A-1.33: Test 7 A, Flow fraction 3 at 4.75 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 3 (Elutriation time: 3.53 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 500 + 355	92,21	18,29	46,53	0,14	1,03	1,03	14,29	69,30
- 355 + 212	138,18	27,41	41,18	0,49	3,60	4,63	18,37	55,39
- 212 + 150	45,33	8,99	41,58	0,32	2,35	6,99	21,88	47,40
- 150 + 106	55,72	11,05	38,00	0,47	3,46	10,44	31,91	16,01
- 106 + 75	55,15	10,94	40,59	0,96	7,06	17,50	39,58	2,49
-75	117,51	23,31	59,41	11,22	82,50	100,00	41,00	30,98
Total	504,10	100,00		13,60	100,00			

Table A-1.34: Test 7 A, Flow fraction 4 at 6.75 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 4 (Elutriation time: 4.87 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 500 + 355	92,21	18,29	46,53	0,09	0,31	0,31	22,22	52,25
- 355 + 212	138,18	27,41	41,18	0,41	1,42	1,74	21,95	46,69
- 212 + 150	45,33	8,99	41,58	0,32	1,11	2,85	34,38	17,34
- 150 + 106	55,72	11,05	38,00	0,65	2,26	5,10	24,62	35,22
- 106 + 75	55,15	10,94	40,59	3,54	12,29	17,40	14,85	63,41
-75	117,51	23,31	59,41	23,79	82,60	100,00	45,00	24,25
Total	504,10	100,00		28,80	100,00			

Table A-1.35: Test 7 A, Underflow

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
- 500 + 355	92,21	18,29	46,53	80,72	22,87	22,87	42,00	-9,74
- 355 + 212	138,18	27,41	41,18	121,30	34,37	57,25	38,00	-7,71
- 212 + 150	45,33	8,99	41,58	37,81	10,71	67,96	44,00	5,81
- 150 + 106	55,72	11,05	38,00	41,94	11,88	79,84	38,00	0,00
- 106 + 75	55,15	10,94	40,59	28,73	8,14	87,99	46,00	13,32
-75	117,51	23,31	59,41	42,40	12,01	100,00	67,00	12,78
Total	504,10	100,00		352,90	100,00			

Table A-1.36: Test 8 A, Flow fraction 1 at 1.5 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 1 (Elutriation time: 55.03 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 500 + 355	94,82	18,76	44,12	4,50	8,34	8,34	60,00	-36,00
- 355 + 212	155,19	30,71	43,00	15,72	29,14	37,49	59,00	-37,21
- 212 + 150	46,25	9,15	45,00	4,68	8,68	46,16	57,43	-27,61
- 150 + 106	43,68	8,64	42,31	12,17	22,56	68,72	61,39	-45,09
- 106 + 75	56,20	11,12	43,56	6,29	11,66	80,39	59,00	-35,43
-75	109,16	21,60	55,45	10,58	19,61	100,00	56,44	-1,79
Total	505,31	100,00		53,94	100,00			

Table A-1.37: Test 8 A, Flow fraction 2 at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 2 (Elutriation time: 8.33 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 500 + 355	94,82	18,76	44,12	0,08	0,61	0,61	12,50	71,67
- 355 + 212	155,19	30,71	43,00	0,25	1,91	2,52	20,00	53,49
- 212 + 150	46,25	9,15	45,00	0,51	3,89	6,41	43,14	4,14
- 150 + 106	43,68	8,64	42,31	0,65	4,96	11,37	44,62	-5,45
- 106 + 75	56,20	11,12	43,56	0,89	6,79	18,15	51,69	-18,64
-75	109,16	21,60	55,45	10,73	81,85	100,00	46,00	17,04
Total	505,31	100,00		13,11	100,00			

Table A-1.38: Test 8 A, Flow fraction 3 at 4.75 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 3 (Elutriation time: 5.20 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 500 + 355	94,82	18,76	44,12	0,04	0,32	0,32	25,00	43,33
- 355 + 212	155,19	30,71	43,00	0,14	1,10	1,42	28,57	33,55
- 212 + 150	46,25	9,15	45,00	0,32	2,53	3,95	59,38	-31,94
- 150 + 106	43,68	8,64	42,31	0,28	2,21	6,16	50,00	-18,18
- 106 + 75	56,20	11,12	43,56	0,69	5,45	11,60	52,17	-19,76
-75	109,16	21,60	55,45	11,20	88,40	100,00	43,00	22,45
Total	505,31	100,00		12,67	100,00			

Table A-1.39: Test 8 A, Flow fraction 4 at 6.75 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 4 (Elutriation time: 4.40 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 500 + 355	94,82	18,76	44,12	0,02	0,12	0,12	50,00	-13,33
- 355 + 212	155,19	30,71	43,00	0,09	0,55	0,67	11,11	74,16
- 212 + 150	46,25	9,15	45,00	0,14	0,86	1,53	42,86	4,76
- 150 + 106	43,68	8,64	42,31	0,13	0,80	2,33	38,46	9,09
- 106 + 75	56,20	11,12	43,56	0,53	3,25	5,58	43,40	0,39
-75	109,16	21,60	55,45	15,39	94,42	100,00	43,00	22,45
Total	505,31	100,00		16,30	100,00			

Table A-1.40: Test 8 A, Underflow

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
- 500 + 355	94,82	18,76	44,12	82,25	21,10	21,10	41,58	-5,74
- 355 + 212	155,19	30,71	43,00	123,21	31,61	52,71	40,59	-5,60
- 212 + 150	46,25	9,15	45,00	36,91	9,47	62,17	38,61	-14,19
- 150 + 106	43,68	8,64	42,31	42,80	10,98	73,15	41,58	-1,71
- 106 + 75	56,20	11,12	43,56	33,70	8,64	81,80	38,61	-11,36
-75	109,16	21,60	55,45	70,96	18,20	100,00	59,00	6,41
Total	505,31	100,00		389,83	100,00			

Table A-1.41: Test 9 A, Flow fraction 1 at 1.5 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 1 (Elutriation time: 55.70 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 500 + 355	89,12	16,66	47,00	4,74	6,31	6,31	43,56	7,31
- 355 + 212	156,33	29,22	34,95	19,33	25,73	32,03	46,00	-31,61
- 212 + 150	58,04	10,85	38,61	8,00	10,65	42,68	39,00	-1,00
- 150 + 106	44,64	8,34	44,55	16,32	21,72	64,40	48,51	-8,89
- 106 + 75	73,94	13,82	54,37	14,71	19,58	83,98	49,00	9,88
-75	113,01	21,12	57,43	12,04	16,02	100,00	48,00	16,41
Total	535,07	100,00		75,14	100,00			

Table A-1.42: Test 9 A, Flow fraction 2 at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 2 (Elutriation time: 12.08 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 500 + 355	89,12	16,66	47,00	0,08	0,40	0,40	12,50	73,40
- 355 + 212	156,33	29,22	34,95	0,45	2,26	2,66	22,22	36,42
- 212 + 150	58,04	10,85	38,61	0,96	4,82	7,48	37,50	2,88
- 150 + 106	44,64	8,34	44,55	0,76	3,81	11,29	36,84	17,31
- 106 + 75	73,94	13,82	54,37	2,32	11,64	22,93	37,00	31,95
-75	113,01	21,12	57,43	15,36	77,07	100,00	38,00	33,83
Total	535,07	100,00		19,93	100,00			

Table A-1.43: Test 9 A, Flow fraction 3 at 4.75 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 3 (Elutriation time: 13.33 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 500 + 355	89,12	16,66	47,00	1,84	4,50	4,50	8,00	82,98
- 355 + 212	156,33	29,22	34,95	8,93	21,83	26,33	4,95	85,84
- 212 + 150	58,04	10,85	38,61	3,04	7,43	33,76	5,94	84,62
- 150 + 106	44,64	8,34	44,55	3,04	7,43	41,19	9,90	77,78
- 106 + 75	73,94	13,82	54,37	3,87	9,46	50,65	14,85	72,68
-75	113,01	21,12	57,43	20,19	49,35	100,00	33,66	41,38
Total	535,07	100,00		40,91	100,00			

Table A-1.44: Test 9 A, Flow fraction 4 at 6.75 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 4 (Elutriation time: 8.62 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 500 + 355	89,12	16,66	47,00	19,22	17,00	17,00	7,00	85,11
- 355 + 212	156,33	29,22	34,95	35,92	31,78	48,78	11,88	66,01
- 212 + 150	58,04	10,85	38,61	12,48	11,04	59,82	12,00	68,92
- 150 + 106	44,64	8,34	44,55	10,80	9,55	69,37	16,83	62,22
- 106 + 75	73,94	13,82	54,37	10,96	9,70	79,07	19,00	65,05
-75	113,01	21,12	57,43	23,66	20,93	100,00	43,00	25,12
Total	535,07	100,00		113,04	100,00			

Table A-1.45: Test 9 A, Underflow

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
- 500 + 355	89,12	16,66	47,00	61,77	22,71	22,71	54,46	15,86
- 355 + 212	156,33	29,22	34,95	87,17	32,04	54,75	54,00	54,50
- 212 + 150	58,04	10,85	38,61	29,52	10,85	65,60	53,47	38,46
- 150 + 106	44,64	8,34	44,55	24,89	9,15	74,75	57,00	27,93
- 106 + 75	73,94	13,82	54,37	22,25	8,18	82,93	56,00	3,00
-75	113,01	21,12	57,43	46,45	17,07	100,00	73,00	27,12
Total	535,07	100,00		272,05	100,00			

Table A-1.46: Test 10 A, Flow fraction 1 at 1.5 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 1 (Elutriation time: 59.62 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 355 + 212	153,93	31,25	46,00	10,58	12,88	12,88	53,00	-15,22
- 212 + 150	60,24	12,23	39,22	9,77	11,89	24,77	55,00	-40,25
- 150 + 106	55,05	11,18	42,16	18,22	22,18	46,96	56,44	-33,87
- 106 + 75	58,18	11,81	47,06	15,66	19,07	66,02	54,00	-14,75
-75	165,13	33,53	53,33	27,91	33,98	100,00	55,45	-3,96
Total	492,54	100,00		82,14	100,00			

Table A-1.47: Test 10 A, Flow fraction 2 at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 2 (Elutriation time: 14.11 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 355 + 212	153,93	31,25	46,00	0,83	2,72	2,72	10,84	76,43
- 212 + 150	60,24	12,23	39,22	0,81	2,66	5,38	30,86	21,30
- 150 + 106	55,05	11,18	42,16	0,90	2,95	8,34	31,11	26,20
- 106 + 75	58,18	11,81	47,06	1,77	5,81	14,15	49,00	-4,13
-75	165,13	33,53	53,33	26,15	85,85	100,00	43,00	19,38
Total	492,54	100,00		30,46	100,00			

Table A-1.48: Test 10 A, Flow fraction 3 at 4.75 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 3 (Elutriation time: 5.13 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 355 + 212	153,93	31,25	46,00	0,11	0,99	0,99	27,27	40,71
- 212 + 150	60,24	12,23	39,22	0,09	0,81	1,80	33,33	15,00
- 150 + 106	55,05	11,18	42,16	0,13	1,17	2,96	38,46	8,77
- 106 + 75	58,18	11,81	47,06	0,44	3,95	6,92	38,64	17,90
-75	165,13	33,53	53,33	10,36	93,08	100,00	40,00	25,00
Total	492,54	100,00		11,13	100,00			

Table A-1.49: Test 10 A, Flow fraction 4 at 6.75 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 4 (Elutriation time: 6.35 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 355 + 212	153,93	31,25	46,00	0,26	0,91	0,91	7,69	83,28
- 212 + 150	60,24	12,23	39,22	0,21	0,74	1,65	28,57	27,14
- 150 + 106	55,05	11,18	42,16	0,81	2,85	4,50	24,69	41,43
- 106 + 75	58,18	11,81	47,06	4,02	14,13	18,63	14,00	70,25
-75	165,13	33,53	53,33	23,15	81,37	100,00	42,57	20,17
Total	492,54	100,00		28,45	100			

Table A-1.50: Test 10 A, Underflow

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
- 355 + 212	153,93	31,25	46,00	143,56	45,48	45,48	36,63	-20,36
- 212 + 150	60,24	12,23	39,22	45,63	14,45	59,93	42,57	8,56
- 150 + 106	55,05	11,18	42,16	44,45	14,08	74,01	36,00	-14,60
- 106 + 75	58,18	11,81	47,06	17,09	5,41	79,43	57,00	21,13
-75	165,13	33,53	53,33	64,95	20,57	100,00	60,00	12,50
Total	492,54	100,00		315,68	100,00			

Table A-1.51: Test 11 A, Flow fraction 1 at 1.5 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 1 (Elutriation time: 64.66 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 355 + 212	187,77	37,72	45,10	15,75	25,23	25,23	56,86	-26,09
- 212 + 150	63,54	12,77	31,37	7,37	11,81	37,03	60,00	-91,25
- 150 + 106	54,87	11,02	38,83	13,19	21,13	58,16	59,00	-51,93
- 106 + 75	54,31	10,91	39,81	10,99	17,60	75,76	59,41	-49,24
-75	137,26	27,58	57,28	15,13	24,24	100,00	55,88	2,44
Total	497,75	100,00		62,43	100,00			

Table A-1.52: Test 11 A, Flow fraction 2 at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 2 (Elutriation time: 11.93 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 355 + 212	187,77	37,72	45,10	0,35	1,66	1,66	34,29	23,98
- 212 + 150	63,54	12,77	31,37	0,39	1,85	3,51	43,59	-38,94
- 150 + 106	54,87	11,02	38,83	0,66	3,13	6,64	46,97	-20,95
- 106 + 75	54,31	10,91	39,81	0,99	4,69	11,33	49,49	-24,34
-75	137,26	27,58	57,28	18,70	88,67	100,00	46,00	19,69
Total	497,75	100,00		21,09	100,00			

Table A-1.53: Test 11 A, Flow fraction 3 at 4.75 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 3 (Elutriation time: 7.57 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 355 + 212	187,77	37,72	45,10	0,22	1,39	1,39	36,36	19,37
- 212 + 150	63,54	12,77	31,37	0,12	0,76	2,15	41,67	-32,81
- 150 + 106	54,87	11,02	38,83	0,16	1,01	3,15	50,00	-28,75
- 106 + 75	54,31	10,91	39,81	0,29	1,83	4,98	62,07	-55,93
-75	137,26	27,58	57,28	15,06	95,02	100,00	43,56	23,95
Total	497,75	100,00		15,85	100,00			

Table A-1.54: Test 11 A, Flow fraction 4 at 6.75 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 4 (Elutriation time: 9.50 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 355 + 212	187,77	37,72	45,10	0,08	0,34	0,34	12,50	72,28
- 212 + 150	63,54	12,77	31,37	0,06	0,25	0,59	33,33	-6,25
- 150 + 106	54,87	11,02	38,83	0,19	0,80	1,40	36,84	5,13
- 106 + 75	54,31	10,91	39,81	1,32	5,59	6,99	28,00	29,66
-75	137,26	27,58	57,28	21,96	93,01	100,00	43,00	24,93
Total	497,75	100,00		23,61	100,00			

Table A-1.55: Test 11 A, Underflow

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
- 355 + 212	187,77	37,72	45,10	148,39	42,66	42,66	40,59	-9,99
- 212 + 150	63,54	12,77	31,37	45,76	13,16	55,82	43,00	37,06
- 150 + 106	54,87	11,02	38,83	46,00	13,22	69,04	42,57	9,63
- 106 + 75	54,31	10,91	39,81	34,47	9,91	78,95	43,56	9,44
-75	137,26	27,58	57,28	73,21	21,05	100,00	60,40	5,44
Total	497,75	100,00		347,83	100,00			

Table A-1.56: Test 12 A, Flow fraction 1 at 1.5 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 1 (Elutriation time: 61.80 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 355 + 212	151,74	30,71	45,19	20,63	40,50	40,50	56,44	-24,88
- 212 + 150	56,61	11,46	37,25	7,09	13,92	54,42	54,46	-46,17
- 150 + 106	56,67	11,47	41,58	11,43	22,44	76,86	56,00	-34,67
- 106 + 75	57,68	11,67	43,69	7,47	14,66	91,52	54,46	-24,64
-75	171,45	34,70	53,47	4,32	8,48	100,00	54,46	-1,85
Total	494,15	100,00		50,94	100,00			

Table A-1.57: Test 12 A, Flow fraction 2 at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 2 (Elutriation time: 18.00 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 355 + 212	151,74	30,71	45,19	1,44	9,41	9,41	47,00	-4,00
- 212 + 150	56,61	11,46	37,25	0,96	6,27	15,69	46,88	-25,82
- 150 + 106	56,67	11,47	41,58	1,09	7,12	22,81	51,00	-22,64
- 106 + 75	57,68	11,67	43,69	2,41	15,75	38,56	48,51	-11,05
-75	171,45	34,70	53,47	9,40	61,44	100,00	46,53	12,96
Total	494,15	100,00		15,30	100,00			

Table A-1.58: Test 12 A, Flow fraction 3 at 4.75 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 3 (Elutriation time: 10.00 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 355 + 212	151,74	30,71	45,19	0,68	3,68	3,68	7,35	83,73
- 212 + 150	56,61	11,46	37,25	0,71	3,85	7,53	38,03	-2,08
- 150 + 106	56,67	11,47	41,58	0,58	3,14	10,67	32,76	21,22
- 106 + 75	57,68	11,67	43,69	1,58	8,56	19,23	36,00	17,60
-75	171,45	34,70	53,47	14,91	80,77	100,00	35,00	34,54
Total	494,15	100,00		18,46	100,00			

Table A-1.59: Test 12 A, Flow fraction 4 at 6.75 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 4 (Elutriation: 14.37 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 355 + 212	151,74	30,71	45,19	21,88	26,29	26,29	8,00	82,30
- 212 + 150	56,61	11,46	37,25	7,90	9,49	35,79	9,00	75,84
- 150 + 106	56,67	11,47	41,58	7,20	8,65	44,44	9,00	78,36
- 106 + 75	57,68	11,67	43,69	6,24	7,50	51,94	14,00	67,96
-75	171,45	34,70	53,47	39,99	48,06	100,00	38,00	28,93
Total	494,15	100,00		83,21	100,00			

Table A-1.60: Test 12 A, Underflow

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
- 355 + 212	151,74	30,71	45,19	117,65	39,60	39,60	49,50	9,54
- 212 + 150	56,61	11,46	37,25	39,10	13,16	52,76	44,55	19,59
- 150 + 106	56,67	11,47	41,58	38,48	12,95	65,72	40,59	-2,38
- 106 + 75	57,68	11,67	43,69	26,10	8,79	74,50	54,00	23,60
-75	171,45	34,70	53,47	75,75	25,50	100,00	65,35	22,22
Total	494,15	100,00		297,08	100,00			

Table A-1.61: Test 13 A, Flow fraction 1 at 1.5 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 1 (Elutriation time: 79.52 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 212 + 150	77,96	15,50	41,35	54,88	43,47	43,47	54,00	-30,60
- 150 + 106	127,93	25,44	39,45	20,28	16,06	59,54	51,49	-30,51
- 106 + 75	87,16	17,33	44,00	22,35	17,70	77,24	49,50	-12,51
-75	209,79	41,72	55,34	28,73	22,76	100,00	49,00	11,46
Total	502,84	100,00		126,24	100,00			

Table A-1.62: Test 13 A, Flow fraction 2 at 2.5 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 2 (Elutriation time: 20.25 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 212 + 150	77,96	15,50	41,35	0,36	1,48	1,48	58,33	-41,09
- 150 + 106	127,93	25,44	39,45	1,48	6,09	7,58	56,00	-41,95
- 106 + 75	87,16	17,33	44,00	3,95	16,26	23,84	58,00	-31,82
-75	209,79	41,72	55,34	24,29	100,00	123,84	49,02	11,42
Total	502,84	100,00		24,29	100,00			

Table A-1.63: Test 13 A, Flow fraction 3 at 4 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 3 (Elutriation time: 14.21 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 212 + 150	77,96	15,50	41,35	0,12	0,30	0,30	8,33	79,84
- 150 + 106	127,93	25,44	39,45	0,20	0,51	0,81	50,00	-26,74
- 106 + 75	87,16	17,33	44,00	1,18	2,98	3,79	25,00	43,18
-75	209,79	41,72	55,34	38,08	96,21	100,00	40,00	27,72
Total	502,84	100,00		39,58	100,00			

Table A-1.64: Test 13 A, Flow fraction 4 at 5.75 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 4 (Elutriation time: 12.11 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 212 + 150	77,96	15,50	41,35	0,30	0,71	0,71	26,67	35,50
- 150 + 106	127,93	25,44	39,45	0,70	1,66	2,37	14,29	63,79
- 106 + 75	87,16	17,33	44,00	7,21	17,11	19,48	13,00	70,45
-75	209,79	41,72	55,34	33,93	80,52	100,00	45,00	18,68
Total	502,84	100,00		42,14	100,00			

Table A-1.65: Test 13 A, Underflow

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
- 212 + 150	77,96	15,50	41,35	46,30	19,33	19,33	39,00	-5,67
- 150 + 106	127,93	25,44	39,45	76,60	31,98	51,31	40,00	1,40
- 106 + 75	87,16	17,33	44,00	42,01	17,54	68,84	46,00	4,55
-75	209,79	41,72	55,34	74,63	31,16	100,00	64,00	15,65
Total	502,84	100,00		239,54	100,00			

Table A-1.66: Test 14 A, Flow fraction 1 at 1.5 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 1 (Elutriation time: 80.00 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 212 + 150	60,03	11,96	42,57	0,91	1,25	1,25	47,25	-10,99
- 150 + 106	91,91	18,31	41,58	9,59	13,16	14,41	59,00	-41,88
- 106 + 75	83,40	16,62	46,60	15,50	21,27	35,68	60,40	-29,60
-75	266,63	53,12	54,46	46,87	64,32	100,00	53,00	2,67
Total	501,97	100,00		72,87	100,00			

Table A-1.67: Test 14 A, Flow fraction 2 at 2.5 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 2 (Elutriation time: 28.33 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 212 + 150	60,03	11,96	42,57	0,62	1,37	1,37	53,23	-25,02
- 150 + 106	91,91	18,31	41,58	1,38	3,04	4,41	45,00	-8,21
- 106 + 75	83,40	16,62	46,60	2,23	4,92	9,33	51,00	-9,44
-75	266,63	53,12	54,46	41,11	90,67	100,00	50,00	8,18
Total	501,97	100,00		45,34	100,00			

Table A-1.68: Test 14 A, Flow fraction 3 at 4 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 3 (Elutriation time: 13.08 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 212 + 150	60,03	11,96	42,57	0,13	0,35	0,35	38,46	9,66
- 150 + 106	91,91	18,31	41,58	0,29	0,79	1,14	24,14	41,95
- 106 + 75	83,40	16,62	46,60	0,57	1,54	2,68	42,11	9,65
-75	266,63	53,12	54,46	35,95	97,32	100,00	42,00	22,87
Total	501,97	100,00		36,94	100,00			

Table A-1.69: Test 14 A, Flow fraction 4 at 5.75 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 4 (Elutriation time: 9.27 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 212 + 150	60,03	11,96	42,57	0,12	0,36	0,36	66,67	-56,59
- 150 + 106	91,91	18,31	41,58	0,21	0,63	1,00	23,81	42,74
- 106 + 75	83,40	16,62	46,60	0,98	2,96	3,95	18,37	60,59
-75	266,63	53,12	54,46	31,82	96,05	100,00	45,00	17,36
Total	501,97	100,00		33,13	100,00			

Table A-1.70: Test 14 A, Underflow

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
- 212 + 150	60,03	11,96	42,57	50,98	17,74	17,74	45,54	6,98
- 150 + 106	91,91	18,31	41,58	75,46	26,26	44,00	45,00	8,21
- 106 + 75	83,40	16,62	46,60	54,14	18,84	62,84	43,00	-7,73
-75	266,63	53,12	54,46	106,79	37,16	100,00	60,40	10,91
Total	501,97	100,00		287,37	100,00			

Table A-1.71: Test 15 A, Flow fraction 1 at 1.5 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 1 (Elutriation time: 73.35 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 212 + 150	87,92	17,27	40,59	40,01	50,04	50,04	56,00	-37,95
- 150 + 106	99,68	19,59	40,78	21,71	27,15	77,19	57,00	-39,79
- 106 + 75	96,12	18,89	43,27	13,48	16,86	94,05	54,00	-24,80
-75	225,22	44,25	50,50	4,76	5,95	100,00	55,00	-8,92
Total	508,94	100,00		79,96	100,00			

Table A-1.72: Test 15 A, Flow fraction 2 at 2.5 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 2 (Elutriation time: 27.97 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 212 + 150	87,92	17,27	40,59	0,88	3,71	3,71	40,91	-0,78
- 150 + 106	99,68	19,59	40,78	1,22	5,14	8,85	42,00	-3,00
- 106 + 75	96,12	18,89	43,27	3,98	16,76	25,61	45,00	-4,00
-75	225,22	44,25	50,50	17,66	74,39	100,00	43,00	14,84
Total	508,94	100,00		23,74	100,00			

Table A-1.73: Test 15 A, Flow fraction 3 at 4 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 3 (Elutriation time: 20.00 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 212 + 150	87,92	17,27	40,59	0,58	2,04	2,04	58,62	-44,41
- 150 + 106	99,68	19,59	40,78	0,69	2,43	4,47	28,99	28,92
- 106 + 75	96,12	18,89	43,27	1,80	6,34	10,81	35,64	17,62
-75	225,22	44,25	50,50	25,33	89,19	100,00	35,00	30,69
Total	508,94	100,00		28,40	100,00			

Table A-1.74: Test 15 A, Flow fraction 4 at 5.75 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Flow fraction 4 (Elutriation time: 11.82 minutes)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
- 212 + 150	87,92	17,27	40,59	4,37	7,61	7,61	6,93	82,93
- 150 + 106	99,68	19,59	40,78	6,66	11,60	19,22	6,93	83,00
- 106 + 75	96,12	18,89	43,27	6,23	10,86	30,07	9,00	79,20
-75	225,22	44,25	50,50	40,13	69,93	100,00	33,66	33,33
Total	508,94	100,00		57,39	100,00			

Table A-1.75: Test 15 A, Underflow

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
- 212 + 150	87,92	17,27	40,59	53,56	18,10	18,10	44,00	8,39
- 150 + 106	99,68	19,59	40,78	64,16	21,68	39,78	43,00	5,45
- 106 + 75	96,12	18,89	43,27	45,66	15,43	55,21	45,54	5,26
-75	225,22	44,25	50,50	132,52	44,79	100,00	63,00	24,76
Total	508,94	100,00		295,90	100,00			

A-2: Primary batch tests data

Table A-2.1: Test 1, 0-15 minutes, 6 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	47,30	9,66	60,41	0,60	1,82	1,82	47,50	21,37
- 600 + 500	21,27	4,34	59,46	0,47	1,42	3,24	45,51	23,45
- 500 + 355	42,81	8,74	60,95	1,38	4,19	7,42	46,94	22,99
- 355 + 212	95,70	19,54	56,58	3,36	10,21	17,63	43,37	23,33
- 212 + 150	87,88	17,95	59,84	5,43	16,51	34,14	51,19	14,46
- 150 + 106	64,61	13,19	58,05	5,63	17,12	51,26	49,82	14,17
- 106 + 75	69,95	14,28	58,47	4,01	12,19	63,45	49,60	15,17
-75	60,17	12,29	58,61	12,01	36,55	100,00	48,82	16,71
Total	489,68	100,00		32,88	100,00			

Table A-2.2: Test 1, 15-30 minutes, 6 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	47,30	9,66	60,41	1,35	3,64	3,64	60,10	0,53
- 600 + 500	21,27	4,34	59,46	0,24	0,65	4,29	54,16	8,90
- 500 + 355	42,81	8,74	60,95	0,29	0,79	5,08	50,93	16,44
- 355 + 212	95,70	19,54	56,58	3,52	9,48	14,56	58,53	-3,46
- 212 + 150	87,88	17,95	59,84	14,04	37,84	52,39	59,98	-0,23
- 150 + 106	64,61	13,19	58,05	3,32	8,94	61,33	60,39	-4,03
- 106 + 75	69,95	14,28	58,47	5,23	14,10	75,43	59,35	-1,50
-75	60,17	12,29	58,61	9,12	24,57	100,00	56,43	3,72
Total	489,68	100,00		37,12	100,00			

Table A-2.3: Test 1, 30-45 minutes, 6 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	47,30	9,66	60,41	1,89	10,53	10,53	61,85	-2,37
- 600 + 500	21,27	4,34	59,46	0,32	1,77	12,30	61,60	-3,61
- 500 + 355	42,81	8,74	60,95	0,63	3,50	15,80	62,50	-2,55
- 355 + 212	95,70	19,54	56,58	1,69	9,40	25,20	62,55	-10,57
- 212 + 150	87,88	17,95	59,84	6,48	36,13	61,32	61,92	-3,47
- 150 + 106	64,61	13,19	58,05	1,95	10,86	72,18	58,69	-1,11
- 106 + 75	69,95	14,28	58,47	3,85	21,47	93,66	61,38	-4,98
-75	60,17	12,29	58,61	1,14	6,34	100,00	56,36	3,84
Total	489,68	100,00		17,94	100,00			

Table A-2.4: Test 1, 45-60 minutes, 6 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	47,30	9,66	60,41	0,02	0,44	0,44	82,25	-36,14
- 600 + 500	21,27	4,34	59,46	0,02	0,44	0,88	61,85	-4,03
- 500 + 355	42,81	8,74	60,95	0,04	0,88	1,76	58,40	4,17
- 355 + 212	95,70	19,54	56,58	0,20	4,73	6,49	55,81	1,36
- 212 + 150	87,88	17,95	59,84	0,33	7,74	14,23	56,91	4,91
- 150 + 106	64,61	13,19	58,05	0,45	10,66	24,89	56,54	2,60
- 106 + 75	69,95	14,28	58,47	1,05	24,68	49,57	57,99	0,82
-75	60,17	12,29	58,61	2,15	50,43	100,00	51,14	12,74
Total	489,68	100,00		4,26	100,00			

Table A-2.5: Test 1, Underflow, 6 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	47,30	9,66	60,41	26,71	11,84	11,84	60,74	0,54
- 600 + 500	21,27	4,34	59,46	11,34	5,03	16,87	59,94	0,81
- 500 + 355	42,81	8,74	60,95	24,07	10,67	27,55	61,09	0,23
- 355 + 212	95,70	19,54	56,58	50,27	22,29	49,84	61,27	7,66
- 212 + 150	87,88	17,95	59,84	22,51	9,98	59,82	55,16	-8,50
- 150 + 106	64,61	13,19	58,05	25,58	11,34	71,16	52,21	-11,18
- 106 + 75	69,95	14,28	58,47	20,01	8,87	80,04	56,76	-3,03
-75	60,17	12,29	58,61	45,02	19,96	100,00	62,49	6,21
Total	489,68	100,00		225,52	100,00			

Table A-2.6: Test 2, 0-15 minutes, 6 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	46,64	9,37	57,95	0,95	0,99	0,99	53,26	8,10
- 600 + 500	20,99	4,21	60,38	0,31	0,33	1,32	45,00	25,49
- 500 + 355	43,38	8,71	59,16	0,65	0,68	2,00	43,55	26,38
- 355 + 212	99,47	19,98	58,60	15,63	16,39	18,39	57,45	1,97
- 212 + 150	106,43	21,38	57,21	24,59	25,77	44,16	55,44	3,10
- 150 + 106	64,59	12,97	59,01	9,65	10,11	54,27	52,72	10,65
- 106 + 75	63,04	12,66	57,49	18,21	19,09	73,36	50,25	12,59
-75	53,38	10,72	57,82	25,41	26,64	100,00	53,68	7,16
Total	497,92	100,00		95,40	100,00			

Table A-2.7: Test 2, 15-30 minutes, 6 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	46,64	9,37	57,95	0,07	0,77	0,77	45,68	21,18
- 600 + 500	20,99	4,21	60,38	0,07	0,80	1,57	49,65	17,78
- 500 + 355	43,38	8,71	59,16	0,22	2,47	4,04	50,93	13,92
- 355 + 212	99,47	19,98	58,60	1,97	22,10	26,14	56,78	3,11
- 212 + 150	106,43	21,38	57,21	1,33	14,89	41,03	57,59	-0,66
- 150 + 106	64,59	12,97	59,01	1,11	12,42	53,45	57,26	2,97
- 106 + 75	63,04	12,66	57,49	1,79	20,09	73,54	57,95	-0,80
-75	53,38	10,72	57,82	2,36	26,46	100,00	55,48	4,05
Total	497,92	100,00		8,93	100,00			

Table A-2.8: Test 2, 30-45 minutes, 6 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	46,64	9,37	57,95	0,02	1,05	1,05	65,98	-13,85
- 600 + 500	20,99	4,21	60,38	0,02	0,75	1,81	75,58	-25,17
- 500 + 355	43,38	8,71	59,16	0,04	1,73	3,54	48,35	18,27
- 355 + 212	99,47	19,98	58,60	0,11	4,66	8,20	35,40	39,59
- 212 + 150	106,43	21,38	57,21	0,11	4,92	13,11	42,17	26,29
- 150 + 106	64,59	12,97	59,01	0,22	9,48	22,59	52,19	11,55
- 106 + 75	63,04	12,66	57,49	0,36	15,94	38,54	57,79	-0,53
-75	53,38	10,72	57,82	1,40	61,46	100,00	54,83	5,18
Total	497,92	100,00		2,29	100,00			

Table A-2.9: Test 2, 45-60 minutes, 6 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	46,64	9,37	57,95	0,02	1,67	1,67	62,26	-7,45
- 600 + 500	20,99	4,21	60,38	0,02	1,20	2,87	48,03	20,47
- 500 + 355	43,38	8,71	59,16	0,03	2,22	5,09	51,77	12,49
- 355 + 212	99,47	19,98	58,60	0,06	5,01	10,10	43,62	25,56
- 212 + 150	106,43	21,38	57,21	0,07	5,68	15,78	50,00	12,61
- 150 + 106	64,59	12,97	59,01	0,12	9,46	25,24	54,71	7,28
- 106 + 75	63,04	12,66	57,49	0,17	13,23	38,47	55,96	2,66
-75	53,38	10,72	57,82	0,78	61,53	100,00	54,88	5,08
Total	497,92	100,00		1,27	100,00			

Table A-2.10: Test 2, Underflow, 6 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	46,64	9,37	57,95	31,76	10,81	10,81	61,71	6,10
- 600 + 500	20,99	4,21	60,38	16,34	5,56	16,37	60,41	0,04
- 500 + 355	43,38	8,71	59,16	33,15	11,28	27,66	62,07	4,68
- 355 + 212	99,47	19,98	58,60	57,37	19,53	47,19	61,90	5,32
- 212 + 150	106,43	21,38	57,21	29,52	10,05	57,23	58,18	1,66
- 150 + 106	64,59	12,97	59,01	31,60	10,75	67,99	53,20	-10,91
- 106 + 75	63,04	12,66	57,49	33,02	11,24	79,23	57,71	0,38
-75	53,38	10,72	57,82	61,03	20,77	100,00	62,78	7,90
Total	497,92	100,00		293,79	100,00			

Table A-2.11: Test 3, 0-15 minutes, 6 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	48,86	9,74	58,96	0,47	0,60	0,60	55,44	5,97
- 600 + 500	21,95	4,38	59,14	0,32	0,40	1,00	52,72	10,85
- 500 + 355	44,30	8,83	58,40	0,38	0,49	1,49	44,94	23,05
- 355 + 212	96,64	19,26	58,76	18,15	23,03	24,52	58,42	0,57
- 212 + 150	114,89	22,90	58,42	23,55	29,89	54,41	56,97	2,48
- 150 + 106	49,46	9,86	58,06	12,74	16,17	70,59	56,25	3,12
- 106 + 75	78,09	15,57	59,67	8,97	11,38	81,96	55,73	6,60
-75	47,47	9,46	58,30	14,21	18,04	100,00	54,28	6,90
Total	501,66	100,00		78,80	100,00			

Table A-2.12: Test 3, 15-30 minutes, 6 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	48,86	9,74	58,96	0,28	1,67	1,67	54,53	7,51
- 600 + 500	21,95	4,38	59,14	0,11	0,63	2,30	43,04	27,22
- 500 + 355	44,30	8,83	58,40	0,20	1,19	3,49	29,73	49,08
- 355 + 212	96,64	19,26	58,76	0,97	5,72	9,21	48,93	16,74
- 212 + 150	114,89	22,90	58,42	1,94	11,39	20,60	59,25	-1,41
- 150 + 106	49,46	9,86	58,06	2,45	14,41	35,01	61,27	-5,53
- 106 + 75	78,09	15,57	59,67	5,80	34,09	69,10	60,97	-2,19
-75	47,47	9,46	58,30	5,26	30,90	100,00	55,33	5,09
Total	501,66	100,00		17,02	100,00			

Table A-2.13: Test 3, 30-45 minutes, 6 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	48,86	9,74	58,96	0,00	0,17	0,17	46,15	21,72
- 600 + 500	21,95	4,38	59,14	0,04	2,81	2,98	53,00	10,39
- 500 + 355	44,30	8,83	58,40	0,07	4,69	7,66	67,72	-15,97
- 355 + 212	96,64	19,26	58,76	0,15	9,89	17,55	65,47	-11,41
- 212 + 150	114,89	22,90	58,42	0,11	7,02	24,58	72,65	-24,35
- 150 + 106	49,46	9,86	58,06	0,15	9,51	34,09	71,24	-22,71
- 106 + 75	78,09	15,57	59,67	0,22	14,01	48,10	73,04	-22,40
-75	47,47	9,46	58,30	0,80	51,90	100,00	71,28	-22,27
Total	501,66	100,00		1,55	100,00			

Table A-2.14: Test 3, 45-60 minutes, 6 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	48,86	9,74	58,96	0,08	5,97	5,97	86,19	-46,18
- 600 + 500	21,95	4,38	59,14	0,05	4,22	10,19	93,25	-57,67
- 500 + 355	44,30	8,83	58,40	0,09	7,06	17,25	84,96	-45,49
- 355 + 212	96,64	19,26	58,76	0,12	9,44	26,69	86,99	-48,03
- 212 + 150	114,89	22,90	58,42	0,07	5,72	32,41	75,76	-29,68
- 150 + 106	49,46	9,86	58,06	0,07	5,42	37,83	75,44	-29,94
- 106 + 75	78,09	15,57	59,67	0,08	6,14	43,97	71,48	-19,80
-75	47,47	9,46	58,30	0,71	56,03	100,00	55,95	4,02
Total	501,66	100,00		1,26	100,00			

Table A-2.15: Test 3, Underflow, 6 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	48,86	9,74	58,96	32,18	10,18	10,18	62,73	6,01
- 600 + 500	21,95	4,38	59,14	18,37	5,81	15,99	60,38	2,06
- 500 + 355	44,30	8,83	58,40	35,25	11,15	27,14	63,45	7,96
- 355 + 212	96,64	19,26	58,76	59,36	18,78	45,92	61,95	5,15
- 212 + 150	114,89	22,90	58,42	31,03	9,81	55,73	58,38	-0,07
- 150 + 106	49,46	9,86	58,06	36,02	11,40	67,13	54,24	-7,04
- 106 + 75	78,09	15,57	59,67	38,36	12,14	79,26	58,85	-1,39
-75	47,47	9,46	58,30	65,55	20,74	100,00	63,55	8,26
Total	501,66	100,00		316,13				

Table A-2.16: Test 4, 0-15 minutes, 8 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	46,08	9,26	61,49	2,95	5,93	5,93	59,57	3,12
- 600 + 500	21,10	4,24	61,66	0,46	0,93	6,86	59,38	3,69
- 500 + 355	43,87	8,82	61,34	1,00	2,01	8,87	58,58	4,50
- 355 + 212	99,21	19,94	60,34	16,33	32,79	41,66	58,89	2,39
- 212 + 150	129,08	25,95	59,32	18,57	37,28	78,94	58,05	2,15
- 150 + 106	48,15	9,68	59,58	3,41	6,85	85,79	54,65	8,28
- 106 + 75	57,40	11,54	59,90	4,69	9,42	95,21	55,78	6,89
-75	52,61	10,57	60,28	2,39	4,79	100,00	52,81	12,39
Total	497,50	100,00		49,81	100,00			

Table A-2.17: Test 4, 15-30 minutes, 8 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	46,08	9,26	61,49	3,98	15,18	15,18	60,09	2,28
- 600 + 500	21,10	4,24	61,66	0,48	1,85	17,03	61,83	-0,29
- 500 + 355	43,87	8,82	61,34	0,80	3,05	20,08	61,69	-0,58
- 355 + 212	99,21	19,94	60,34	1,97	7,50	27,58	61,44	-1,83
- 212 + 150	129,08	25,95	59,32	9,13	34,82	62,40	60,28	-1,62
- 150 + 106	48,15	9,68	59,58	3,45	13,16	75,56	60,09	-0,85
- 106 + 75	57,40	11,54	59,90	3,61	13,76	89,32	59,15	1,25
-75	52,61	10,57	60,28	2,80	10,68	100,00	55,79	7,44
Total	497,50	100,00		26,21	100,00			

Table A-2.18: Test 4, 30-45 minutes, 8 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	46,08	9,26	61,49	0,06	0,97	0,97	62,24	-1,22
- 600 + 500	21,10	4,24	61,66	0,04	0,59	1,56	63,25	-2,59
- 500 + 355	43,87	8,82	61,34	0,07	1,06	2,62	55,30	9,85
- 355 + 212	99,21	19,94	60,34	0,19	2,99	5,61	61,09	-1,25
- 212 + 150	129,08	25,95	59,32	0,36	5,51	11,12	58,51	1,38
- 150 + 106	48,15	9,68	59,58	0,36	5,59	16,71	59,09	0,83
- 106 + 75	57,40	11,54	59,90	1,30	20,08	36,79	58,23	2,79
-75	52,61	10,57	60,28	4,11	63,21	100,00	51,02	15,36
Total	497,50	100,00		6,50	100,00			

Table A-2.19: Test 4, 45-60 minutes, 8 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	46,08	9,26	61,49	0,04	2,38	2,38	91,07	-48,10
- 600 + 500	21,10	4,24	61,66	0,01	0,86	3,23	89,66	-45,41
- 500 + 355	43,87	8,82	61,34	0,04	2,20	5,43	88,98	-45,06
- 355 + 212	99,21	19,94	60,34	0,05	2,94	8,37	42,48	29,59
- 212 + 150	129,08	25,95	59,32	0,03	1,76	10,14	65,89	-11,06
- 150 + 106	48,15	9,68	59,58	0,06	3,71	13,84	61,15	-2,62
- 106 + 75	57,40	11,54	59,90	0,21	12,50	26,34	62,65	-4,59
-75	52,61	10,57	60,28	1,25	73,66	100,00	49,24	18,30
Total	497,50	100,00		1,69	100,00			

Table A-2.20: Test 4, Underflow, 8 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	46,08	9,26	61,49	35,14	9,45	9,45	62,58	1,74
- 600 + 500	21,10	4,24	61,66	18,09	4,86	14,31	61,88	0,36
- 500 + 355	43,87	8,82	61,34	37,76	10,15	24,46	60,69	-1,07
- 355 + 212	99,21	19,94	60,34	72,60	19,52	43,98	57,87	-4,27
- 212 + 150	129,08	25,95	59,32	90,90	24,44	68,42	56,95	-4,16
- 150 + 106	48,15	9,68	59,58	36,78	9,89	78,31	54,93	-8,47
- 106 + 75	57,40	11,54	59,90	42,82	11,51	89,82	54,03	-10,87
-75	52,61	10,57	60,28	37,86	10,18	100,00	61,41	1,84
Total	497,50	100,00		35,14	100,00			

Table A-2.21: Test 5, 0-15 minutes, 8 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	45,57	9,15	59,55	5,95	11,13	11,13	58,36	2,01
- 600 + 500	21,10	4,23	60,71	0,81	1,51	12,64	57,90	4,62
- 500 + 355	44,47	8,93	59,90	3,94	7,38	20,02	58,97	1,57
- 355 + 212	91,71	18,41	59,98	7,32	13,70	33,71	57,95	3,39
- 212 + 150	126,05	25,30	59,03	16,46	30,80	64,51	57,75	2,18
- 150 + 106	50,22	10,08	59,03	5,96	11,14	75,66	56,25	4,72
- 106 + 75	59,20	11,88	57,30	7,09	13,25	88,91	56,74	0,98
-75	59,83	12,01	57,68	5,93	11,09	100,00	55,47	3,83
Total	498,14	100,00		53,45	100,00			

Table A-2.22: Test 5, 15-30 minutes, 8 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	45,57	9,15	59,55	11,63	48,15	48,15	59,12	0,73
- 600 + 500	21,10	4,23	60,71	0,98	4,04	52,19	60,18	0,86
- 500 + 355	44,47	8,93	59,90	0,84	3,49	55,68	59,93	-0,05
- 355 + 212	91,71	18,41	59,98	2,04	8,45	64,13	60,42	-0,72
- 212 + 150	126,05	25,30	59,03	3,04	12,58	76,70	59,49	-0,77
- 150 + 106	50,22	10,08	59,03	2,93	12,12	88,82	59,87	-1,42
- 106 + 75	59,20	11,88	57,30	1,46	6,04	94,86	58,38	-1,88
-75	59,83	12,01	57,68	1,24	5,14	100,00	55,83	3,20
Total	498,14	100,00		24,16	100,00			

Table A-2.23: Test 5, 30-45 minutes, 8 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	45,57	9,15	59,55	0,13	2,80	2,80	69,37	-16,48
- 600 + 500	21,10	4,23	60,71	0,06	1,26	4,06	61,30	-0,97
- 500 + 355	44,47	8,93	59,90	0,11	2,28	6,34	67,69	-13,00
- 355 + 212	91,71	18,41	59,98	0,34	7,23	13,57	74,04	-23,44
- 212 + 150	126,05	25,30	59,03	0,57	12,00	25,57	72,13	-22,18
- 150 + 106	50,22	10,08	59,03	0,65	13,66	39,23	62,50	-5,88
- 106 + 75	59,20	11,88	57,30	0,88	18,55	57,78	57,67	-0,64
-75	59,83	12,01	57,68	2,01	42,22	100,00	47,94	16,88
Total	498,14	100,00		4,76	100,00			

Table A-2.24: Test 5, 45-60 minutes, 8 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	45,57	9,15	59,55	0,01	0,53	0,53	37,78	36,57
- 600 + 500	21,10	4,23	60,71	0,00	0,19	0,72	39,39	35,11
- 500 + 355	44,47	8,93	59,90	0,01	0,62	1,35	49,06	18,11
- 355 + 212	91,71	18,41	59,98	0,04	2,43	3,78	43,10	28,15
- 212 + 150	126,05	25,30	59,03	0,10	5,63	9,41	51,10	13,44
- 150 + 106	50,22	10,08	59,03	0,06	3,65	13,07	51,94	12,02
- 106 + 75	59,20	11,88	57,30	0,22	12,96	26,02	54,84	4,29
-75	59,83	12,01	57,68	1,26	73,98	100,00	43,58	24,44
Total	498,14	100,00		1,70	100,00			

Table A-2.25: Test 5, Underflow, 8 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	45,57	9,15	59,55	27,01	6,72	6,72	63,40	6,07
- 600 + 500	21,10	4,23	60,71	18,67	4,65	11,37	62,55	2,95
- 500 + 355	44,47	8,93	59,90	38,38	9,56	20,93	61,76	3,00
- 355 + 212	91,71	18,41	59,98	79,50	19,79	40,72	58,83	-1,96
- 212 + 150	126,05	25,30	59,03	102,71	25,57	66,29	58,15	-1,52
- 150 + 106	50,22	10,08	59,03	39,40	9,81	76,10	56,44	-4,59
- 106 + 75	59,20	11,88	57,30	48,07	11,97	88,07	55,17	-3,86
-75	59,83	12,01	57,68	47,91	11,93	100,00	62,56	7,80
Total	498,14	100,00		401,64	100,00			

Table A-2.26: Test 6, 0-15 minutes, 8 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	49,02	9,83	60,66	7,35	12,51	12,51	59,15	2,49
- 600 + 500	21,11	4,23	59,84	0,86	1,46	13,97	59,05	1,32
- 500 + 355	43,91	8,81	59,88	3,06	5,21	19,17	59,75	0,22
- 355 + 212	93,58	18,77	59,51	16,68	28,38	47,56	59,22	0,47
- 212 + 150	88,16	17,68	58,76	13,76	23,42	70,97	58,33	0,75
- 150 + 106	51,70	10,37	59,34	6,11	10,39	81,36	57,59	2,95
- 106 + 75	72,25	14,49	58,29	6,05	10,30	91,66	56,89	2,40
-75	78,90	15,82	58,15	4,90	8,34	100,00	55,62	4,35
Total	498,63	100,00		58,78	100,00			

Table A-2.27: Test 6, 15-30 minutes, 8 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	49,02	9,83	60,66	2,64	13,75	13,75	58,76	3,13
- 600 + 500	21,11	4,23	59,84	0,20	1,06	14,82	57,72	3,54
- 500 + 355	43,91	8,81	59,88	0,52	2,70	17,52	58,62	2,11
- 355 + 212	93,58	18,77	59,51	2,04	10,66	28,18	57,91	2,69
- 212 + 150	88,16	17,68	58,76	3,06	15,96	44,15	58,78	-0,03
- 150 + 106	51,70	10,37	59,34	0,69	3,59	47,74	58,33	1,70
- 106 + 75	72,25	14,49	58,29	4,50	23,49	71,23	58,24	0,10
-75	78,90	15,82	58,15	5,52	28,77	100,00	53,82	7,46
Total	498,63	100,00		19,17	100,00			

Table A-2.28: Test 6, 30-45 minutes, 8 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	49,02	9,83	60,66	0,01	0,21	0,21	54,72	9,80
- 600 + 500	21,11	4,23	59,84	0,01	0,32	0,54	54,32	9,22
- 500 + 355	43,91	8,81	59,88	0,01	0,55	1,08	51,47	14,04
- 355 + 212	93,58	18,77	59,51	0,18	7,25	8,33	57,02	4,17
- 212 + 150	88,16	17,68	58,76	0,31	12,30	20,63	59,01	-0,42
- 150 + 106	51,70	10,37	59,34	0,22	8,94	29,57	57,20	3,61
- 106 + 75	72,25	14,49	58,29	0,54	21,51	51,08	53,09	8,92
-75	78,90	15,82	58,15	1,22	48,92	100,00	49,77	14,42
Total	498,63	100,00		2,49	100,00			

Table A-2.29: Test 6, 45-60 minutes, 8 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	49,02	9,83	60,66	0,00	0,00	0,00	0,00	100,00
- 600 + 500	21,11	4,23	59,84	0,00	0,00	0,00	0,00	100,00
- 500 + 355	43,91	8,81	59,88	0,00	0,09	0,09	41,67	30,41
- 355 + 212	93,58	18,77	59,51	0,01	0,87	0,96	51,72	13,08
- 212 + 150	88,16	17,68	58,76	0,04	3,02	3,98	52,61	10,48
- 150 + 106	51,70	10,37	59,34	0,08	5,66	9,65	54,57	8,04
- 106 + 75	72,25	14,49	58,29	0,08	6,11	15,76	52,39	10,12
-75	78,90	15,82	58,15	1,12	84,24	100,00	44,92	22,76
Total	498,63	100,00		1,33	100,00			

Table A-2.30: Test 6, Underflow, 8 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	49,02	9,83	60,66	37,86	9,36	9,36	64,03	5,27
- 600 + 500	21,11	4,23	59,84	19,44	4,81	14,17	62,75	4,64
- 500 + 355	43,91	8,81	59,88	39,10	9,67	23,84	62,38	4,01
- 355 + 212	93,58	18,77	59,51	72,42	17,91	41,75	59,03	-0,80
- 212 + 150	88,16	17,68	58,76	68,85	17,03	58,78	58,34	-0,74
- 150 + 106	51,70	10,37	59,34	43,27	10,70	69,48	57,35	-3,47
- 106 + 75	72,25	14,49	58,29	59,25	14,65	84,14	55,28	-5,45
-75	78,90	15,82	58,15	64,15	15,86	100,00	63,04	7,76
Total	498,63	100,00		404,34	100,00			

Table A-2.31: Test 7, 0-15 minutes, 12 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	47,03	9,45	61,22	7,23	17,26	17,26	58,90	3,80
- 600 + 500	21,91	4,40	59,05	0,95	2,28	19,54	58,36	1,16
- 500 + 355	43,95	8,83	59,13	1,68	4,00	23,55	56,29	4,79
- 355 + 212	103,13	20,72	59,61	10,55	25,19	48,74	57,73	3,15
- 212 + 150	113,51	22,80	59,22	8,79	20,98	69,72	57,95	2,13
- 150 + 106	56,05	11,26	58,22	2,49	5,94	75,66	55,72	4,30
- 106 + 75	77,48	15,56	59,66	6,21	14,84	90,51	58,64	1,71
-75	34,74	6,98	58,92	3,98	9,49	100,00	58,03	1,50
Total	497,79	100,00		41,87	100,00			

Table A-2.32: Test 7, 15-30 minutes, 12 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	47,03	9,45	61,22	1,34	8,12	8,12	58,50	4,45
- 600 + 500	21,91	4,40	59,05	0,30	1,81	9,94	58,29	1,29
- 500 + 355	43,95	8,83	59,13	1,71	10,31	20,25	53,09	10,21
- 355 + 212	103,13	20,72	59,61	1,98	11,96	32,21	57,30	3,87
- 212 + 150	113,51	22,80	59,22	2,17	13,10	45,31	58,54	1,15
- 150 + 106	56,05	11,26	58,22	2,12	12,81	58,12	60,07	-3,17
- 106 + 75	77,48	15,56	59,66	2,20	13,33	71,45	59,25	0,69
-75	34,74	6,98	58,92	4,72	28,55	100,00	55,91	5,10
Total`	497,79	100,00		16,54	100,00			

Table A-2.33: Test 7, 30-45 minutes, 12 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	47,03	9,45	61,22	0,34	4,99	4,99	51,94	15,16
- 600 + 500	21,91	4,40	59,05	0,15	2,19	7,18	50,53	14,42
- 500 + 355	43,95	8,83	59,13	0,24	3,56	10,74	49,82	15,75
- 355 + 212	103,13	20,72	59,61	0,64	9,34	20,08	52,54	11,86
- 212 + 150	113,51	22,80	59,22	0,41	5,99	26,06	53,95	8,90
- 150 + 106	56,05	11,26	58,22	0,77	11,23	37,29	55,34	4,94
- 106 + 75	77,48	15,56	59,66	1,05	15,30	52,59	52,62	11,80
-75	34,74	6,98	58,92	3,25	47,41	100,00	47,53	19,32
Total	497,79	100,00		6,86	100,00			

Table A-2.34: Test 7, 45-60 minutes, 12 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	47,03	9,45	61,22	0,01	0,17	0,17	57,32	6,38
- 600 + 500	21,91	4,40	59,05	0,01	0,20	0,37	38,54	34,73
- 500 + 355	43,95	8,83	59,13	0,04	0,90	1,28	48,73	17,59
- 355 + 212	103,13	20,72	59,61	0,33	6,86	8,14	53,29	10,60
- 212 + 150	113,51	22,80	59,22	0,35	7,29	15,43	55,09	6,96
- 150 + 106	56,05	11,26	58,22	0,27	5,55	20,98	56,96	2,16
- 106 + 75	77,48	15,56	59,66	0,72	15,10	36,08	55,07	7,70
-75	34,74	6,98	58,92	3,06	63,92	100,00	44,94	23,73
Total	497,79	100,00		4,79	100,00			

Table A-2.35: Test 7, Underflow, 12 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	**Remains (Underflow)**				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	47,03	9,45	61,22	35,06	8,91	8,91	62,63	2,25
- 600 + 500	21,91	4,40	59,05	18,85	4,79	13,70	62,31	5,24
- 500 + 355	43,95	8,83	59,13	37,05	9,42	23,12	60,50	2,26
- 355 + 212	103,13	20,72	59,61	82,46	20,96	44,07	59,86	0,43
- 212 + 150	113,51	22,80	59,22	93,65	23,80	67,87	59,21	-0,01
- 150 + 106	56,05	11,26	58,22	46,38	11,79	79,65	61,04	4,62
- 106 + 75	77,48	15,56	59,66	61,91	15,73	95,39	60,84	1,95
-75	34,74	6,98	58,92	18,16	4,61	100,00	67,03	12,10
Total	497,79	100,00		393,51	100,00			

Table A-2.36: Test 8, 0-15 minutes, 12 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	**0-15 minutes**				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	45,83	9,15	59,22	5,13	11,31	11,31	58,55	1,12
- 600 + 500	21,36	4,26	58,73	0,53	1,17	12,49	56,43	3,93
- 500 + 355	42,11	8,41	59,95	1,36	3,00	15,48	55,47	7,47
- 355 + 212	87,83	17,54	59,50	10,65	23,49	38,97	59,04	0,77
- 212 + 150	122,85	24,53	58,15	15,87	35,00	73,97	57,38	1,33
- 150 + 106	73,42	14,66	58,91	3,24	7,15	81,12	55,69	5,46
- 106 + 75	60,50	12,08	57,86	4,58	10,09	91,21	55,99	3,22
-75	46,96	9,38	57,65	3,99	8,79	100,00	56,12	2,64
Total	500,84	100,00		45,34	100,00			

Table A-2.37: Test 8, 15-30 minutes, 12 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	45,83	9,15	59,22	5,21	27,35	27,35	57,90	2,23
- 600 + 500	21,36	4,26	58,73	0,48	2,53	29,88	58,01	1,23
- 500 + 355	42,11	8,41	59,95	0,59	3,10	32,98	58,05	3,17
- 355 + 212	87,83	17,54	59,50	3,27	17,16	50,14	57,77	2,91
- 212 + 150	122,85	24,53	58,15	1,31	6,88	57,02	58,59	-0,75
- 150 + 106	73,42	14,66	58,91	2,17	11,39	68,41	58,94	-0,06
- 106 + 75	60,50	12,08	57,86	3,01	15,80	84,21	57,04	1,41
-75	46,96	9,38	57,65	3,01	15,79	100,00	54,26	5,87
Total	500,84	100,00		19,05	100,00			

Table A-2.38: Test 8, 30-45 minutes, 12 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	45,83	9,15	59,22	0,20	2,70	2,70	51,30	13,37
- 600 + 500	21,36	4,26	58,73	0,13	1,81	4,50	50,19	14,55
- 500 + 355	42,11	8,41	59,95	0,13	1,82	6,32	51,70	13,76
- 355 + 212	87,83	17,54	59,50	0,47	6,46	12,78	56,44	5,14
- 212 + 150	122,85	24,53	58,15	0,35	4,77	17,55	56,22	3,31
- 150 + 106	73,42	14,66	58,91	1,07	14,71	32,26	53,60	9,02
- 106 + 75	60,50	12,08	57,86	1,81	24,88	57,14	51,96	10,19
-75	46,96	9,38	57,65	3,12	42,86	100,00	46,36	19,57
Total	500,84	100,00		7,27	100,00			

Table A-2.39: Test 8, 45-60 minutes, 12 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	45,83	9,15	59,22	0,04	0,88	0,88	37,11	37,33
- 600 + 500	21,36	4,26	58,73	0,01	0,24	1,11	53,68	8,60
- 500 + 355	42,11	8,41	59,95	0,02	0,45	1,56	37,36	37,68
- 355 + 212	87,83	17,54	59,50	0,07	1,81	3,37	49,73	16,43
- 212 + 150	122,85	24,53	58,15	0,15	3,66	7,04	53,36	8,25
- 150 + 106	73,42	14,66	58,91	0,13	3,16	10,19	52,71	10,51
- 106 + 75	60,50	12,08	57,86	0,97	24,15	34,35	52,14	9,88
-75	46,96	9,38	57,65	2,64	65,65	100,00	46,22	19,82
Total	500,84	100,00		4,03	100,00			

Table A-2.40: Test 8, Underflow, 12 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	45,83	9,15	59,22	32,44	8,29	8,29	62,39	5,08
- 600 + 500	21,36	4,26	58,73	18,58	4,75	13,04	61,78	4,93
- 500 + 355	42,11	8,41	59,95	36,81	9,41	22,45	59,60	-0,60
- 355 + 212	87,83	17,54	59,50	67,50	17,26	39,71	59,59	0,15
- 212 + 150	122,85	24,53	58,15	96,76	24,74	64,45	59,95	3,00
- 150 + 106	73,42	14,66	58,91	61,46	15,71	80,16	60,45	2,55
- 106 + 75	60,50	12,08	57,86	46,12	11,79	91,95	60,45	4,29
-75	46,96	9,38	57,65	31,47	8,05	100,00	66,99	13,95
Total	500,84	100,00		391,15	100,00			

Table A-2.41: Test 9, 0-15 minutes, 12 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	57,80	11,55	59,91	8,95	23,48	23,48	59,49	0,70
- 600 + 500	25,18	5,03	59,63	1,12	2,94	26,42	59,32	0,52
- 500 + 355	51,89	10,37	58,84	1,47	3,85	30,27	57,89	1,61
- 355 + 212	108,88	21,75	59,00	5,54	14,52	44,79	58,71	0,49
- 212 + 150	98,13	19,60	59,51	13,89	36,42	81,21	59,19	0,53
- 150 + 106	55,88	11,16	59,24	3,97	10,40	91,61	58,63	1,03
- 106 + 75	48,17	9,62	57,38	2,34	6,14	97,75	51,14	10,87
-75	54,65	10,92	57,99	0,86	2,25	100,00	55,90	3,61
Total	500,58	100,00		38,13	100,00			

Table A-2.42: Test 9, 15-30 minutes, 12 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	57,80	11,55	59,91	1,17	7,77	7,77	56,02	6,49
- 600 + 500	25,18	5,03	59,63	0,43	2,87	10,64	55,30	7,25
- 500 + 355	51,89	10,37	58,84	0,30	2,00	12,64	55,61	5,50
- 355 + 212	108,88	21,75	59,00	2,94	19,48	32,12	56,30	4,57
- 212 + 150	98,13	19,60	59,51	2,58	17,11	49,23	57,01	4,19
- 150 + 106	55,88	11,16	59,24	1,42	9,42	58,65	55,37	6,54
- 106 + 75	48,17	9,62	57,38	3,88	25,73	84,38	54,84	4,43
-75	54,65	10,92	57,99	2,35	15,62	100,00	50,71	12,55
Total	500,58	100,00		15,06	100,00			

Table A-2.43: Test 9, 30-45 minutes, 12 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	**30-45 minutes**				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	57,80	11,55	59,91	0,02	0,36	0,36	42,80	28,56
- 600 + 500	25,18	5,03	59,63	0,01	0,21	0,57	36,30	39,13
- 500 + 355	51,89	10,37	58,84	0,01	0,20	0,77	40,31	31,49
- 355 + 212	108,88	21,75	59,00	0,37	5,75	6,52	52,82	10,47
- 212 + 150	98,13	19,60	59,51	0,40	6,22	12,74	57,56	3,26
- 150 + 106	55,88	11,16	59,24	0,53	8,19	20,93	63,44	-7,09
- 106 + 75	48,17	9,62	57,38	1,42	21,91	42,83	49,60	13,56
-75	54,65	10,92	57,99	3,71	57,17	100,00	45,54	21,46
Total	500,58	100,00		6,48				

Table A-2.44: Test 9, 45-60 minutes, 12 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	**45-60 minutes**				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	57,80	11,55	59,91	0,03	0,86	0,86	45,85	23,47
- 600 + 500	25,18	5,03	59,63	0,02	0,50	1,36	38,36	35,66
- 500 + 355	51,89	10,37	58,84	0,02	0,56	1,92	56,11	4,64
- 355 + 212	108,88	21,75	59,00	0,07	2,13	4,04	47,14	20,09
- 212 + 150	98,13	19,60	59,51	0,14	4,42	8,46	52,92	11,06
- 150 + 106	55,88	11,16	59,24	0,31	9,56	18,02	52,82	10,84
- 106 + 75	48,17	9,62	57,38	0,97	30,22	48,24	48,79	14,97
-75	54,65	10,92	57,99	1,66	51,76	100,00	41,28	28,81
Total	500,58	100,00		3,21	100,00			

Table A-2.45: Test 9, Underflow, 12 channels at 3 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	57,80	11,55	59,91	45,25	10,88	10,88	62,56	4,24
- 600 + 500	25,18	5,03	59,63	22,42	5,39	16,27	62,08	3,96
- 500 + 355	51,89	10,37	58,84	47,58	11,44	27,72	59,42	0,97
- 355 + 212	108,88	21,75	59,00	94,97	22,84	50,56	58,63	-0,63
- 212 + 150	98,13	19,60	59,51	77,07	18,53	69,09	59,58	0,12
- 150 + 106	55,88	11,16	59,24	47,18	11,35	80,44	58,74	-0,86
- 106 + 75	48,17	9,62	57,38	37,58	9,04	89,47	61,01	5,94
-75	54,65	10,92	57,99	43,77	10,53	100,00	72,24	19,73
Total	500,58	100,00		415,81	100,00			

Table A-2.46: Test 10, 0-15 minutes, 6 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	21,73	4,36	59,49	0,17	0,14	0,14	52,46	11,82
- 600 + 500	5,18	1,04	57,32	0,21	0,17	0,30	52,85	7,79
- 500 + 355	46,41	9,30	58,84	1,11	0,88	1,18	58,49	0,59
- 355 + 212	95,72	19,18	61,29	11,26	8,97	10,16	60,31	1,59
- 212 + 150	95,98	19,23	59,29	26,93	21,45	31,60	58,05	2,09
- 150 + 106	92,66	18,57	60,11	11,47	9,13	40,74	58,43	2,79
- 106 + 75	69,57	13,94	57,25	15,46	12,31	53,05	52,89	7,60
-75	71,79	14,39	58,45	58,96	46,95	100,00	53,81	7,95
Total	499,04	100,00		125,57	100,00			

Table A-2.47: Test 10, 15-30 minutes, 6 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	21,73	4,36	59,49	0,02	0,83	0,83	67,69	-13,77
- 600 + 500	5,18	1,04	57,32	0,01	0,33	1,17	28,26	50,69
- 500 + 355	46,41	9,30	58,84	0,02	0,60	1,77	26,51	54,95
- 355 + 212	95,72	19,18	61,29	0,07	2,56	4,33	45,66	25,50
- 212 + 150	95,98	19,23	59,29	0,04	1,36	5,69	44,77	24,49
- 150 + 106	92,66	18,57	60,11	0,07	2,40	8,09	51,44	14,42
- 106 + 75	69,57	13,94	57,25	0,20	7,43	15,51	41,32	27,82
-75	71,79	14,39	58,45	2,32	84,49	100,00	50,69	13,28
Total	499,04	100,00		2,75	100,00			

Table A-2.48: Test 10, 30-45 minutes, 6 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	21,73	4,36	59,49	0,02	1,43	1,43	60,29	-1,34
- 600 + 500	5,18	1,04	57,32	0,01	0,39	1,82	41,82	27,04
- 500 + 355	46,41	9,30	58,84	0,01	0,90	2,72	47,66	19,01
- 355 + 212	95,72	19,18	61,29	0,03	2,22	4,94	57,28	6,55
- 212 + 150	95,98	19,23	59,29	0,03	2,42	7,36	55,36	6,63
- 150 + 106	92,66	18,57	60,11	0,05	3,17	10,53	57,96	3,57
- 106 + 75	69,57	13,94	57,25	0,11	7,44	17,98	38,58	32,60
-75	71,79	14,39	58,45	1,17	82,02	100,00	51,93	11,16
Total	499,04	100,00		1,42	100			

Table A-2.49: Test 10, 45-60 minutes, 6 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	21,73	4,36	59,49	0,01	0,66	0,66	57,69	3,03
- 600 + 500	5,18	1,04	57,32	0,01	0,80	1,47	65,08	-13,55
- 500 + 355	46,41	9,30	58,84	0,01	1,19	2,65	55,91	4,98
- 355 + 212	95,72	19,18	61,29	0,03	3,33	5,98	54,79	10,61
- 212 + 150	95,98	19,23	59,29	0,02	2,88	8,86	54,87	7,46
- 150 + 106	92,66	18,57	60,11	0,04	5,02	13,88	63,71	-5,98
- 106 + 75	69,57	13,94	57,25	0,02	3,01	16,89	41,10	28,20
-75	71,79	14,39	58,45	0,65	83,11	100,00	50,08	14,31
Total	499,04	100,00		0,78	100,00			

Table A-2.50: Test 10, Underflow, 6 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	21,73	4,36	59,49	19,58	5,84	5,84	57,11	-4,18
- 600 + 500	5,18	1,04	57,32	4,50	1,34	7,18	59,58	3,80
- 500 + 355	46,41	9,30	58,84	41,19	12,28	19,46	56,11	-4,87
- 355 + 212	95,72	19,18	61,29	76,74	22,88	42,34	52,50	-16,75
- 212 + 150	95,98	19,23	59,29	62,75	18,71	61,06	50,28	-17,92
- 150 + 106	92,66	18,57	60,11	73,75	21,99	83,05	58,95	-1,97
- 106 + 75	69,57	13,94	57,25	48,94	14,59	97,64	59,25	3,38
-75	71,79	14,39	58,45	7,91	2,36	100,00	69,98	16,47
Total	499,04	100,00		335,35	100,00			

Table A-2.51: Test 11, 0-15 minutes, 6 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	53,88	10,81	58,33	0,69	0,53	0,53	54,86	5,95
- 600 + 500	24,22	4,86	56,98	0,42	0,33	0,86	51,20	10,14
- 500 + 355	47,54	9,54	56,78	1,02	0,80	1,66	51,22	9,79
- 355 + 212	93,21	18,71	53,40	14,60	11,38	13,04	53,13	0,50
- 212 + 150	83,55	16,77	57,39	23,35	18,20	31,24	55,54	3,22
- 150 + 106	66,26	13,30	60,30	24,41	19,03	50,27	54,59	9,46
- 106 + 75	69,89	14,03	58,85	15,01	11,70	61,98	54,18	7,92
-75	59,76	11,99	58,79	48,77	38,02	100,00	57,53	2,15
Total	498,32	100,00		128,27	100,00			

Table A-2.52: Test 11, 15-30 minutes, 6 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	53,88	10,81	58,33	0,06	2,32	2,32	74,15	-27,13
- 600 + 500	24,22	4,86	56,98	0,02	0,57	2,89	37,25	34,62
- 500 + 355	47,54	9,54	56,78	0,03	1,05	3,94	36,07	36,48
- 355 + 212	93,21	18,71	53,40	0,13	4,85	8,79	51,70	3,19
- 212 + 150	83,55	16,77	57,39	0,07	2,78	11,57	57,74	-0,61
- 150 + 106	66,26	13,30	60,30	0,06	2,28	13,85	52,55	12,86
- 106 + 75	69,89	14,03	58,85	0,18	6,84	20,69	38,79	34,09
-75	59,76	11,99	58,79	2,12	79,31	100,00	51,51	12,38
Total	498,32	100,00		2,67	100,00			

Table A-2.53: Test 11, 30-45 minutes, 6 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	53,88	10,81	58,33	0,01	1,21	1,21	40,41	30,72
- 600 + 500	24,22	4,86	56,98	0,01	0,55	1,76	31,82	44,16
- 500 + 355	47,54	9,54	56,78	0,01	0,59	2,35	35,21	37,99
- 355 + 212	93,21	18,71	53,40	0,02	1,37	3,72	43,03	19,42
- 212 + 150	83,55	16,77	57,39	0,02	1,95	5,66	47,66	16,95
- 150 + 106	66,26	13,30	60,30	0,03	2,72	8,38	49,70	17,59
- 106 + 75	69,89	14,03	58,85	0,05	4,28	12,66	43,80	25,57
-75	59,76	11,99	58,79	1,05	87,34	100,00	50,22	14,58
Total	498,32	100,00		1,21	100,00			

Table A-2.54: Test 11, 45-60 minutes, 6 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	53,88	10,81	58,33	0,01	2,56	2,56	14,42	75,27
- 600 + 500	24,22	4,86	56,98	0,00	1,08	3,64	56,82	0,29
- 500 + 355	47,54	9,54	56,78	0,01	1,79	5,43	53,42	5,92
- 355 + 212	93,21	18,71	53,40	0,02	5,68	11,11	57,58	-7,82
- 212 + 150	83,55	16,77	57,39	0,01	2,58	13,69	48,57	15,36
- 150 + 106	66,26	13,30	60,30	0,02	4,13	17,82	60,12	0,30
- 106 + 75	69,89	14,03	58,85	0,04	10,08	27,89	44,15	24,98
-75	59,76	11,99	58,79	0,29	72,11	100,00	51,16	12,98
Total	498,32	100,00		0,41	100,00			

Table A-2.55: Test 11, Underflow, 6 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	53,88	10,81	58,33	50,45	14,52	14,52	61,73	5,51
- 600 + 500	24,22	4,86	56,98	22,58	6,50	21,02	58,60	2,76
- 500 + 355	47,54	9,54	56,78	44,15	12,71	33,72	58,06	2,19
- 355 + 212	93,21	18,71	53,40	74,52	21,45	55,17	56,33	5,21
- 212 + 150	83,55	16,77	57,39	57,09	16,43	71,60	57,79	0,70
- 150 + 106	66,26	13,30	60,30	39,66	11,41	83,01	58,71	-2,71
- 106 + 75	69,89	14,03	58,85	51,88	14,93	97,94	59,30	0,76
-75	59,76	11,99	58,79	7,15	2,06	100,00	69,23	15,09
Total	498,32	100,00		347,48	100,00			

Table A-2.56: Test 12, 0-15 minutes, 6 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	36,63	7,35	61,25	0,45	0,34	0,34	57,36	6,36
- 600 + 500	17,89	3,59	56,85	0,28	0,21	0,56	52,28	8,04
- 500 + 355	45,15	9,06	59,53	0,91	0,71	1,26	58,78	1,25
- 355 + 212	94,58	18,99	61,33	11,80	9,11	10,37	60,18	1,88
- 212 + 150	106,38	21,35	59,39	34,60	26,71	37,09	57,51	3,16
- 150 + 106	53,54	10,75	62,52	6,16	4,76	41,84	57,51	8,01
- 106 + 75	68,03	13,66	56,90	13,46	10,39	52,23	53,15	6,58
-75	75,97	15,25	61,37	61,87	47,77	100,00	61,08	0,46
Total	498,18	100,00		129,52	100,00			

Table A-2.57: Test 12, 15-30 minutes, 6 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	36,63	7,35	61,25	0,01	0,68	0,68	45,93	25,02
- 600 + 500	17,89	3,59	56,85	0,00	0,16	0,84	40,63	28,54
- 500 + 355	45,15	9,06	59,53	0,01	0,33	1,16	44,62	25,06
- 355 + 212	94,58	18,99	61,33	0,03	1,52	2,68	46,86	23,59
- 212 + 150	106,38	21,35	59,39	0,05	2,62	5,30	59,20	0,32
- 150 + 106	53,54	10,75	62,52	0,05	2,52	7,82	53,39	14,61
- 106 + 75	68,03	13,66	56,90	0,15	7,48	15,30	26,21	53,94
-75	75,97	15,25	61,37	1,69	84,70	100,00	53,16	13,38
Total	498,18	100,00		1,99	100,00			

Table A-2.58: Test 12, 30-45 minutes, 6 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	36,63	7,35	61,25	0,03	1,17	1,17	60,74	0,84
- 600 + 500	17,89	3,59	56,85	0,02	0,61	1,78	55,77	1,90
- 500 + 355	45,15	9,06	59,53	0,02	0,93	2,71	59,92	-0,64
- 355 + 212	94,58	18,99	61,33	0,04	1,68	4,39	59,35	3,24
- 212 + 150	106,38	21,35	59,39	0,05	1,99	6,39	57,48	3,21
- 150 + 106	53,54	10,75	62,52	0,05	2,01	8,40	47,16	24,56
- 106 + 75	68,03	13,66	56,90	0,26	10,02	18,42	23,90	57,99
-75	75,97	15,25	61,37	2,08	81,58	100,00	53,86	12,23
Total	498,18	100,00		2,55	100,00			

Table A-2.59: Test 12, 45-60 minutes, 6 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	36,63	7,35	61,25	0,05	7,60	7,60	79,25	-29,38
- 600 + 500	17,89	3,59	56,85	0,01	1,02	8,62	61,76	-8,65
- 500 + 355	45,15	9,06	59,53	0,01	1,43	10,05	53,68	9,82
- 355 + 212	94,58	18,99	61,33	0,02	2,69	12,73	56,42	8,00
- 212 + 150	106,38	21,35	59,39	0,02	3,56	16,29	59,92	-0,89
- 150 + 106	53,54	10,75	62,52	0,04	5,44	21,73	70,99	-13,56
- 106 + 75	68,03	13,66	56,90	0,08	11,88	33,61	48,42	14,90
-75	75,97	15,25	61,37	0,44	66,39	100,00	54,99	10,39
Total	498,18	100,00		0,67	100,00			

Table A-2.60: Test 12, Underflow, 6 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	36,63	7,35	61,25	34,28	9,93	9,93	62,56	2,09
- 600 + 500	17,89	3,59	56,85	16,71	4,84	14,77	56,73	-0,21
- 500 + 355	45,15	9,06	59,53	41,98	12,16	26,93	56,94	-4,55
- 355 + 212	94,58	18,99	61,33	78,56	22,75	49,68	56,83	-7,92
- 212 + 150	106,38	21,35	59,39	68,07	19,71	69,40	52,63	-12,83
- 150 + 106	53,54	10,75	62,52	44,88	13,00	82,39	54,93	-13,81
- 106 + 75	68,03	13,66	56,90	51,39	14,88	97,28	57,48	1,02
-75	75,97	15,25	61,37	9,40	2,72	100,00	72,24	15,06
Total	498,18	100,00		345,28	100,00			

Table A-2.61: Test 13, 0-15 minutes, 8 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	55,89	11,19	63,68	0,28	0,29	0,29	63,65	0,05
- 600 + 500	24,18	4,84	56,60	0,40	0,41	0,70	56,45	0,25
- 500 + 355	48,57	9,72	62,91	1,22	1,26	1,96	60,07	4,52
- 355 + 212	100,58	20,14	61,09	25,28	26,00	27,96	56,47	7,56
- 212 + 150	111,58	22,34	57,74	31,71	32,61	60,58	57,39	0,61
- 150 + 106	31,87	6,38	59,37	2,99	3,08	63,65	56,14	5,44
- 106 + 75	75,21	15,06	58,33	11,96	12,30	75,95	55,36	5,09
-75	51,53	10,32	57,90	23,38	24,05	100,00	53,69	7,27
Total	499,41	100,00		97,23	100			

Table A-2.62: Test 13, 15-30 minutes, 8 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	55,89	11,19	63,68	0,03	0,84	0,84	46,18	27,47
- 600 + 500	24,18	4,84	56,60	0,01	0,32	1,15	39,39	30,39
- 500 + 355	48,57	9,72	62,91	0,01	0,36	1,51	45,54	27,61
- 355 + 212	100,58	20,14	61,09	0,08	2,59	4,11	57,83	5,33
- 212 + 150	111,58	22,34	57,74	0,08	2,67	6,78	59,93	-3,79
- 150 + 106	31,87	6,38	59,37	0,06	1,77	8,55	53,97	9,10
- 106 + 75	75,21	15,06	58,33	0,23	7,31	15,86	51,05	12,48
-75	51,53	10,32	57,90	2,63	84,14	100,00	49,28	14,89
Total	499,41	100,00		3,13	100,00			

Table A-2.63: Test 13, 30-45minutes, 8 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	**30-45 minutes**				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	55,89	11,19	63,68	0,05	2,15	2,15	48,56	23,74
- 600 + 500	24,18	4,84	56,60	0,01	0,57	2,73	62,79	-10,94
- 500 + 355	48,57	9,72	62,91	0,02	0,87	3,60	46,70	25,76
- 355 + 212	100,58	20,14	61,09	0,05	2,08	5,68	44,99	26,35
- 212 + 150	111,58	22,34	57,74	0,04	1,94	7,61	44,16	23,51
- 150 + 106	31,87	6,38	59,37	0,09	3,94	11,55	44,88	24,41
- 106 + 75	75,21	15,06	58,33	0,13	5,71	17,27	40,42	30,71
-75	51,53	10,32	57,90	1,87	82,73	100,00	47,53	17,91
Total	499,41	100,00		2,26	100,00			

Table A-2.64: Test 13, 45-60 minutes, 8 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	**45-60 minutes**				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	55,89	11,19	63,68	0,01	0,76	0,76	31,62	50,35
- 600 + 500	24,18	4,84	56,60	0,00	0,26	1,01	52,17	7,81
- 500 + 355	48,57	9,72	62,91	0,01	0,40	1,41	43,06	31,56
- 355 + 212	100,58	20,14	61,09	0,03	1,94	3,35	54,15	11,35
- 212 + 150	111,58	22,34	57,74	0,09	4,75	8,10	54,04	6,42
- 150 + 106	31,87	6,38	59,37	0,09	5,24	13,34	53,81	9,36
- 106 + 75	75,21	15,06	58,33	0,14	7,61	20,95	41,46	28,92
-75	51,53	10,32	57,90	1,42	79,05	100,00	48,51	16,22
Total	499,41	100,00		1,80	100,00			

Table A-2.65: Test 13, Underflow, 8 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	55,89	11,19	63,68	52,19	14,06	14,06	57,35	-11,03
- 600 + 500	24,18	4,84	56,60	22,33	6,01	20,07	59,11	4,26
- 500 + 355	48,57	9,72	62,91	44,47	11,98	32,05	57,58	-9,25
- 355 + 212	100,58	20,14	61,09	70,63	19,02	51,07	52,58	-16,17
- 212 + 150	111,58	22,34	57,74	74,88	20,17	71,23	56,97	-1,36
- 150 + 106	31,87	6,38	59,37	26,92	7,25	78,49	54,56	-8,82
- 106 + 75	75,21	15,06	58,33	58,99	15,89	94,37	55,99	-4,19
-75	51,53	10,32	57,90	20,89	5,63	100,00	67,78	14,57
Total	499,41	100,00		371,29	100,00			

Table A-2.66: Test 14, 0-15 minutes, 8 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	51,40	10,30	60,79	0,69	0,65	0,65	59,08	2,82
- 600 + 500	22,84	4,58	60,67	1,34	1,26	1,92	60,00	1,10
- 500 + 355	45,88	9,19	62,74	3,81	3,60	5,51	61,46	2,05
- 355 + 212	100,24	20,09	61,00	15,98	15,10	20,61	60,19	1,33
- 212 + 150	100,43	20,13	59,08	30,59	28,91	49,52	58,15	1,57
- 150 + 106	41,46	8,31	59,64	17,99	17,00	66,53	56,45	5,36
- 106 + 75	82,70	16,58	56,83	15,56	14,70	81,23	55,82	1,77
-75	54,00	10,82	58,72	19,86	18,77	100,00	54,15	7,78
Total	498,94	100,00		105,80	100			

Table A-2.67: Test 14, 15-30 minutes, 8 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	51,40	10,30	60,79	0,00	0,04	0,04	30,77	49,39
- 600 + 500	22,84	4,58	60,67	0,01	0,18	0,22	35,90	40,83
- 500 + 355	45,88	9,19	62,74	0,03	0,52	0,74	39,10	37,68
- 355 + 212	100,24	20,09	61,00	0,08	1,29	2,04	50,18	17,74
- 212 + 150	100,43	20,13	59,08	0,14	2,19	4,23	59,73	-1,11
- 150 + 106	41,46	8,31	59,64	0,15	2,30	6,53	54,74	8,22
- 106 + 75	82,70	16,58	56,83	0,66	10,28	16,81	54,52	4,06
-75	54,00	10,82	58,72	5,35	83,19	100,00	48,02	18,22
Total	498,94	100,00		6,43	100,00			

Table A-2.68: Test 14, 30-45 minutes, 8 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	51,40	10,30	60,79	0,03	1,39	1,39	55,36	8,93
- 600 + 500	22,84	4,58	60,67	0,01	0,32	1,71	48,75	19,64
- 500 + 355	45,88	9,19	62,74	0,02	0,68	2,40	50,89	18,90
- 355 + 212	100,24	20,09	61,00	0,06	2,34	4,73	54,06	11,38
- 212 + 150	100,43	20,13	59,08	0,04	1,60	6,33	45,96	22,20
- 150 + 106	41,46	8,31	59,64	0,06	2,34	8,66	39,90	33,11
- 106 + 75	82,70	16,58	56,83	0,07	2,68	11,35	39,25	30,94
-75	54,00	10,82	58,72	2,20	88,65	100,00	43,34	26,20
Total	498,94	100,00		2,48	100,00			

Table A-2.69: Test 14, 45-60 minutes, 8 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	**45-60 minutes**				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	51,40	10,30	60,79	0,02	1,32	1,32	41,52	31,70
- 600 + 500	22,84	4,58	60,67	0,01	0,48	1,80	37,80	37,68
- 500 + 355	45,88	9,19	62,74	0,02	0,91	2,71	53,55	14,66
- 355 + 212	100,24	20,09	61,00	0,03	1,93	4,64	63,41	-3,96
- 212 + 150	100,43	20,13	59,08	0,03	1,67	6,30	53,52	9,40
- 150 + 106	41,46	8,31	59,64	0,04	2,25	8,55	55,87	6,31
- 106 + 75	82,70	16,58	56,83	0,08	4,99	13,54	39,69	30,15
-75	54,00	10,82	58,72	1,47	86,46	100,00	46,84	20,23
Total	498,94	100,00		1,70	100,00			

Table A-2.70: Test 14, Underflow, 8 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	**Remains (Underflow)**				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	51,40	10,30	60,79	47,61	13,24	13,24	60,88	0,15
- 600 + 500	22,84	4,58	60,67	20,19	5,61	18,85	61,44	1,27
- 500 + 355	45,88	9,19	62,74	39,48	10,98	29,83	59,72	-5,07
- 355 + 212	100,24	20,09	61,00	79,05	21,98	51,82	50,76	-20,18
- 212 + 150	100,43	20,13	59,08	65,45	18,20	70,02	60,00	1,54
- 150 + 106	41,46	8,31	59,64	21,83	6,07	76,09	54,52	-9,39
- 106 + 75	82,70	16,58	56,83	62,36	17,34	93,43	55,93	-1,60
-75	54,00	10,82	58,72	23,62	6,57	100,00	69,05	14,96
Total	498,94	100,00		359,58	100,00			

Table A-2.71: Test 15, 0-15 minutes, 8 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	57,02	11,42	63,49	1,13	1,11	1,11	56,93	10,33
- 600 + 500	24,86	4,98	59,87	1,16	1,14	2,25	58,94	1,55
- 500 + 355	49,36	9,89	62,11	2,78	2,72	4,97	60,22	3,05
- 355 + 212	100,54	20,14	59,96	25,42	24,89	29,85	58,70	2,11
- 212 + 150	110,95	22,22	59,57	26,59	26,03	55,89	56,69	4,82
- 150 + 106	37,88	7,59	59,49	5,93	5,81	61,69	57,71	3,00
- 106 + 75	59,83	11,98	58,09	18,66	18,27	79,96	54,67	5,90
-75	58,86	11,79	58,08	20,46	20,04	100,00	54,00	7,02
Total	499,30	100,00		102,13	100,00			

Table A-2.72: Test 15, 15-30 minutes, 8 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	57,02	11,42	63,49	0,23	3,27	3,27	88,32	-39,11
- 600 + 500	24,86	4,98	59,87	0,04	0,59	3,86	62,13	-3,78
- 500 + 355	49,36	9,89	62,11	0,07	1,02	4,88	65,00	-4,65
- 355 + 212	100,54	20,14	59,96	0,17	2,50	7,38	67,38	-12,37
- 212 + 150	110,95	22,22	59,57	0,36	5,16	12,54	61,59	-3,40
- 150 + 106	37,88	7,59	59,49	0,36	5,25	17,79	56,71	4,68
- 106 + 75	59,83	11,98	58,09	0,96	13,93	31,72	53,11	8,58
-75	58,86	11,79	58,08	4,70	68,28	100,00	49,01	15,62
Total	499,30	100,00		6,88	100,00			

Table A-2.73: Test 15, 30-45 minutes, 8 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	**30-45 minutes**				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	57,02	11,42	63,49	0,07	1,66	1,66	51,16	19,43
- 600 + 500	24,86	4,98	59,87	0,02	0,37	2,04	55,15	7,88
- 500 + 355	49,36	9,89	62,11	0,04	0,82	2,85	46,11	25,76
- 355 + 212	100,54	20,14	59,96	0,18	4,11	6,96	57,99	3,28
- 212 + 150	110,95	22,22	59,57	0,12	2,73	9,69	57,25	3,89
- 150 + 106	37,88	7,59	59,49	0,13	3,04	12,73	54,96	7,62
- 106 + 75	59,83	11,98	58,09	0,66	14,84	27,57	60,97	-4,96
-75	58,86	11,79	58,08	3,20	72,43	100,00	52,07	10,35
Total	499,30	100,00		4,42	100,00			

Table A-2.74: Test 15, 45-60 minutes, 8 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	**45-60 minutes**				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	57,02	11,42	63,49	0,02	1,14	1,14	46,60	26,61
- 600 + 500	24,86	4,98	59,87	0,01	0,43	1,57	56,16	6,18
- 500 + 355	49,36	9,89	62,11	0,01	0,48	2,05	48,15	22,48
- 355 + 212	100,54	20,14	59,96	0,02	1,34	3,39	44,89	25,14
- 212 + 150	110,95	22,22	59,57	0,06	3,42	6,81	47,30	20,58
- 150 + 106	37,88	7,59	59,49	0,09	5,29	12,10	55,23	7,17
- 106 + 75	59,83	11,98	58,09	0,13	7,83	19,92	37,23	35,90
-75	58,86	11,79	58,08	1,35	80,08	100,00	51,25	11,76
Total	499,30	100,00		1,68	100,00			

Table A-2.75: Test 15, Underflow, 8 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	57,02	11,42	63,49	52,78	14,46	14,46	56,18	-13,02
- 600 + 500	24,86	4,98	59,87	22,45	6,15	20,61	57,61	-3,91
- 500 + 355	49,36	9,89	62,11	44,15	12,10	32,71	57,18	-8,62
- 355 + 212	100,54	20,14	59,96	71,01	19,46	52,17	57,94	-3,49
- 212 + 150	110,95	22,22	59,57	79,64	21,82	73,99	55,75	-6,85
- 150 + 106	37,88	7,59	59,49	29,80	8,16	82,15	53,62	-10,96
- 106 + 75	59,83	11,98	58,09	37,46	10,26	92,41	57,92	-0,30
-75	58,86	11,79	58,08	27,69	7,59	100,00	69,34	16,24
Total	499,30	100,00		364,98	100,00			

Table A-2.76: Test 16, 0-15 minutes, 12 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	36,73	7,35	55,79	0,45	0,40	0,40	48,29	13,43
- 600 + 500	24,52	4,90	57,74	0,45	0,40	0,80	32,20	44,24
- 500 + 355	47,82	9,56	57,32	4,79	4,30	5,10	23,47	59,06
- 355 + 212	97,99	19,60	61,29	12,97	11,62	16,72	25,51	58,37
- 212 + 150	117,79	23,56	56,28	20,73	18,58	35,29	48,40	13,99
- 150 + 106	44,12	8,82	59,71	6,96	6,23	41,53	35,56	40,45
- 106 + 75	62,74	12,55	56,28	21,47	19,24	60,77	47,57	15,47
-75	68,29	13,66	57,83	43,78	39,23	100,00	49,02	15,24
Total	500,00	100,00		111,60	100,00			

Table A-2.77: Test 16, 15-30 minutes, 12 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	36,73	7,35	55,79	0,07	0,24	0,24	57,91	-3,81
- 600 + 500	24,52	4,90	57,74	0,23	0,84	1,08	6,97	87,92
- 500 + 355	47,82	9,56	57,32	1,95	7,09	8,17	8,87	84,52
- 355 + 212	97,99	19,60	61,29	5,79	21,05	29,22	12,59	79,45
- 212 + 150	117,79	23,56	56,28	2,75	9,99	39,21	12,10	78,50
- 150 + 106	44,12	8,82	59,71	3,01	10,94	50,15	14,34	75,99
- 106 + 75	62,74	12,55	56,28	2,88	10,47	60,62	24,45	56,56
-75	68,29	13,66	57,83	10,84	39,38	100,00	54,04	6,55
Total	500,00	100,00		27,52	100,00			

Table A-2.78: Test 16, 30-45 minutes, 12 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	36,73	7,35	55,79	0,06	0,38	0,38	65,80	-17,96
- 600 + 500	24,52	4,90	57,74	0,12	0,82	1,20	9,07	84,29
- 500 + 355	47,82	9,56	57,32	0,92	6,11	7,31	9,70	83,08
- 355 + 212	97,99	19,60	61,29	3,22	21,31	28,61	14,94	75,62
- 212 + 150	117,79	23,56	56,28	1,74	11,52	40,14	15,73	72,05
- 150 + 106	44,12	8,82	59,71	1,94	12,85	52,99	17,74	70,29
- 106 + 75	62,74	12,55	56,28	1,94	12,83	65,82	28,20	49,90
-75	68,29	13,66	57,83	5,17	34,18	100,00	59,08	-2,16
Total	500,00	100,00		15,13	100,00			

Table A-2.79: Test 16, 45-60 minutes, 12 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	36,73	7,35	55,79	0,10	1,00	1,00	59,59	-6,83
- 600 + 500	24,52	4,90	57,74	0,10	1,02	2,02	11,90	79,38
- 500 + 355	47,82	9,56	57,32	0,53	5,36	7,38	12,59	78,04
- 355 + 212	97,99	19,60	61,29	3,26	33,09	40,47	16,40	73,24
- 212 + 150	117,79	23,56	56,28	1,06	10,75	51,22	23,70	57,88
- 150 + 106	44,12	8,82	59,71	1,28	12,97	64,19	31,18	47,79
- 106 + 75	62,74	12,55	56,28	1,10	11,19	75,38	40,07	28,81
-75	68,29	13,66	57,83	2,43	24,62	100,00	64,31	-11,19
Total	500,00	100,00		9,85	100,00			

Table A-2.80: Test 16, Underflow, 12 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	36,73	7,35	55,79	34,26	10,73	10,73	59,60	6,40
- 600 + 500	24,52	4,90	57,74	22,43	7,03	17,76	58,32	0,99
- 500 + 355	47,82	9,56	57,32	37,64	11,80	29,56	63,54	9,79
- 355 + 212	97,99	19,60	61,29	69,11	21,66	51,22	66,45	7,76
- 212 + 150	117,79	23,56	56,28	86,93	27,24	78,46	65,85	14,53
- 150 + 106	44,12	8,82	59,71	29,39	9,21	87,67	67,62	11,69
- 106 + 75	62,74	12,55	56,28	33,58	10,52	98,19	69,45	18,96
-75	68,29	13,66	57,83	5,77	1,81	100,00	72,97	20,75
Total	500,00	100,00		319,11	100,00			

Table A-2.81: Test 17, 0-15 minutes, 12 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	55,73	11,14	57,05	5,00	4,33	4,33	53,20	6,73
- 600 + 500	23,48	4,69	58,36	0,78	0,68	5,01	41,81	28,35
- 500 + 355	48,42	9,68	57,67	7,05	6,10	11,11	35,21	38,94
- 355 + 212	102,36	20,46	54,05	31,63	27,37	38,48	41,30	23,60
- 212 + 150	129,54	25,89	57,94	22,07	19,10	57,59	47,03	18,84
- 150 + 106	50,85	10,16	59,14	16,29	14,10	71,68	45,22	23,54
- 106 + 75	49,65	9,92	58,69	15,86	13,73	85,41	43,94	25,14
-75	40,38	8,07	56,77	16,86	14,59	100,00	44,29	21,98
Total	500,41	100,00		115,55	100,00			

Table A-2.82: Test 17, 15-30 minutes, 12 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	55,73	11,14	57,05	0,05	0,24	0,24	50,71	11,11
- 600 + 500	23,48	4,69	58,36	0,08	0,37	0,61	18,31	68,62
- 500 + 355	48,42	9,68	57,67	1,11	5,33	5,94	7,71	86,64
- 355 + 212	102,36	20,46	54,05	3,88	18,61	24,55	11,91	77,97
- 212 + 150	129,54	25,89	57,94	2,23	10,70	35,25	13,67	76,41
- 150 + 106	50,85	10,16	59,14	2,71	13,03	48,28	15,67	73,51
- 106 + 75	49,65	9,92	58,69	2,34	11,24	59,52	32,36	44,87
-75	40,38	8,07	56,77	8,43	40,48	100,00	46,91	17,37
Total`	500,41	100,00		20,83	100,00			

Table A-2.83: Test 17, 30-45 minutes, 12 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	55,73	11,14	57,05	0,08	0,47	0,47	54,56	4,36
- 600 + 500	23,48	4,69	58,36	0,10	0,58	1,05	16,41	71,88
- 500 + 355	48,42	9,68	57,67	1,21	6,73	7,78	9,19	84,07
- 355 + 212	102,36	20,46	54,05	3,81	21,15	28,93	12,86	76,20
- 212 + 150	129,54	25,89	57,94	2,05	11,38	40,30	13,51	76,69
- 150 + 106	50,85	10,16	59,14	2,22	12,33	52,63	15,64	73,56
- 106 + 75	49,65	9,92	58,69	2,02	11,22	63,85	25,29	56,91
-75	40,38	8,07	56,77	6,51	36,15	100,00	58,63	-3,27
Total	500,41	100,00		18,01	100,00			

Table A-2.84: Test 17, 45-60 minutes, 12 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	55,73	11,14	57,05	0,00	0,03	0,03	38,64	32,27
- 600 + 500	23,48	4,69	58,36	0,10	0,66	0,69	25,65	56,05
- 500 + 355	48,42	9,68	57,67	0,99	6,81	7,49	1,87	96,75
- 355 + 212	102,36	20,46	54,05	3,52	24,11	31,60	24,09	55,42
- 212 + 150	129,54	25,89	57,94	1,70	11,61	43,21	29,04	49,87
- 150 + 106	50,85	10,16	59,14	1,80	12,29	55,50	33,90	42,69
- 106 + 75	49,65	9,92	58,69	1,76	12,05	67,55	43,84	25,30
-75	40,38	8,07	56,77	4,74	32,45	100,00	66,81	-17,69
Total	500,41	100,00		14,61	100,00			

Table A-2.85: Test 17, Underflow, 12 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	55,73	11,14	57,05	48,05	15,26	15,26	57,25	0,37
- 600 + 500	23,48	4,69	58,36	21,30	6,76	22,03	60,73	3,90
- 500 + 355	48,42	9,68	57,67	36,15	11,48	33,51	63,90	9,75
- 355 + 212	102,36	20,46	54,05	56,55	17,96	51,47	67,06	19,40
- 212 + 150	129,54	25,89	57,94	96,42	30,62	82,10	62,60	7,44
- 150 + 106	50,85	10,16	59,14	26,45	8,40	90,50	67,41	12,26
- 106 + 75	49,65	9,92	58,69	26,28	8,35	98,84	70,92	17,24
-75	40,38	8,07	56,77	3,64	1,16	100,00	73,52	22,78
Total	500,41	100,00		314,84	100,00			

Table A-2.86: Test 18, 0-15 minutes, 12 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	51,97	10,37	59,01	3,12	2,63	2,63	53,25	9,76
- 600 + 500	22,57	4,51	58,25	1,09	0,92	3,54	43,04	26,11
- 500 + 355	43,47	8,68	58,09	4,89	4,11	7,66	25,05	56,88
- 355 + 212	119,01	23,76	58,66	30,58	25,73	33,38	45,13	23,06
- 212 + 150	143,95	28,74	58,48	31,27	26,31	59,69	46,60	20,32
- 150 + 106	22,41	4,47	60,07	4,12	3,47	63,16	36,82	38,71
- 106 + 75	48,08	9,60	57,22	17,03	14,33	77,49	48,28	15,61
-75	49,44	9,87	57,52	26,76	22,51	100,00	49,13	14,57
Total	500,91	100,00		118,86	100,00			

Table A-2.87: Test 18, 15-30 minutes, 12 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	51,97	10,37	59,01	0,05	0,27	0,27	50,65	14,15
- 600 + 500	22,57	4,51	58,25	0,06	0,31	0,58	11,94	79,50
- 500 + 355	43,47	8,68	58,09	0,84	4,29	4,88	8,88	84,71
- 355 + 212	119,01	23,76	58,66	3,68	18,89	23,76	10,83	81,53
- 212 + 150	143,95	28,74	58,48	2,12	10,91	34,68	11,12	80,99
- 150 + 106	22,41	4,47	60,07	2,57	13,20	47,88	12,57	79,06
- 106 + 75	48,08	9,60	57,22	2,26	11,61	59,49	29,79	47,94
-75	49,44	9,87	57,52	7,89	40,51	100,00	45,74	20,47
Total	500,91	100,00		19,46	100,00			

Table A-2.88: Test 18, 30-45 minutes, 12 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	51,97	10,37	59,01	0,04	0,31	0,31	60,21	-2,04
- 600 + 500	22,57	4,51	58,25	0,06	0,50	0,80	12,76	78,09
- 500 + 355	43,47	8,68	58,09	0,72	5,75	6,55	9,79	83,15
- 355 + 212	119,01	23,76	58,66	2,67	21,41	27,96	12,38	78,89
- 212 + 150	143,95	28,74	58,48	1,32	10,57	38,54	10,87	81,41
- 150 + 106	22,41	4,47	60,07	1,53	12,31	50,85	14,51	75,85
- 106 + 75	48,08	9,60	57,22	1,55	12,42	63,27	22,04	61,49
-75	49,44	9,87	57,52	4,58	36,73	100,00	54,45	5,33
Total	500,91	100,00		12,47	100,00			

Table A-2.89: Test 18, 45-60 minutes, 12 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	51,97	10,37	59,01	0,08	0,65	0,65	43,91	25,59
- 600 + 500	22,57	4,51	58,25	0,20	1,57	2,23	8,22	85,89
- 500 + 355	43,47	8,68	58,09	1,08	8,41	10,64	10,80	81,40
- 355 + 212	119,01	23,76	58,66	2,60	20,14	30,77	15,45	73,66
- 212 + 150	143,95	28,74	58,48	1,16	8,98	39,76	15,57	73,37
- 150 + 106	22,41	4,47	60,07	1,64	12,72	52,48	19,92	66,83
- 106 + 75	48,08	9,60	57,22	0,75	5,78	58,26	30,98	45,86
-75	49,44	9,87	57,52	5,39	41,74	100,00	54,12	5,90
Total	500,91	100,00		12,90	100,00			

Table A-2.90: Test 18, Underflow, 12 channels at 6 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	51,97	10,37	59,01	46,24	14,43	14,43	57,92	-1,88
- 600 + 500	22,57	4,51	58,25	20,10	6,27	20,71	58,03	-0,38
- 500 + 355	43,47	8,68	58,09	34,15	10,66	31,37	63,89	9,07
- 355 + 212	119,01	23,76	58,66	75,52	23,57	54,94	65,32	10,20
- 212 + 150	143,95	28,74	58,48	102,67	32,05	86,99	68,02	14,02
- 150 + 106	22,41	4,47	60,07	11,91	3,72	90,71	66,41	9,55
- 106 + 75	48,08	9,60	57,22	25,18	7,86	98,57	68,57	16,55
-75	49,44	9,87	57,52	4,59	1,43	100,00	74,59	22,89
Total	500,91	100,00		320,36	100,00		57,92	-1,88

Table A-2.91: Test 19, 0-15 minutes, 6 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	52,37	10,48	55,62	1,55	1,12	1,12	44,73	19,57
- 600 + 500	22,89	4,58	57,30	0,55	0,40	1,52	31,69	44,70
- 500 + 355	47,54	9,51	57,94	1,82	1,31	2,83	33,25	42,61
- 355 + 212	94,53	18,92	56,15	9,10	6,58	9,41	47,08	16,15
- 212 + 150	104,44	20,90	56,64	10,28	7,43	16,84	50,15	11,46
- 150 + 106	34,17	6,84	59,57	8,88	6,42	23,26	47,13	20,88
- 106 + 75	49,56	9,92	56,85	21,19	15,31	38,57	41,17	27,58
-75	94,22	18,85	58,99	84,99	61,43	100,00	56,43	4,32
Total	499,73			138,35	100,00			

Table A-2.92: Test 19, 15-30 minutes, 6 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	52,37	10,48	55,62	0,07	1,21	1,21	45,07	18,96
- 600 + 500	22,89	4,58	57,30	0,03	0,56	1,77	30,34	47,05
- 500 + 355	47,54	9,51	57,94	0,14	2,38	4,15	17,27	70,20
- 355 + 212	94,53	18,92	56,15	0,48	8,34	12,49	29,60	47,28
- 212 + 150	104,44	20,90	56,64	0,54	9,48	21,96	45,22	20,16
- 150 + 106	34,17	6,84	59,57	0,47	8,16	30,12	36,16	39,29
- 106 + 75	49,56	9,92	56,85	0,73	12,74	42,86	30,54	46,29
-75	94,22	18,85	58,99	3,27	57,14	100,00	57,44	2,62
Total	499,73			5,72	100,00			

Table A-2.93: Test 19, 30-45 minutes, 6 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	52,37	10,48	55,62	0,03	0,75	0,75	33,46	39,85
- 600 + 500	22,89	4,58	57,30	0,03	0,82	1,57	23,31	59,32
- 500 + 355	47,54	9,51	57,94	0,20	5,48	7,06	19,30	66,69
- 355 + 212	94,53	18,92	56,15	0,50	13,85	20,90	19,90	64,55
- 212 + 150	104,44	20,90	56,64	0,16	4,48	25,38	29,56	47,81
- 150 + 106	34,17	6,84	59,57	0,22	5,98	31,36	31,56	47,02
- 106 + 75	49,56	9,92	56,85	0,44	12,21	43,57	24,66	56,62
-75	94,22	18,85	58,99	2,04	56,43	100,00	60,35	-2,31
Total	499,73			3,61	100,00			

Table A-2.94: Test 19, 45-60 minutes, 6 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	52,37	10,48	55,62	0,05	1,76	1,76	49,68	10,67
- 600 + 500	22,89	4,58	57,30	0,02	0,79	2,56	42,65	25,56
- 500 + 355	47,54	9,51	57,94	0,05	2,06	4,62	42,08	27,38
- 355 + 212	94,53	18,92	56,15	0,18	6,94	11,56	44,61	20,56
- 212 + 150	104,44	20,90	56,64	0,11	4,24	15,80	41,40	26,91
- 150 + 106	34,17	6,84	59,57	0,16	6,17	21,96	33,84	43,19
- 106 + 75	49,56	9,92	56,85	0,40	14,85	36,81	34,47	39,36
-75	94,22	18,85	58,99	1,68	63,19	100,00	60,41	-2,41
Total	499,73			2,66	100,00			

Table A-2.95: Test 19, Underflow, 6 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	52,37	10,48	55,62	48,15	14,51	14,51	54,76	-1,57
- 600 + 500	22,89	4,58	57,30	21,15	6,37	20,88	56,41	-1,58
- 500 + 355	47,54	9,51	57,94	43,07	12,98	33,85	57,19	-1,32
- 355 + 212	94,53	18,92	56,15	80,05	24,12	57,97	52,17	-7,63
- 212 + 150	104,44	20,90	56,64	88,68	26,72	84,69	57,77	1,95
- 150 + 106	34,17	6,84	59,57	23,22	7,00	91,68	60,41	1,39
- 106 + 75	49,56	9,92	56,85	25,47	7,67	99,36	68,86	17,44
-75	94,22	18,85	58,99	2,13	0,64	100,00	69,86	15,57
Total	499,73			331,91	100,00			

Table A-2.96: Test 20, 0-15 minutes, 6 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	59,45	11,91	59,62	4,97	3,25	3,25	57,36	3,79
- 600 + 500	23,11	4,63	58,30	1,05	0,69	3,94	50,34	13,65
- 500 + 355	52,05	10,42	56,43	3,68	2,41	6,35	52,18	7,54
- 355 + 212	95,96	19,22	53,49	10,79	7,07	13,42	50,12	6,29
- 212 + 150	87,46	17,52	59,67	23,41	15,34	28,77	59,59	0,13
- 150 + 106	43,67	8,75	61,48	8,11	5,31	34,08	41,23	32,94
- 106 + 75	53,28	10,67	55,52	22,63	14,83	48,91	42,68	23,11
-75	84,29	16,88	58,97	77,94	51,09	100,00	56,89	3,52
Total	499,26	100		152,56	100,00			

Table A-2.97: Test 20, 15-30 minutes, 6 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	59,45	11,91	59,62	0,04	1,17	1,17	33,33	44,09
- 600 + 500	23,11	4,63	58,30	0,04	1,24	2,41	30,54	47,62
- 500 + 355	52,05	10,42	56,43	0,12	3,60	6,01	23,53	58,30
- 355 + 212	95,96	19,22	53,49	0,35	9,98	15,99	30,07	43,78
- 212 + 150	87,46	17,52	59,67	0,21	6,15	22,14	40,55	32,04
- 150 + 106	43,67	8,75	61,48	0,27	7,84	29,98	36,27	41,00
- 106 + 75	53,28	10,67	55,52	0,62	17,88	47,87	24,68	55,54
-75	84,29	16,88	58,97	1,80	52,13	100,00	58,38	1,01
Total	499,26	100		3,46	100,00			

Table A-2.98: Test 20, 30-45 minutes, 6 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	59,45	11,91	59,62	0,03	2,92	2,92	62,61	-5,03
- 600 + 500	23,11	4,63	58,30	0,01	1,32	4,25	40,94	29,78
- 500 + 355	52,05	10,42	56,43	0,02	1,81	6,06	34,80	38,33
- 355 + 212	95,96	19,22	53,49	0,05	4,06	10,12	47,48	11,23
- 212 + 150	87,46	17,52	59,67	0,03	2,30	12,42	42,08	29,47
- 150 + 106	43,67	8,75	61,48	0,07	6,30	18,72	28,07	54,34
- 106 + 75	53,28	10,67	55,52	0,24	21,05	39,77	22,03	60,31
-75	84,29	16,88	58,97	0,68	60,23	100,00	63,24	-7,24
Total	499,26	100		1,13	100,00			

Table A-2.99: Test 20, 45-60 minutes, 6 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	59,45	11,91	59,62	0,04	3,93	3,93	61,44	-3,05
- 600 + 500	23,11	4,63	58,30	0,02	1,58	5,50	47,02	19,35
- 500 + 355	52,05	10,42	56,43	0,05	4,97	10,48	34,03	39,69
- 355 + 212	95,96	19,22	53,49	0,11	11,61	22,09	37,59	29,72
- 212 + 150	87,46	17,52	59,67	0,04	3,76	25,85	48,06	19,46
- 150 + 106	43,67	8,75	61,48	0,07	7,15	33,00	30,51	50,37
- 106 + 75	53,28	10,67	55,52	0,18	18,97	51,97	20,48	63,10
-75	84,29	16,88	58,97	0,46	48,03	100,00	67,67	-14,75
Total	499,26	100		0,96	100,00			

Table A-2.100: Test 20, Underflow, 6 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	59,45	11,91	59,62	51,66	15,94	15,94	56,49	-5,54
- 600 + 500	23,11	4,63	58,30	20,89	6,45	22,38	58,83	0,89
- 500 + 355	52,05	10,42	56,43	45,77	14,12	36,51	59,75	5,56
- 355 + 212	95,96	19,22	53,49	80,43	24,82	61,32	51,90	-3,05
- 212 + 150	87,46	17,52	59,67	60,59	18,69	80,02	53,42	-11,70
- 150 + 106	43,67	8,75	61,48	33,40	10,31	90,32	55,14	-11,50
- 106 + 75	53,28	10,67	55,52	28,13	8,68	99,00	65,71	15,52
-75	84,29	16,88	58,97	3,24	1,00	100,00	75,16	21,54
Total	499,26	100		324,10	100,00			

Table A-2.101: Test 21, 0-15 minutes, 6 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	**0-15 minutes**				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	63,29	12,68	52,38	0,13	0,09	0,09	30,49	41,79
- 600 + 500	26,02	5,21	53,44	0,10	0,07	0,16	28,57	46,53
- 500 + 355	54,32	10,88	55,91	0,26	0,18	0,34	21,40	61,71
- 355 + 212	108,97	21,83	52,90	2,66	1,83	2,16	52,95	-0,08
- 212 + 150	71,40	14,30	59,74	11,32	7,78	9,95	59,23	0,85
- 150 + 106	32,42	6,49	57,07	13,49	9,28	19,22	54,50	4,51
- 106 + 75	42,72	8,56	55,66	21,46	14,76	33,98	47,02	15,53
-75	100,04	20,04	58,58	96,01	66,02	100,00	56,40	3,73
Total	499,19	100		145,43	100,00			

Table A-2.102: Test 21, 15-30 minutes, 6 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	**15-30 minutes**				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	63,29	12,68	52,38	0,02	0,76	0,76	58,22	-11,16
- 600 + 500	26,02	5,21	53,44	0,02	0,57	1,33	35,67	33,25
- 500 + 355	54,32	10,88	55,91	0,05	1,66	2,99	27,47	50,86
- 355 + 212	108,97	21,83	52,90	0,15	5,15	8,15	25,15	52,47
- 212 + 150	71,40	14,30	59,74	0,11	3,64	11,79	32,90	44,92
- 150 + 106	32,42	6,49	57,07	0,27	9,18	20,97	25,17	55,89
- 106 + 75	42,72	8,56	55,66	0,56	18,76	39,72	22,83	58,98
-75	100,04	20,04	58,58	1,79	60,28	100,00	60,75	-3,70
Total	499,19	100		2,98	100,00			

Table A-2.103: Test 21, 30-45 minutes, 6 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	63,29	12,68	52,38	0,00	0,31	0,31	42,86	18,18
- 600 + 500	26,02	5,21	53,44	0,01	0,73	1,04	39,76	25,60
- 500 + 355	54,32	10,88	55,91	0,02	2,06	3,10	37,34	33,21
- 355 + 212	108,97	21,83	52,90	0,06	5,23	8,33	43,34	18,08
- 212 + 150	71,40	14,30	59,74	0,04	3,23	11,56	43,44	27,28
- 150 + 106	32,42	6,49	57,07	0,11	9,69	21,25	32,85	42,44
- 106 + 75	42,72	8,56	55,66	0,27	23,54	44,80	24,39	56,18
-75	100,04	20,04	58,58	0,63	55,20	100,00	67,15	-14,63
Total	499,19	100		1,13	100,00			

Table A-2.104: Test 21, 45-60 minutes, 6 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	63,29	12,68	52,38	0,02	1,94	1,94	56,02	-6,96
- 600 + 500	26,02	5,21	53,44	0,01	0,77	2,71	9,09	82,99
- 500 + 355	54,32	10,88	55,91	0,01	0,92	3,63	21,52	61,51
- 355 + 212	108,97	21,83	52,90	0,02	2,85	6,47	4,10	92,25
- 212 + 150	71,40	14,30	59,74	0,02	2,62	9,10	40,44	32,30
- 150 + 106	32,42	6,49	57,07	0,09	10,57	19,67	17,44	69,44
- 106 + 75	42,72	8,56	55,66	0,20	23,43	43,09	20,22	63,67
-75	100,04	20,04	58,58	0,49	56,91	100,00	68,92	-17,66
Total	499,19	100		0,86	100,00			

Table A-2.105: Test 21, Underflow, 6 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	63,29	12,68	52,38	59,97	18,10	18,10	55,74	6,03
- 600 + 500	26,02	5,21	53,44	24,60	7,42	25,52	50,31	-6,21
- 500 + 355	54,32	10,88	55,91	51,28	15,48	41,00	55,89	-0,03
- 355 + 212	108,97	21,83	52,90	100,77	30,41	71,41	59,71	11,39
- 212 + 150	71,40	14,30	59,74	56,92	17,18	88,59	60,63	1,47
- 150 + 106	32,42	6,49	57,07	17,53	5,29	93,88	60,05	4,96
- 106 + 75	42,72	8,56	55,66	19,22	5,80	99,68	68,15	18,33
-75	100,04	20,04	58,58	1,06	0,32	100,00	77,08	24,00
Total	499,19	100		331,36	100,00			

Table A-2.106: Test 22, 0-15 minutes, 8 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	72,00	14,39	55,84	0,60	0,56	0,56	54,81	1,84
- 600 + 500	31,13	6,22	54,68	0,33	0,31	0,87	51,15	6,45
- 500 + 355	63,41	12,68	53,72	0,60	0,56	1,42	50,44	6,12
- 355 + 212	126,19	25,23	60,42	16,85	15,67	17,10	59,76	1,09
- 212 + 150	97,60	19,51	59,55	29,40	27,34	44,44	58,42	1,90
- 150 + 106	31,31	6,26	57,07	3,75	3,49	47,92	55,59	2,60
- 106 + 75	22,07	4,41	58,12	11,78	10,96	58,88	53,07	8,69
-75	56,50	11,30	58,50	44,21	41,12	100,00	53,61	8,35
Total	500,22	100		107,52	100,00			

Table A-2.107: Test 22, 15-30 minutes, 8 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	72,00	14,39	55,84	0,02	0,83	0,83	54,96	1,58
- 600 + 500	31,13	6,22	54,68	0,01	0,44	1,27	47,66	12,85
- 500 + 355	63,41	12,68	53,72	0,03	1,19	2,47	43,68	18,70
- 355 + 212	126,19	25,23	60,42	0,10	3,43	5,89	48,70	19,40
- 212 + 150	97,60	19,51	59,55	0,11	3,82	9,71	52,29	12,20
- 150 + 106	31,31	6,26	57,07	0,23	7,76	17,48	43,83	23,20
- 106 + 75	22,07	4,41	58,12	0,54	18,64	36,12	26,47	54,45
-75	56,50	11,30	58,50	1,86	63,88	100,00	57,48	1,73
Total	500,22	100		2,91	100,00			

Table A-2.108: Test 22, 30-45 minutes, 8 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	72,00	14,39	55,84	0,04	1,43	1,43	65,50	-17,30
- 600 + 500	31,13	6,22	54,68	0,02	0,70	2,13	67,46	-23,37
- 500 + 355	63,41	12,68	53,72	0,08	2,63	4,76	74,37	-38,43
- 355 + 212	126,19	25,23	60,42	0,16	5,46	10,22	70,55	-16,75
- 212 + 150	97,60	19,51	59,55	0,10	3,46	13,68	51,01	14,34
- 150 + 106	31,31	6,26	57,07	0,24	7,99	21,67	28,90	49,36
- 106 + 75	22,07	4,41	58,12	0,66	21,89	43,56	20,62	64,52
-75	56,50	11,30	58,50	1,69	56,44	100,00	55,85	4,52
Total`	500,22	100		2,99	100,00			

Table A-2.109: Test 22, 45-60 minutes, 8 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	72,00	14,39	55,84	0,01	0,57	0,57	30,00	46,28
- 600 + 500	31,13	6,22	54,68	0,01	0,43	1,00	36,90	32,51
- 500 + 355	63,41	12,68	53,72	0,02	0,99	1,99	40,41	24,77
- 355 + 212	126,19	25,23	60,42	0,05	2,73	4,72	43,96	27,24
- 212 + 150	97,60	19,51	59,55	0,07	3,50	8,22	40,09	32,69
- 150 + 106	31,31	6,26	57,07	0,20	10,40	18,61	18,00	68,46
- 106 + 75	22,07	4,41	58,12	0,59	30,18	48,80	16,54	71,54
-75	56,50	11,30	58,50	1,00	51,20	100,00	59,26	-1,31
Total	500,22	100		1,94	100,00			

Table A-2.110: Test 22, Underflow, 8 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	72,00	14,39	55,84	67,76	18,53	18,53	53,15	-5,06
- 600 + 500	31,13	6,22	54,68	29,22	7,99	26,53	53,41	-2,38
- 500 + 355	63,41	12,68	53,72	59,55	16,29	42,81	49,04	-9,56
- 355 + 212	126,19	25,23	60,42	103,57	28,33	71,14	45,95	-31,50
- 212 + 150	97,60	19,51	59,55	64,53	17,65	88,79	45,03	-32,26
- 150 + 106	31,31	6,26	57,07	25,55	6,99	95,78	59,84	4,63
- 106 + 75	22,07	4,41	58,12	8,07	2,21	97,99	65,68	11,51
-75	56,50	11,30	58,50	7,36	2,01	100,00	75,84	22,86
Total	500,22	100		365,61	100,00			

Table A-2.111: Test 23, 0-15 minutes, 8 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	55,35	11,08	57,91	0,18	0,14	0,14	35,57	38,57
- 600 + 500	24,09	4,82	57,48	0,11	0,08	0,22	25,89	54,96
- 500 + 355	49,72	9,95	57,28	0,24	0,19	0,41	18,48	67,74
- 355 + 212	108,47	21,71	56,29	1,77	1,35	1,76	44,82	20,38
- 212 + 150	79,66	15,94	60,83	3,87	2,95	4,70	58,73	3,46
- 150 + 106	25,80	5,16	60,06	4,25	3,24	7,94	54,49	9,28
- 106 + 75	18,28	3,66	55,15	8,65	6,60	14,54	50,48	8,47
-75	138,28	27,67	57,86	112,06	85,46	100,00	56,53	2,29
Total	499,65	100		131,13	100,00			

Table A-2.112: Test 23, 15-30 minutes, 8 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	55,35	11,08	57,91	0,04	0,85	0,85	26,84	53,66
- 600 + 500	24,09	4,82	57,48	0,03	0,55	1,39	20,39	64,52
- 500 + 355	49,72	9,95	57,28	0,08	1,76	3,16	23,79	58,47
- 355 + 212	108,47	21,71	56,29	0,31	6,70	9,86	33,21	41,01
- 212 + 150	79,66	15,94	60,83	0,26	5,58	15,44	39,41	35,21
- 150 + 106	25,80	5,16	60,06	0,32	6,90	22,33	25,75	57,14
- 106 + 75	18,28	3,66	55,15	0,90	19,27	41,60	15,78	71,39
-75	138,28	27,67	57,86	2,73	58,40	100,00	57,11	1,30
Total	499,65	100		4,67	100,00			

Table A-2.113: Test 23, 30-45 minutes, 8 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	55,35	11,08	57,91	0,03	0,60	0,60	38,28	33,90
- 600 + 500	24,09	4,82	57,48	0,01	0,29	0,89	29,29	49,05
- 500 + 355	49,72	9,95	57,28	0,04	0,87	1,76	36,90	35,57
- 355 + 212	108,47	21,71	56,29	0,12	2,50	4,27	37,73	32,97
- 212 + 150	79,66	15,94	60,83	0,12	2,54	6,81	29,33	51,78
- 150 + 106	25,80	5,16	60,06	0,44	9,07	15,88	14,27	76,25
- 106 + 75	18,28	3,66	55,15	1,14	23,60	39,47	42,56	22,83
-75	138,28	27,67	57,86	2,92	60,53	100,00	60,76	-5,01
Total	499,65	100		4,82	100,00			

Table A-2.114: Test 23, 45-60 minutes, 8 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	55,35	11,08	57,91	0,01	0,74	0,74	28,05	51,56
- 600 + 500	24,09	4,82	57,48	0,01	0,53	1,26	20,34	64,62
- 500 + 355	49,72	9,95	57,28	0,03	2,66	3,93	25,93	54,74
- 355 + 212	108,47	21,71	56,29	0,01	1,09	5,02	22,13	60,68
- 212 + 150	79,66	15,94	60,83	0,04	3,56	8,58	18,64	69,36
- 150 + 106	25,80	5,16	60,06	0,14	12,66	21,24	12,54	79,13
- 106 + 75	18,28	3,66	55,15	0,32	29,09	50,33	13,04	76,36
-75	138,28	27,67	57,86	0,55	49,67	100,00	56,40	2,53
Total	499,65	100		1,12	100,00			

Table A-2.115: Test 23, Underflow, 8 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	55,35	11,08	57,91	52,33	15,39	15,39	60,78	4,72
- 600 + 500	24,09	4,82	57,48	22,74	6,69	22,08	59,17	2,86
- 500 + 355	49,72	9,95	57,28	46,86	13,78	35,86	55,01	-4,12
- 355 + 212	108,47	21,71	56,29	100,94	29,69	65,55	50,21	-12,11
- 212 + 150	79,66	15,94	60,83	71,60	21,06	86,60	51,32	-18,54
- 150 + 106	25,80	5,16	60,06	19,62	5,77	92,37	57,88	-3,77
- 106 + 75	18,28	3,66	55,15	6,91	2,03	94,41	65,47	15,77
-75	138,28	27,67	57,86	19,02	5,59	100,00	75,58	23,44
Total	499,65	100		340,03	100,00		60,78	4,72

Table A-2.116: Test 24, 0-15 minutes, 8 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	63,56	12,74	59,59	6,13	4,86	4,86	56,81	4,66
- 600 + 500	27,56	5,52	60,49	5,41	4,29	9,14	60,04	0,74
- 500 + 355	56,46	11,31	61,92	6,33	5,01	14,15	60,73	1,92
- 355 + 212	127,09	25,47	60,11	18,17	14,39	28,54	58,25	3,09
- 212 + 150	93,46	18,73	60,43	27,86	22,06	50,60	56,02	7,29
- 150 + 106	28,51	5,71	60,94	3,08	2,44	53,03	52,79	13,37
- 106 + 75	40,10	8,04	60,62	18,56	14,70	67,73	48,55	19,91
-75	62,31	12,49	57,71	40,75	32,27	100,00	54,05	6,33
Total	499,05	100,00		126,29	100,00			

Table A-2.117: Test 24, 15-30 minutes, 8 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	63,56	12,74	59,59	0,15	1,95	1,95	52,25	12,31
- 600 + 500	27,56	5,52	60,49	0,05	0,58	2,53	55,41	8,40
- 500 + 355	56,46	11,31	61,92	0,22	2,78	5,31	61,39	0,85
- 355 + 212	127,09	25,47	60,11	0,40	5,13	10,43	56,04	6,76
- 212 + 150	93,46	18,73	60,43	0,39	5,00	15,43	52,56	13,01
- 150 + 106	28,51	5,71	60,94	0,62	7,93	23,36	42,38	30,45
- 106 + 75	40,10	8,04	60,62	2,14	27,62	50,98	31,91	47,36
-75	62,31	12,49	57,71	3,81	49,02	100,00	58,31	-1,05
Total	499,05	100,00		7,76	100,00			

Table A-2.118: Test 24, 30-45 minutes, 8 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	63,56	12,74	59,59	0,04	1,02	1,02	28,50	52,17
- 600 + 500	27,56	5,52	60,49	0,02	0,48	1,50	43,41	28,24
- 500 + 355	56,46	11,31	61,92	0,03	0,85	2,35	41,49	33,00
- 355 + 212	127,09	25,47	60,11	0,11	2,80	5,15	49,95	16,89
- 212 + 150	93,46	18,73	60,43	0,18	4,86	10,01	67,77	-12,16
- 150 + 106	28,51	5,71	60,94	0,44	11,65	21,65	50,48	17,16
- 106 + 75	40,10	8,04	60,62	1,07	28,29	49,94	38,77	36,04
-75	62,31	12,49	57,71	1,89	50,06	100,00	60,67	-5,13
Total	499,05	100,00		3,78	100,00			

Table A-2.119: Test 24, 45-60 minutes, 8 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	63,56	12,74	59,59	1,20	10,00	10,00	74,82	-25,56
- 600 + 500	27,56	5,52	60,49	0,20	1,68	11,68	73,98	-22,30
- 500 + 355	56,46	11,31	61,92	0,51	4,23	15,91	75,73	-22,30
- 355 + 212	127,09	25,47	60,11	1,32	11,01	26,92	81,09	-34,91
- 212 + 150	93,46	18,73	60,43	1,57	13,15	40,08	84,07	-39,12
- 150 + 106	28,51	5,71	60,94	1,02	8,49	48,57	85,54	-40,38
- 106 + 75	40,10	8,04	60,62	1,07	8,94	57,51	79,16	-30,58
-75	62,31	12,49	57,71	5,09	42,49	100,00	86,32	-49,59
Total	499,05	100,00		11,97	100,00			

Table A-2.120: Test 24, Underflow, 8 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	63,56	12,74	59,59	53,80	16,05	16,05	52,08	-14,41
- 600 + 500	27,56	5,52	60,49	21,01	6,27	22,31	56,92	-6,27
- 500 + 355	56,46	11,31	61,92	47,41	14,14	36,45	54,54	-13,52
- 355 + 212	127,09	25,47	60,11	102,82	30,67	67,12	46,17	-30,19
- 212 + 150	93,46	18,73	60,43	60,91	18,17	85,29	51,52	-17,29
- 150 + 106	28,51	5,71	60,94	22,42	6,69	91,98	57,36	-6,22
- 106 + 75	40,10	8,04	60,62	16,56	4,94	96,92	63,48	4,50
-75	62,31	12,49	57,71	10,34	3,08	100,00	75,81	23,88
Total	499,05	100,00		335,27	100,00			

Table A-2.121: Test 25, 0-15 minutes, 12 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	82,84	16,53	59,00	2,43	1,11	1,11	18,36	68,87
- 600 + 500	67,62	13,49	57,22	5,43	2,48	3,59	9,02	84,24
- 500 + 355	42,53	8,49	60,69	16,65	7,59	11,18	15,75	74,04
- 355 + 212	86,13	17,18	59,63	43,68	19,93	31,11	23,82	60,05
- 212 + 150	45,94	9,17	61,58	36,55	16,67	47,78	37,00	39,91
- 150 + 106	34,14	6,81	63,26	21,52	9,81	57,59	40,56	35,88
- 106 + 75	57,21	11,41	62,73	26,35	12,02	69,61	54,81	12,63
-75	84,80	16,92	61,06	66,61	30,39	100,00	36,81	39,72
Total	501,21	100,00		219,23	100,00			

Table A-2.122: Test 25, 15-30 minutes, 12 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	82,84	16,53	59,00	0,20	1,03	1,03	7,40	87,45
- 600 + 500	67,62	13,49	57,22	0,42	2,19	3,22	12,07	78,90
- 500 + 355	42,53	8,49	60,69	1,01	5,20	8,42	24,47	59,68
- 355 + 212	86,13	17,18	59,63	3,79	19,63	28,04	33,57	43,71
- 212 + 150	45,94	9,17	61,58	2,31	11,97	40,02	39,53	35,81
- 150 + 106	34,14	6,81	63,26	2,34	12,13	52,14	47,29	25,24
- 106 + 75	57,21	11,41	62,73	2,52	13,05	65,19	60,08	4,22
-75	84,80	16,92	61,06	6,73	34,81	100,00	59,21	3,03
Total	501,21	100,00		19,33	100,00			

Table A-2.123: Test 25, 30-45 minutes, 12 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	82,84	16,53	59,00	0,28	2,75	2,75	15,30	74,07
- 600 + 500	67,62	13,49	57,22	0,26	2,53	5,28	14,80	74,13
- 500 + 355	42,53	8,49	60,69	0,43	4,18	9,46	31,40	48,26
- 355 + 212	86,13	17,18	59,63	1,34	13,14	22,60	48,42	18,80
- 212 + 150	45,94	9,17	61,58	1,04	10,17	32,78	53,05	13,84
- 150 + 106	34,14	6,81	63,26	1,24	12,16	44,94	55,36	12,48
- 106 + 75	57,21	11,41	62,73	1,88	18,41	63,35	54,74	12,74
-75	84,80	16,92	61,06	3,73	36,65	100,00	53,31	12,69
Total	501,21	100,00		10,19	100,00			

Table A-2.124: Test 25, 45-60 minutes, 12 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	82,84	16,53	59,00	0,28	4,18	4,18	34,74	41,12
- 600 + 500	67,62	13,49	57,22	0,16	2,42	6,60	21,65	62,16
- 500 + 355	42,53	8,49	60,69	0,22	3,26	9,86	44,11	27,32
- 355 + 212	86,13	17,18	59,63	0,69	10,29	20,15	57,41	3,72
- 212 + 150	45,94	9,17	61,58	0,60	8,91	29,06	57,18	7,14
- 150 + 106	34,14	6,81	63,26	0,81	12,08	41,13	63,23	0,05
- 106 + 75	57,21	11,41	62,73	1,21	18,02	59,15	64,46	-2,76
-75	84,80	16,92	61,06	2,74	40,85	100,00	66,10	-8,24
Total	501,21	100,00		6,70	100,00			

Table A-2.125: Test 25, Underflow, 12 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	82,84	16,53	59,00	75,68	32,41	32,41	58,21	-1,36
- 600 + 500	67,62	13,49	57,22	58,27	24,96	57,37	68,36	16,30
- 500 + 355	42,53	8,49	60,69	23,02	9,86	67,23	71,93	15,63
- 355 + 212	86,13	17,18	59,63	34,79	14,90	82,14	77,02	22,58
- 212 + 150	45,94	9,17	61,58	5,17	2,21	84,35	77,36	20,40
- 150 + 106	34,14	6,81	63,26	7,82	3,35	87,70	76,25	17,04
- 106 + 75	57,21	11,41	62,73	23,99	10,27	97,97	77,25	18,80
-75	84,80	16,92	61,06	4,73	2,03	100,00	75,68	19,32
Total	501,21	100,00		233,47	100,00			

Table A-2.126: Test 26, 0-15 minutes, 12 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	81,88	16,36	58,19	1,43	0,65	0,65	11,84	79,66
- 600 + 500	66,83	13,35	57,02	4,22	1,93	2,58	8,47	85,15
- 500 + 355	39,51	7,90	59,77	13,52	6,17	8,75	13,99	76,59
- 355 + 212	75,02	14,99	58,76	34,62	15,81	24,56	24,92	57,59
- 212 + 150	39,29	7,85	60,61	28,72	13,12	37,68	33,82	44,20
- 150 + 106	35,01	7,00	62,42	21,50	9,82	47,50	37,89	39,30
- 106 + 75	62,07	12,40	61,82	30,23	13,80	61,30	38,84	37,17
-75	100,82	20,15	60,17	84,74	38,70	100,00	55,34	8,03
Total	500,43	100,00		218,97	100,00			

Table A-2.127: Test 26, 15-30 minutes, 12 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	81,88	16,36	58,19	0,23	0,95	0,95	6,95	88,05
- 600 + 500	66,83	13,35	57,02	0,56	2,27	3,22	9,92	82,61
- 500 + 355	39,51	7,90	59,77	1,42	5,74	8,95	20,68	65,41
- 355 + 212	75,02	14,99	58,76	4,91	19,87	28,82	36,08	38,59
- 212 + 150	39,29	7,85	60,61	3,03	12,28	41,10	40,56	33,08
- 150 + 106	35,01	7,00	62,42	3,25	13,17	54,28	45,30	27,42
- 106 + 75	62,07	12,40	61,82	3,87	15,68	69,96	58,93	4,68
-75	100,82	20,15	60,17	7,42	30,04	100,00	77,52	-28,85
Total	500,43	100,00		24,69	100,00			

Table A-2.128: Test 26, 30-45 minutes, 12 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	81,88	16,36	58,19	0,16	1,14	1,14	17,74	69,51
- 600 + 500	66,83	13,35	57,02	0,22	1,61	2,75	16,51	71,05
- 500 + 355	39,51	7,90	59,77	0,54	3,86	6,62	24,47	59,07
- 355 + 212	75,02	14,99	58,76	2,48	17,88	24,50	44,59	24,11
- 212 + 150	39,29	7,85	60,61	1,96	14,12	38,61	50,82	16,16
- 150 + 106	35,01	7,00	62,42	2,04	14,71	53,33	57,08	8,56
- 106 + 75	62,07	12,40	61,82	2,41	17,43	70,75	53,42	13,58
-75	100,82	20,15	60,17	4,05	29,25	100,00	53,54	11,02
Total	500,43	100,00		13,85	100,00			

Table A-2.129: Test 26, 45-60 minutes, 12 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	81,88	16,36	58,19	0,46	3,81	3,81	67,90	-16,69
- 600 + 500	66,83	13,35	57,02	0,35	2,88	6,69	50,35	11,71
- 500 + 355	39,51	7,90	59,77	0,86	7,16	13,85	52,16	12,74
- 355 + 212	75,02	14,99	58,76	2,45	20,31	34,16	54,03	8,04
- 212 + 150	39,29	7,85	60,61	1,51	12,51	46,67	57,72	4,77
- 150 + 106	35,01	7,00	62,42	1,60	13,24	59,91	60,13	3,66
- 106 + 75	62,07	12,40	61,82	1,91	15,79	75,71	61,70	0,19
-75	100,82	20,15	60,17	2,93	24,29	100,00	59,15	1,68
Total	500,43	100,00		12,08	100,00			

Table A-2.130: Test 26, Underflow, 12 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	81,88	16,36	58,19	75,62	34,48	34,48	59,75	2,61
- 600 + 500	66,83	13,35	57,02	58,41	26,63	61,12	66,13	13,77
- 500 + 355	39,51	7,90	59,77	22,02	10,04	71,16	72,79	17,89
- 355 + 212	75,02	14,99	58,76	29,04	13,24	84,40	73,88	20,47
- 212 + 150	39,29	7,85	60,61	3,87	1,76	86,16	73,54	17,58
- 150 + 106	35,01	7,00	62,42	6,29	2,87	89,03	76,04	17,91
- 106 + 75	62,07	12,40	61,82	22,47	10,24	99,27	75,49	18,11
-75	100,82	20,15	60,17	1,59	0,73	100,00	73,26	17,87
Total	500,43	100,00		219,30	100,00			

Table A-2.131: Test 27, 0-15 minutes, 12 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	83,32	16,70	58,97	11,10	5,09	5,09	50,32	14,67
- 600 + 500	68,01	13,63	57,42	8,74	4,01	9,10	30,57	46,75
- 500 + 355	45,30	9,08	60,56	20,96	9,61	18,70	24,41	59,69
- 355 + 212	96,71	19,38	59,52	45,41	20,82	39,52	31,26	47,48
- 212 + 150	42,32	8,48	62,12	28,72	13,17	52,68	41,63	32,98
- 150 + 106	43,05	8,63	62,00	27,58	12,64	65,32	34,96	43,61
- 106 + 75	52,03	10,43	62,63	22,42	10,28	75,60	40,48	35,38
-75	68,33	13,69	60,91	53,23	24,40	100,00	53,10	12,82
Total	499,07	100		218,15	100,00			

Table A-2.132: Test 27, 15-30 minutes, 12 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	83,32	16,70	58,97	0,30	1,03	1,03	11,62	80,29
- 600 + 500	68,01	13,63	57,42	0,70	2,39	3,42	11,97	79,16
- 500 + 355	45,30	9,08	60,56	1,36	4,69	8,11	31,89	47,34
- 355 + 212	96,71	19,38	59,52	6,74	23,17	31,28	46,65	21,63
- 212 + 150	42,32	8,48	62,12	4,45	15,29	46,57	46,98	24,37
- 150 + 106	43,05	8,63	62,00	3,60	12,37	58,94	53,12	14,33
- 106 + 75	52,03	10,43	62,63	4,50	15,48	74,41	59,20	5,49
-75	68,33	13,69	60,91	7,44	25,59	100,00	62,15	-2,04
Total	499,07	100		29,08	100,00			

Table A-2.133: Test 27, 30-45 minutes, 12 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	83,32	16,70	58,97	0,09	0,81	0,81	12,43	78,92
- 600 + 500	68,01	13,63	57,42	0,13	1,22	2,03	13,97	75,66
- 500 + 355	45,30	9,08	60,56	0,26	2,39	4,42	30,86	49,04
- 355 + 212	96,71	19,38	59,52	2,29	21,05	25,47	54,73	8,05
- 212 + 150	42,32	8,48	62,12	1,88	17,31	42,78	56,46	9,11
- 150 + 106	43,05	8,63	62,00	1,73	15,92	58,71	55,02	11,25
- 106 + 75	52,03	10,43	62,63	1,86	17,12	75,83	55,33	11,67
-75	68,33	13,69	60,91	2,63	24,17	100,00	57,43	5,72
Total	499,07	100		10,89	100,00			

Table A-2.134: Test 27, 45-60 minutes, 12 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	83,32	16,70	58,97	0,08	0,94	0,94	26,49	55,08
- 600 + 500	68,01	13,63	57,42	0,12	1,54	2,48	29,67	48,33
- 500 + 355	45,30	9,08	60,56	0,16	1,93	4,41	58,82	2,87
- 355 + 212	96,71	19,38	59,52	1,13	13,98	18,39	58,55	1,63
- 212 + 150	42,32	8,48	62,12	1,25	15,54	33,93	58,38	6,01
- 150 + 106	43,05	8,63	62,00	1,06	13,22	47,15	57,94	6,55
- 106 + 75	52,03	10,43	62,63	1,73	21,47	68,62	57,12	8,80
-75	68,33	13,69	60,91	2,53	31,38	100,00	58,98	3,16
Total	499,07	100		8,05	100,00			

Table A-2.135: Test 27, Underflow, 12 channels at 9 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	83,32	16,70	58,97	68,17	30,81	30,81	60,43	2,42
- 600 + 500	68,01	13,63	57,42	55,40	25,04	55,85	62,91	8,73
- 500 + 355	45,30	9,08	60,56	21,43	9,69	65,54	74,36	18,56
- 355 + 212	96,71	19,38	59,52	39,09	17,67	83,20	78,70	24,38
- 212 + 150	42,32	8,48	62,12	5,71	2,58	85,79	77,23	19,57
- 150 + 106	43,05	8,63	62,00	8,63	3,90	89,69	78,20	20,72
- 106 + 75	52,03	10,43	62,63	20,44	9,24	98,93	78,59	20,30
-75	68,33	13,69	60,91	2,38	1,07	100,00	77,41	21,32
Total	499,07	100		221,26	100,00			

Table A-2.136: Test 28, 0-15 minutes, 6 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	68,47	13,73	65,40	1,66	1,03	1,03	64,25	1,76
- 600 + 500	30,54	6,12	62,63	0,21	0,13	1,15	59,10	5,63
- 500 + 355	40,92	8,20	62,68	0,48	0,30	1,45	58,32	6,96
- 355 + 212	95,93	19,23	63,35	5,05	3,12	4,56	62,76	0,94
- 212 + 150	54,14	10,86	54,82	7,13	4,40	8,96	51,17	6,67
- 150 + 106	27,98	5,61	54,66	9,14	5,64	14,60	33,26	39,15
- 106 + 75	52,78	10,58	57,78	25,10	15,50	30,10	50,19	13,15
-75	128,01	25,66	65,08	113,22	69,90	100,00	64,42	1,02
Total	498,77	100,00		161,97	100,00			

Table A-2.137: Test 28, 15-30 minutes, 6 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	68,47	13,73	65,40	0,05	1,49	1,49	61,32	6,24
- 600 + 500	30,54	6,12	62,63	0,06	1,75	3,23	70,19	-12,08
- 500 + 355	40,92	8,20	62,68	0,09	2,53	5,77	80,18	-27,92
- 355 + 212	95,93	19,23	63,35	0,20	5,49	11,26	68,30	-7,81
- 212 + 150	54,14	10,86	54,82	0,27	7,49	18,74	41,37	24,53
- 150 + 106	27,98	5,61	54,66	0,59	16,40	35,14	31,98	41,49
- 106 + 75	52,78	10,58	57,78	0,66	18,48	53,62	50,34	12,88
-75	128,01	25,66	65,08	1,65	46,38	100,00	75,63	-16,21
Total	498,77	100,00		3,57	100,00			

Table A-2.138: Test 28, 30-45 minutes, 6 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	68,47	13,73	65,40	0,06	1,55	1,55	65,29	0,17
- 600 + 500	30,54	6,12	62,63	0,02	0,61	2,16	65,45	-4,51
- 500 + 355	40,92	8,20	62,68	0,03	0,83	2,99	63,88	-1,92
- 355 + 212	95,93	19,23	63,35	0,10	2,78	5,77	31,13	50,86
- 212 + 150	54,14	10,86	54,82	0,42	11,82	17,59	35,40	35,43
- 150 + 106	27,98	5,61	54,66	0,74	20,62	38,21	27,09	50,44
- 106 + 75	52,78	10,58	57,78	0,73	20,34	58,56	48,86	15,45
-75	128,01	25,66	65,08	1,49	41,44	100,00	77,33	-18,83
Total	498,77	100,00		3,59	100,00			

Table A-2.139: Test 28, 45-60 minutes, 6 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	**45-60 minutes**				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	68,47	13,73	65,40	0,04	1,43	1,43	67,49	-3,19
- 600 + 500	30,54	6,12	62,63	0,04	1,52	2,95	58,97	5,83
- 500 + 355	40,92	8,20	62,68	0,09	3,50	6,45	44,83	28,48
- 355 + 212	95,93	19,23	63,35	0,35	13,62	20,07	53,86	14,98
- 212 + 150	54,14	10,86	54,82	0,21	8,29	28,37	47,42	13,51
- 150 + 106	27,98	5,61	54,66	0,33	12,72	41,08	45,69	16,40
- 106 + 75	52,78	10,58	57,78	0,39	15,06	56,14	65,92	-14,07
-75	128,01	25,66	65,08	1,13	43,86	100,00	82,73	-27,12
Total	498,77	100,00		2,57	100,00			

Table A-2.140: Test 28, Underflow, 6 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	**Remains (Underflow)**				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	68,47	13,73	65,40	63,34	20,38	20,38	50,67	-29,07
- 600 + 500	30,54	6,12	62,63	28,70	9,24	29,62	54,14	-15,68
- 500 + 355	40,92	8,20	62,68	38,22	12,30	41,92	53,85	-16,40
- 355 + 212	95,93	19,23	63,35	85,72	27,59	69,51	55,16	-14,86
- 212 + 150	54,14	10,86	54,82	43,81	14,10	83,61	58,20	5,81
- 150 + 106	27,98	5,61	54,66	16,33	5,26	88,87	63,46	13,87
- 106 + 75	52,78	10,58	57,78	24,60	7,92	96,78	76,40	24,36
-75	128,01	25,66	65,08	9,99	3,22	100,00	74,89	13,10
Total	498,77	100,00		310,72	100,00			

Table A-2.141: Test 29, 0-15 minutes, 6 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	66,42	13,26	61,19	1,34	0,83	0,83	60,64	0,90
- 600 + 500	29,26	5,84	57,93	0,30	0,19	1,01	56,13	3,11
- 500 + 355	53,02	10,59	55,59	0,43	0,26	1,28	53,04	4,58
- 355 + 212	93,83	18,74	55,54	3,35	2,07	3,35	55,10	0,79
- 212 + 150	41,64	8,32	54,56	6,75	4,17	7,52	42,15	22,74
- 150 + 106	38,96	7,78	54,65	7,22	4,46	11,98	16,33	70,13
- 106 + 75	44,25	8,84	57,48	22,79	14,08	26,07	41,66	27,53
-75	133,38	26,64	58,41	119,63	73,93	100,00	57,32	1,87
Total	500,76	100		161,80	100,00			

Table A-2.142: Test 29, 15-30 minutes, 6 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	66,42	13,26	61,19	0,02	0,75	0,75	51,49	15,87
- 600 + 500	29,26	5,84	57,93	0,01	0,39	1,15	65,71	-13,43
- 500 + 355	53,02	10,59	55,59	0,03	0,97	2,11	69,88	-25,72
- 355 + 212	93,83	18,74	55,54	0,08	3,14	5,25	48,03	13,52
- 212 + 150	41,64	8,32	54,56	0,25	9,28	14,53	13,81	74,68
- 150 + 106	38,96	7,78	54,65	0,55	20,61	35,14	19,20	64,87
- 106 + 75	44,25	8,84	57,48	0,65	24,22	59,36	52,61	8,47
-75	133,38	26,64	58,41	1,09	40,64	100,00	77,27	-32,29
Total	500,76	100		2,68	100,00			

Table A-2.143: Test 29, 30-45 minutes, 6 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	66,42	13,26	61,19	0,02	0,81	0,81	71,86	-17,43
- 600 + 500	29,26	5,84	57,93	0,03	1,05	1,86	74,03	-27,79
- 500 + 355	53,02	10,59	55,59	0,01	0,61	2,46	59,06	-6,25
- 355 + 212	93,83	18,74	55,54	0,07	2,68	5,14	25,04	54,92
- 212 + 150	41,64	8,32	54,56	0,31	12,42	17,56	11,02	79,81
- 150 + 106	38,96	7,78	54,65	0,55	22,24	39,80	16,40	69,99
- 106 + 75	44,25	8,84	57,48	0,45	18,46	58,26	43,75	23,89
-75	133,38	26,64	58,41	1,03	41,74	100,00	75,51	-29,28
Total	500,76	100		2,46	100,00			

Table A-2.144: Test 29, 45-60 minutes, 6 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	66,42	13,26	61,19	0,01	1,08	1,08	26,05	57,43
- 600 + 500	29,26	5,84	57,93	0,01	0,65	1,73	58,33	-0,69
- 500 + 355	53,02	10,59	55,59	0,01	0,81	2,54	58,89	-5,94
- 355 + 212	93,83	18,74	55,54	0,04	3,57	6,12	53,92	2,91
- 212 + 150	41,64	8,32	54,56	0,11	9,92	16,04	12,12	77,78
- 150 + 106	38,96	7,78	54,65	0,23	20,80	36,84	17,27	68,40
- 106 + 75	44,25	8,84	57,48	0,21	19,25	56,09	47,18	17,92
-75	133,38	26,64	58,41	0,49	43,91	100,00	76,43	-30,85
Total	500,76	100		1,11	100,00			

Table A-2.145: Test 29, Underflow, 6 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	66,42	13,26	61,19	62,43	19,54	19,54	51,26	-19,37
- 600 + 500	29,26	5,84	57,93	27,76	8,69	28,24	54,22	-6,84
- 500 + 355	53,02	10,59	55,59	50,45	15,79	44,03	54,89	-1,27
- 355 + 212	93,83	18,74	55,54	86,68	27,14	71,17	52,06	-6,69
- 212 + 150	41,64	8,32	54,56	32,85	10,29	81,45	55,93	2,45
- 150 + 106	38,96	7,78	54,65	29,19	9,14	90,59	68,30	19,98
- 106 + 75	44,25	8,84	57,48	19,34	6,05	96,65	75,18	23,54
-75	133,38	26,64	58,41	10,71	3,35	100,00	75,02	22,15
Total	500,76	100		319,40	100,00			

Table A-2.146: Test 30, 0-15 minutes, 6 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	62,22	12,40	58,91	1,88	1,20	1,20	56,59	3,94
- 600 + 500	23,14	4,61	54,99	0,19	0,12	1,33	33,42	39,23
- 500 + 355	59,31	11,82	58,61	2,68	1,71	3,04	57,14	2,51
- 355 + 212	98,99	19,73	50,83	4,54	2,90	5,94	40,69	19,95
- 212 + 150	53,72	10,71	53,51	7,58	4,84	10,78	37,66	29,63
- 150 + 106	41,83	8,34	55,67	13,58	8,68	19,46	37,75	32,19
- 106 + 75	41,78	8,33	58,80	20,04	12,81	32,27	41,75	28,99
-75	120,78	24,07	59,45	105,97	67,73	100,00	57,53	3,23
Total	501,77	100,00		156,47	100,00			

Table A-2.147: Test 30, 15-30 minutes, 6 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	62,22	12,40	58,91	0,18	1,77	1,77	54,38	7,69
- 600 + 500	23,14	4,61	54,99	0,05	0,46	2,23	64,73	-17,71
- 500 + 355	59,31	11,82	58,61	0,08	0,81	3,04	42,15	28,09
- 355 + 212	98,99	19,73	50,83	0,79	7,88	10,92	11,55	77,27
- 212 + 150	53,72	10,71	53,51	1,85	18,52	29,44	1,46	97,27
- 150 + 106	41,83	8,34	55,67	1,93	19,25	48,69	24,66	55,70
- 106 + 75	41,78	8,33	58,80	1,83	18,30	66,99	55,49	5,63
-75	120,78	24,07	59,45	3,31	33,01	100,00	77,10	-29,69
Total	501,77	100,00		10,01	100,00			

Table A-2.148: Test 30, 30-45 minutes, 6 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	62,22	12,40	58,91	0,02	1,53	1,53	55,25	6,21
- 600 + 500	23,14	4,61	54,99	0,01	0,95	2,48	38,94	29,19
- 500 + 355	59,31	11,82	58,61	0,02	1,55	4,03	58,15	0,79
- 355 + 212	98,99	19,73	50,83	0,06	5,36	9,39	49,13	3,34
- 212 + 150	53,72	10,71	53,51	0,10	8,73	18,11	20,77	61,18
- 150 + 106	41,83	8,34	55,67	0,19	15,99	34,10	20,68	62,86
- 106 + 75	41,78	8,33	58,80	0,19	16,22	50,32	44,41	24,47
-75	120,78	24,07	59,45	0,59	49,68	100,00	72,69	-22,27
Total	501,77	100,00		1,19	100,00			

Table A-2.149: Test 30, 45-60 minutes, 6 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	62,22	12,40	58,91	0,01	1,46	1,46	25,19	57,24
- 600 + 500	23,14	4,61	54,99	0,02	2,60	4,06	82,83	-50,63
- 500 + 355	59,31	11,82	58,61	0,02	1,73	5,79	73,55	-25,48
- 355 + 212	98,99	19,73	50,83	0,04	4,07	9,85	38,63	24,00
- 212 + 150	53,72	10,71	53,51	0,09	9,49	19,34	20,68	61,35
- 150 + 106	41,83	8,34	55,67	0,16	17,43	36,77	25,00	55,09
- 106 + 75	41,78	8,33	58,80	0,13	15,00	51,78	44,62	24,11
-75	120,78	24,07	59,45	0,43	48,22	100,00	7,07	88,11
Total	501,77	100,00		0,90	100,00			

Table A-2.150: Test 30, Underflow, 6 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	62,22	12,40	58,91	57,73	18,05	18,05	54,01	-9,06
- 600 + 500	23,14	4,61	54,99	21,95	6,86	24,91	52,85	-4,05
- 500 + 355	59,31	11,82	58,61	54,25	16,96	41,87	50,47	-16,14
- 355 + 212	98,99	19,73	50,83	89,82	28,08	69,95	55,70	8,74
- 212 + 150	53,72	10,71	53,51	42,34	13,24	83,18	64,79	17,41
- 150 + 106	41,83	8,34	55,67	24,94	7,80	90,98	68,18	18,35
- 106 + 75	41,78	8,33	58,80	18,79	5,87	96,86	76,65	23,29
-75	120,78	24,07	59,45	10,06	3,14	100,00	75,54	21,31
Total	501,77	100,00		319,88	100,00			

Table A-2.151: Test 31, 0-15 minutes, 8 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	38,49	7,71	58,89	1,41	0,88	0,88	49,56	15,83
- 600 + 500	22,72	4,55	58,19	0,35	0,22	1,10	20,43	64,89
- 500 + 355	53,28	10,67	58,84	0,77	0,48	1,58	13,14	77,67
- 355 + 212	122,85	24,60	57,92	6,07	3,80	5,38	42,80	26,10
- 212 + 150	74,53	14,92	58,42	6,86	4,29	9,67	40,02	31,49
- 150 + 106	29,60	5,93	59,35	7,97	4,98	14,65	21,11	64,42
- 106 + 75	31,56	6,32	58,22	24,89	15,55	30,20	40,89	29,77
-75	126,36	25,30	58,66	111,68	69,80	100,00	56,55	3,60
Total	499,40	100,00		160,00	100,00			

Table A-2.152: Test 31, 15-30 minutes, 8 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	38,49	7,71	58,89	0,13	1,20	1,20	46,68	20,73
- 600 + 500	22,72	4,55	58,19	0,10	0,96	2,16	26,27	54,86
- 500 + 355	53,28	10,67	58,84	0,32	2,94	5,10	12,99	77,93
- 355 + 212	122,85	24,60	57,92	1,42	13,07	18,17	11,03	80,96
- 212 + 150	74,53	14,92	58,42	1,60	14,73	32,90	10,39	82,21
- 150 + 106	29,60	5,93	59,35	2,04	18,77	51,67	14,48	75,61
- 106 + 75	31,56	6,32	58,22	1,63	15,05	66,72	29,48	49,36
-75	126,36	25,30	58,66	3,61	33,28	100,00	66,14	-12,75
Total	499,40	100,00		10,84	100,00			

Table A-2.153: Test 31, 30-45 minutes, 8 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	38,49	7,71	58,89	0,03	0,64	0,64	38,66	34,36
- 600 + 500	22,72	4,55	58,19	0,03	0,63	1,27	16,45	71,73
- 500 + 355	53,28	10,67	58,84	0,09	1,92	3,19	14,06	76,11
- 355 + 212	122,85	24,60	57,92	0,63	12,97	16,16	13,00	77,56
- 212 + 150	74,53	14,92	58,42	0,93	18,96	35,12	8,45	85,54
- 150 + 106	29,60	5,93	59,35	1,11	22,63	57,75	14,03	76,36
- 106 + 75	31,56	6,32	58,22	0,72	14,77	72,53	32,53	44,13
-75	126,36	25,30	58,66	1,34	27,47	100,00	71,22	-21,41
Total	499,40	100,00		4,89	100,00			

Table A-2.154: Test 31, 45-60 minutes, 8 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	38,49	7,71	58,89	0,06	1,53	1,53	32,24	45,26
- 600 + 500	22,72	4,55	58,19	0,04	1,05	2,58	25,00	57,04
- 500 + 355	53,28	10,67	58,84	0,12	2,97	5,56	12,80	78,25
- 355 + 212	122,85	24,60	57,92	0,57	14,35	19,90	20,35	64,87
- 212 + 150	74,53	14,92	58,42	0,67	16,81	36,71	10,36	82,27
- 150 + 106	29,60	5,93	59,35	0,74	18,68	55,39	15,64	73,65
- 106 + 75	31,56	6,32	58,22	0,52	13,02	68,42	32,83	43,61
-75	126,36	25,30	58,66	1,25	31,58	100,00	70,28	-19,80
Total	499,40	100,00		3,97	100,00			

Table A-2.155: Test 31, Underflow, 8 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	38,49	7,71	58,89	35,75	11,53	11,53	52,22	-12,77
- 600 + 500	22,72	4,55	58,19	21,54	6,94	18,47	54,55	-6,68
- 500 + 355	53,28	10,67	58,84	50,42	16,26	34,73	36,23	-62,40
- 355 + 212	122,85	24,60	57,92	110,73	35,71	70,44	56,12	-3,21
- 212 + 150	74,53	14,92	58,42	62,55	20,17	90,61	63,71	8,30
- 150 + 106	29,60	5,93	59,35	17,22	5,55	96,16	69,26	14,31
- 106 + 75	31,56	6,32	58,22	3,69	1,19	97,35	75,53	22,91
-75	126,36	25,30	58,66	8,22	2,65	100,00	76,35	23,17
Total	499,40	100,00		310,10	100,00			

Table A-2.156: Test 32, 0-15 minutes, 8 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	59,61	11,91	58,89	8,70	5,12	5,12	57,28	2,74
- 600 + 500	37,18	7,43	58,19	0,88	0,52	5,64	42,05	27,74
- 500 + 355	53,18	10,62	58,84	1,75	1,03	6,67	39,03	33,67
- 355 + 212	130,70	26,10	57,92	8,44	4,97	11,64	49,78	14,06
- 212 + 150	28,30	5,65	58,42	9,35	5,51	17,14	45,63	21,90
- 150 + 106	39,09	7,81	59,35	11,64	6,85	24,00	32,74	44,83
- 106 + 75	28,56	5,70	58,22	21,65	12,75	36,75	40,50	30,44
-75	124,10	24,78	58,66	107,42	63,25	100,00	56,17	4,25
Total	500,72	100,00		169,82	100,00			

Table A-2.157: Test 32, 15-30 minutes, 8 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	59,61	11,91	58,89	0,15	1,05	1,05	51,59	12,40
- 600 + 500	37,18	7,43	58,19	0,24	1,65	2,69	65,77	-13,02
- 500 + 355	53,18	10,62	58,84	1,00	6,95	9,65	79,20	-34,61
- 355 + 212	130,70	26,10	57,92	2,14	14,86	24,51	49,49	14,57
- 212 + 150	28,30	5,65	58,42	2,37	16,39	40,90	24,57	57,94
- 150 + 106	39,09	7,81	59,35	2,68	18,56	59,45	25,61	56,84
- 106 + 75	28,56	5,70	58,22	2,17	15,03	74,48	44,01	24,40
-75	124,10	24,78	58,66	3,68	25,52	100,00	71,74	-22,30
Total	500,72	100,00		14,43	100,00			

Table A-2.158: Test 32, 30-45 minutes, 8 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	59,61	11,91	58,89	0,06	0,82	0,82	30,20	48,73
- 600 + 500	37,18	7,43	58,19	0,07	1,00	1,82	24,85	57,29
- 500 + 355	53,18	10,62	58,84	0,15	2,24	4,07	18,45	68,64
- 355 + 212	130,70	26,10	57,92	0,93	13,57	17,64	11,46	80,21
- 212 + 150	28,30	5,65	58,42	1,29	18,74	36,38	9,87	83,10
- 150 + 106	39,09	7,81	59,35	1,36	19,83	56,21	17,17	71,07
- 106 + 75	28,56	5,70	58,22	0,95	13,78	69,99	38,40	34,05
-75	124,10	24,78	58,66	2,06	30,01	100,00	73,00	-24,45
Total	500,72	100,00		6,86	100,00			

Table A-2.159: Test 32, 45-60 minutes, 8 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	59,61	11,91	58,89	0,06	1,99	1,99	56,03	4,87
- 600 + 500	37,18	7,43	58,19	0,03	0,99	2,98	32,70	43,80
- 500 + 355	53,18	10,62	58,84	0,07	2,15	5,13	19,83	66,30
- 355 + 212	130,70	26,10	57,92	0,40	12,55	17,68	13,46	76,77
- 212 + 150	28,30	5,65	58,42	0,57	17,64	35,33	11,02	81,14
- 150 + 106	39,09	7,81	59,35	0,61	19,00	54,33	18,89	68,17
- 106 + 75	28,56	5,70	58,22	0,45	14,04	68,37	39,59	32,00
-75	124,10	24,78	58,66	1,02	31,63	100,00	73,16	-24,71
Total	500,72	100,00		3,21	100,00			

Table A-2.160: Test 32, Underflow, 8 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	59,61	11,91	58,89	48,87	16,53	16,53	59,90	1,69
- 600 + 500	37,18	7,43	58,19	34,71	11,74	28,27	56,48	-3,04
- 500 + 355	53,18	10,62	58,84	48,44	16,38	44,65	57,69	-2,00
- 355 + 212	130,70	26,10	57,92	114,63	38,77	83,42	60,01	3,49
- 212 + 150	28,30	5,65	58,42	14,22	4,81	88,23	64,06	8,81
- 150 + 106	39,09	7,81	59,35	22,00	7,44	95,67	70,86	16,24
- 106 + 75	28,56	5,70	58,22	3,23	1,09	96,76	76,36	23,76
-75	124,10	24,78	58,66	9,58	3,24	100,00	78,47	25,24
Total	500,72	100,00		295,67	100,00			

Table A-2.161: Test 33, 0-15 minutes, 8 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	60,16	12,00	52,23	1,19	0,73	0,73	51,80	0,81
- 600 + 500	27,62	5,51	58,27	0,44	0,27	1,00	23,26	60,08
- 500 + 355	53,72	10,72	54,22	1,32	0,82	1,82	32,31	40,42
- 355 + 212	115,77	23,10	52,41	10,90	6,72	8,54	49,13	6,25
- 212 + 150	37,39	7,46	53,41	15,21	9,38	17,91	49,26	7,77
- 150 + 106	28,34	5,65	56,36	7,26	4,48	22,39	20,98	62,77
- 106 + 75	58,50	11,67	58,84	21,18	13,06	35,45	42,88	27,12
-75	119,74	23,89	57,66	104,69	64,55	100,00	56,59	1,85
Total	501,24	100,00		162,18	100,00			

Table A-2.162: Test 33, 15-30 minutes, 8 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	60,16	12,00	52,23	0,14	1,12	1,12	43,82	16,10
- 600 + 500	27,62	5,51	58,27	0,23	1,92	3,03	64,51	-10,71
- 500 + 355	53,72	10,72	54,22	0,71	5,88	8,91	66,33	-22,33
- 355 + 212	115,77	23,10	52,41	1,78	14,71	23,63	33,22	36,61
- 212 + 150	37,39	7,46	53,41	1,92	15,84	39,46	20,87	60,93
- 150 + 106	28,34	5,65	56,36	2,02	16,68	56,14	22,30	60,43
- 106 + 75	58,50	11,67	58,84	1,80	14,89	71,03	40,68	30,86
-75	119,74	23,89	57,66	3,51	28,97	100,00	69,83	-21,11
Total	501,24	100,00		12,11	100,00			

Table A-2.163: Test 33, 30-45 minutes, 8 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	60,16	12,00	52,23	0,08	1,04	1,04	16,54	68,33
- 600 + 500	27,62	5,51	58,27	0,08	1,08	2,12	10,12	82,63
- 500 + 355	53,72	10,72	54,22	0,32	4,28	6,39	8,39	84,52
- 355 + 212	115,77	23,10	52,41	1,33	17,64	24,04	9,85	81,21
- 212 + 150	37,39	7,46	53,41	1,18	15,71	39,75	10,88	79,63
- 150 + 106	28,34	5,65	56,36	1,39	18,54	58,29	17,21	69,47
- 106 + 75	58,50	11,67	58,84	0,97	12,95	71,24	36,67	37,68
-75	119,74	23,89	57,66	2,16	28,76	100,00	73,81	-28,02
Total	501,24	100,00		7,52	100,00			

Table A-2.164: Test 33, 45-60 minutes, 8 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	60,16	12,00	52,23	0,14	2,06	2,06	39,85	23,70
- 600 + 500	27,62	5,51	58,27	0,14	2,20	4,26	14,84	74,54
- 500 + 355	53,72	10,72	54,22	0,46	7,01	11,27	15,24	71,90
- 355 + 212	115,77	23,10	52,41	1,56	23,75	35,02	13,92	73,44
- 212 + 150	37,39	7,46	53,41	1,15	17,46	52,48	13,52	74,68
- 150 + 106	28,34	5,65	56,36	1,04	15,75	68,23	21,44	61,96
- 106 + 75	58,50	11,67	58,84	0,66	9,99	78,22	41,34	29,75
-75	119,74	23,89	57,66	1,43	21,78	100,00	74,47	-29,16
Total	501,24	100,00		6,58	100,00			

Table A-2.165: Test 33, Underflow, 8 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	60,16	12,00	52,23	56,57	18,74	18,74	55,61	6,08
- 600 + 500	27,62	5,51	58,27	25,79	8,54	27,28	58,33	0,10
- 500 + 355	53,72	10,72	54,22	49,12	16,27	43,55	56,46	3,96
- 355 + 212	115,77	23,10	52,41	96,70	32,03	75,58	54,46	3,76
- 212 + 150	37,39	7,46	53,41	17,30	5,73	81,31	69,20	22,82
- 150 + 106	28,34	5,65	56,36	16,05	5,32	86,63	72,71	22,49
- 106 + 75	58,50	11,67	58,84	32,70	10,83	97,46	76,39	22,97
-75	119,74	23,89	57,66	7,68	2,54	100,00	77,54	25,65
Total	501,24	100,00		301,91	100,00		55,61	6,08

Table A-2.166: Test 34, 0-15 minutes, 12 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	61,07	12,22	58,89	9,75	3,52	3,52	22,89	61,13
- 600 + 500	25,84	5,17	58,19	10,53	3,80	7,33	12,04	79,30
- 500 + 355	40,88	8,18	58,84	23,16	8,37	15,69	19,33	67,15
- 355 + 212	85,33	17,08	57,92	59,79	21,60	37,29	33,73	41,76
- 212 + 150	56,45	11,30	58,42	32,23	11,64	48,94	37,65	35,56
- 150 + 106	78,40	15,69	59,35	29,81	10,77	59,71	41,27	30,46
- 106 + 75	54,89	10,99	58,22	27,00	9,76	69,46	42,62	26,79
-75	96,74	19,36	58,66	84,53	30,54	100,00	55,93	4,66
Total	499,60	100,00		276,80	100,00			

Table A-2.167: Test 34, 15-30 minutes, 12 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	61,07	12,22	58,89	0,26	1,07	1,07	35,50	39,72
- 600 + 500	25,84	5,17	58,19	0,25	1,04	2,11	40,81	29,87
- 500 + 355	40,88	8,18	58,84	0,93	3,86	5,97	59,07	-0,40
- 355 + 212	85,33	17,08	57,92	6,15	25,60	31,57	68,14	-17,64
- 212 + 150	56,45	11,30	58,42	4,58	19,05	50,62	68,15	-16,66
- 150 + 106	78,40	15,69	59,35	3,92	16,34	66,96	70,66	-19,07
- 106 + 75	54,89	10,99	58,22	3,06	12,76	79,71	74,64	-28,21
-75	96,74	19,36	58,66	4,87	20,29	100,00	79,70	-35,87
Total	499,60	100,00		24,02	100,00			

Table A-2.168: Test 34, 30-45 minutes, 12 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	61,07	12,22	58,89	0,10	0,89	0,89	63,91	-8,53
- 600 + 500	25,84	5,17	58,19	0,05	0,43	1,32	34,93	39,97
- 500 + 355	40,88	8,18	58,84	0,17	1,57	2,89	46,06	21,72
- 355 + 212	85,33	17,08	57,92	2,28	21,26	24,15	75,44	-30,24
- 212 + 150	56,45	11,30	58,42	2,45	22,86	47,01	78,32	-34,07
- 150 + 106	78,40	15,69	59,35	2,46	22,98	69,99	79,51	-33,98
- 106 + 75	54,89	10,99	58,22	1,71	15,91	85,91	80,96	-39,06
-75	96,74	19,36	58,66	1,51	14,09	100,00	81,13	-38,31
Total	499,60	100,00		10,72	100,00			

Table A-2.169: Test 34, 45-60 minutes, 12 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	61,07	12,22	58,89	0,03	0,51	0,51	53,89	8,48
- 600 + 500	25,84	5,17	58,19	0,01	0,24	0,74	40,94	29,65
- 500 + 355	40,88	8,18	58,84	0,07	1,05	1,79	56,67	3,68
- 355 + 212	85,33	17,08	57,92	1,31	20,73	22,53	78,73	-35,93
- 212 + 150	56,45	11,30	58,42	1,49	23,49	46,02	81,18	-38,96
- 150 + 106	78,40	15,69	59,35	1,56	24,59	70,61	81,63	-37,54
- 106 + 75	54,89	10,99	58,22	1,00	15,73	86,34	81,97	-40,79
-75	96,74	19,36	58,66	0,87	13,66	100,00	81,53	-38,99
Total	499,60	100,00		6,34	100,00			

Table A-2.170: Test 34, Underflow, 12 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	61,07	12,22	58,89	49,41	28,03	28,03	56,98	-3,35
- 600 + 500	25,84	5,17	58,19	14,55	8,25	36,29	70,83	17,84
- 500 + 355	40,88	8,18	58,84	16,06	9,11	45,40	65,46	10,11
- 355 + 212	85,33	17,08	57,92	15,33	8,70	54,10	78,31	26,03
- 212 + 150	56,45	11,30	58,42	15,23	8,64	62,74	78,06	25,16
- 150 + 106	78,40	15,69	59,35	39,42	22,36	85,10	77,67	23,59
- 106 + 75	54,89	10,99	58,22	21,46	12,17	97,27	77,02	24,41
-75	96,74	19,36	58,66	4,81	2,73	100,00	72,36	18,93
Total	499,60	100,00		176,27	100,00			

Table A-2.171: Test 35, 0-15 minutes, 12 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	27,56	5,51	60,04	4,27	1,53	1,53	16,18	73,05
- 600 + 500	25,22	5,04	59,72	5,41	1,93	3,46	15,00	74,89
- 500 + 355	32,52	6,51	59,30	14,18	5,07	8,53	22,38	62,27
- 355 + 212	83,44	16,69	56,80	39,57	14,16	22,69	34,01	40,12
- 212 + 150	54,99	11,00	55,03	29,11	10,42	33,11	43,48	20,98
- 150 + 106	79,52	15,91	60,80	31,64	11,32	44,43	36,93	39,26
- 106 + 75	55,91	11,19	57,79	25,48	9,12	53,55	38,52	33,33
-75	140,72	28,15	58,30	129,82	46,45	100,00	56,51	3,06
Total	499,88	100,00		279,46	100,00			

Table A-2.172: Test 35, 15-30 minutes, 12 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	27,56	5,51	60,04	0,21	0,86	0,86	24,42	59,33
- 600 + 500	25,22	5,04	59,72	0,16	0,68	1,54	30,40	49,09
- 500 + 355	32,52	6,51	59,30	0,62	2,58	4,12	51,34	13,42
- 355 + 212	83,44	16,69	56,80	5,50	22,94	27,06	71,67	-26,19
- 212 + 150	54,99	11,00	55,03	4,22	17,62	44,68	71,11	-29,22
- 150 + 106	79,52	15,91	60,80	3,86	16,11	60,79	70,90	-16,63
- 106 + 75	55,91	11,19	57,79	3,77	15,72	76,51	74,22	-28,44
-75	140,72	28,15	58,30	5,63	23,49	100,00	81,87	-40,43
Total	499,88	100,00		23,96	100,00			

Table A-2.173: Test 35, 30-45 minutes, 12 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	27,56	5,51	60,04	0,03	0,20	0,20	22,68	62,22
- 600 + 500	25,22	5,04	59,72	0,03	0,17	0,37	28,52	52,25
- 500 + 355	32,52	6,51	59,30	0,15	0,98	1,34	52,61	11,28
- 355 + 212	83,44	16,69	56,80	3,97	25,60	26,94	74,92	-31,91
- 212 + 150	54,99	11,00	55,03	2,96	19,11	46,06	76,51	-39,05
- 150 + 106	79,52	15,91	60,80	3,15	20,36	66,41	77,56	-27,57
- 106 + 75	55,91	11,19	57,79	2,95	19,05	85,46	80,98	-40,13
-75	140,72	28,15	58,30	2,25	14,54	100,00	83,13	-42,59
Total	499,88	100,00		15,49	100,00			

Table A-2.174: Test 35, 45-60 minutes, 12 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	27,56	5,51	60,04	0,02	0,16	0,16	50,00	16,72
- 600 + 500	25,22	5,04	59,72	0,01	0,14	0,31	37,67	36,92
- 500 + 355	32,52	6,51	59,30	0,08	0,81	1,12	59,58	-0,48
- 355 + 212	83,44	16,69	56,80	1,78	17,60	18,71	77,87	-37,10
- 212 + 150	54,99	11,00	55,03	2,41	23,78	42,49	80,07	-45,51
- 150 + 106	79,52	15,91	60,80	2,69	26,57	69,06	81,45	-33,98
- 106 + 75	55,91	11,19	57,79	1,99	19,66	88,72	83,16	-43,91
-75	140,72	28,15	58,30	1,14	11,28	100,00	83,08	-42,51
Total	499,88	100,00		10,13	100,00			

Table A-2.175: Test 35, Underflow, 12 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	27,56	5,51	60,04	22,23	13,48	13,48	65,22	7,94
- 600 + 500	25,22	5,04	59,72	18,92	11,48	24,96	72,00	17,07
- 500 + 355	32,52	6,51	59,30	16,88	10,24	35,20	76,82	22,81
- 355 + 212	83,44	16,69	56,80	31,49	19,10	54,30	79,35	28,42
- 212 + 150	54,99	11,00	55,03	15,73	9,54	63,84	77,53	29,02
- 150 + 106	79,52	15,91	60,80	36,84	22,35	86,19	77,32	21,37
- 106 + 75	55,91	11,19	57,79	20,96	12,71	98,90	75,85	23,81
-75	140,72	28,15	58,30	1,81	1,10	100,00	66,75	12,66
Total	499,88	100,00		164,86	100,00			

Table A-2.176: Test 35, 0-15 minutes, 12 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	0-15 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	34,69	6,94	56,77	18,45	7,10	7,10	53,11	6,44
- 600 + 500	26,50	5,30	56,74	7,77	2,99	10,10	20,80	63,34
- 500 + 355	49,31	9,86	57,35	19,59	7,55	17,64	26,26	54,21
- 355 + 212	87,34	17,47	56,72	44,08	16,97	34,61	33,63	40,71
- 212 + 150	57,98	11,60	57,13	18,60	7,16	41,77	30,21	47,11
- 150 + 106	77,38	15,48	58,00	28,16	10,84	52,62	35,61	38,60
- 106 + 75	53,94	10,79	56,55	24,14	9,29	61,91	38,49	31,94
-75	112,88	22,58	59,79	98,92	38,09	100,00	55,86	6,58
Total	500,02	100,00		259,70	100,00			

Table A-2.177: Test 36, 15-30 minutes, 12 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	15-30 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	34,69	6,94	56,77	0,23	0,95	0,95	23,04	59,42
- 600 + 500	26,50	5,30	56,74	0,18	0,75	1,71	28,16	50,37
- 500 + 355	49,31	9,86	57,35	0,52	2,15	3,86	47,41	17,33
- 355 + 212	87,34	17,47	56,72	4,68	19,39	23,25	69,09	-21,80
- 212 + 150	57,98	11,60	57,13	3,91	16,21	39,45	69,56	-21,75
- 150 + 106	77,38	15,48	58,00	3,81	15,77	55,22	71,42	-23,14
- 106 + 75	53,94	10,79	56,55	3,90	16,16	71,38	76,26	-34,85
-75	112,88	22,58	59,79	6,91	28,62	100,00	81,75	-36,71
Total	500,02	100,00		24,14	100,00			

Table A-2.178: Test 36, 30-45 minutes, 12 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	30-45 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	34,69	6,94	56,77	0,08	0,51	0,51	15,67	72,40
- 600 + 500	26,50	5,30	56,74	0,08	0,47	0,98	25,16	55,66
- 500 + 355	49,31	9,86	57,35	0,25	1,50	2,47	47,47	17,23
- 355 + 212	87,34	17,47	56,72	3,39	20,58	23,05	73,43	-29,47
- 212 + 150	57,98	11,60	57,13	3,12	18,95	42,00	75,07	-31,40
- 150 + 106	77,38	15,48	58,00	3,34	20,26	62,26	76,31	-31,58
- 106 + 75	53,94	10,79	56,55	3,16	19,18	81,44	80,50	-42,35
-75	112,88	22,58	59,79	3,06	18,56	100,00	82,31	-37,66
Total	500,02	100,00		16,48	100,00			

Table A-2.179: Test 36, 45-60 minutes, 12 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	45-60 minutes				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	34,69	6,94	56,77	0,07	0,50	0,50	14,56	74,36
- 600 + 500	26,50	5,30	56,74	0,07	0,49	0,99	27,11	52,23
- 500 + 355	49,31	9,86	57,35	0,26	1,75	2,74	50,00	12,81
- 355 + 212	87,34	17,47	56,72	3,83	25,87	28,61	77,16	-36,05
- 212 + 150	57,98	11,60	57,13	3,19	21,56	50,17	79,43	-39,03
- 150 + 106	77,38	15,48	58,00	3,49	23,57	73,74	81,54	-40,59
- 106 + 75	53,94	10,79	56,55	2,31	15,63	89,37	83,26	-47,22
-75	112,88	22,58	59,79	1,57	10,63	100,00	82,40	-37,81
Total	500,02	100,00		14,79	100,00			

Table A-2.180: Test 36, Underflow, 12 channels at 12 l/min

Size range (µm)	Feed mass (g)	Feed mass (%)	Feed ash content (%)	Remains (Underflow)				
				Mass (g)	Mass (%)	Cum. mass (%)	Ash content (%)	Increase in ash compared to feed (%)
-1000 + 600	34,69	6,94	56,77	15,38	8,57	8,57	56,67	-0,18
- 600 + 500	26,50	5,30	56,74	17,84	9,95	18,52	73,36	22,65
- 500 + 355	49,31	9,86	57,35	27,83	15,52	34,04	77,18	25,70
- 355 + 212	87,34	17,47	56,72	30,43	16,97	51,00	79,87	28,99
- 212 + 150	57,98	11,60	57,13	28,28	15,77	66,77	77,56	26,34
- 150 + 106	77,38	15,48	58,00	37,43	20,87	87,64	76,82	24,50
- 106 + 75	53,94	10,79	56,55	19,82	11,05	98,69	78,29	27,76
-75	112,88	22,58	59,79	2,35	1,31	100,00	67,88	11,91
Total	500,02	100,00		179,36	100,00	465,23		

A-3: Semi-continuous test data

Table A-3.1: Test 37, Details of feed mass

Size range (µm)	Feed addition at 0 minutes (g)	Feed mass (%)	Feed addition after 15 minutes (g)	Feed addition after 30 minutes (g)	Feed addition after 45 minutes (g)	Feed addition after 60 minutes (g)	Feed addition after 75 minutes (g)	Feed addition after 90 minutes (g)	Feed addition after 105 minutes (g)
-1000 + 600	54,23	10,62	27,67	27,63	27,49	27,49	27,32	27,23	27,25
- 600 + 500	27,59	5,40	14,08	14,06	13,99	13,98	13,90	13,85	13,86
- 500 + 355	48,95	9,59	24,98	24,94	24,82	24,81	24,66	24,58	24,60
- 355 + 212	95,95	18,79	48,96	48,89	48,65	48,64	48,35	48,18	48,22
- 212 + 150	43,72	8,56	22,31	22,28	22,17	22,16	22,03	21,95	21,97
- 150 + 106	60,87	11,92	31,06	31,01	30,86	30,85	30,67	30,56	30,59
- 106 + 75	66,36	13,00	33,86	33,81	33,64	33,64	33,44	33,32	33,35
-75	112,98	22,13	57,65	57,57	57,28	57,27	56,93	56,73	56,78
Total (g)	510,66	100,00	260,58	260,18	258,90	258,85	257,30	256,40	256,63

Table A-3.2: Test 37, Details of product time fractions 1&2

Size range (µm)	Average feed ash content (%)	**0-15 minutes**				**15-30 minutes**			
		Mass (g)	Mass (%)	Ash content (%)	Upgrade (%)	Mass (g)	Mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	55,22	6,14	2,50	39,26	28,90	2,03	2,37	50,98	7,67
- 600 + 500	56,85	5,77	2,35	13,09	76,97	0,66	0,78	20,04	64,75
- 500 + 355	57,52	13,91	5,66	17,80	69,06	3,89	4,54	11,38	80,22
- 355 + 212	55,57	32,96	13,41	25,19	54,68	11,25	13,14	21,77	60,82
- 212 + 150	57,37	25,98	10,57	43,69	23,85	6,46	7,55	27,85	51,45
- 150 + 106	54,29	26,52	10,79	52,01	4,21	6,43	7,50	27,07	50,13
- 106 + 75	58,83	23,13	9,41	39,51	32,84	10,34	12,08	44,55	24,27
-75	62,92	111,38	45,32	55,32	12,08	44,57	52,05	49,37	21,54
Total		245,78	100,00			85,63	100,00		

Table A-3.3: Test 37, Details of product time fractions 3&4

Size range (µm)	Average feed ash content (%)	30-45 minutes				45-60 minutes			
		Mass (g)	Mass (%)	Ash content (%)	Upgrade (%)	Mass (g)	Mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	55,22	6,86	3,82	32,42	41,30	7,39	4,60	24,51	55,61
- 600 + 500	56,85	6,53	3,63	19,78	65,22	5,64	3,51	17,92	68,47
- 500 + 355	57,52	13,92	7,75	24,47	57,46	10,69	6,65	22,75	60,44
- 355 + 212	55,57	34,77	19,36	35,08	36,87	24,18	15,03	27,80	49,97
- 212 + 150	57,37	14,32	7,97	30,02	47,67	13,38	8,32	33,70	41,27
- 150 + 106	54,29	13,85	7,71	27,66	49,04	16,83	10,46	48,29	11,05
- 106 + 75	58,83	18,79	10,46	42,25	28,17	24,37	15,15	49,99	15,03
-75	62,92	70,58	39,30	59,53	5,39	58,38	36,29	59,16	5,98
Total		179,61	100,00			160,86	100,00		

Table A-3.4: Test 37, Details of product time fractions 5&6

Size range (µm)	Average feed ash content (%)	60-75 minutes				75-90 minutes			
		Mass (g)	Mass (%)	Ash content (%)	Upgrade (%)	Mass (g)	Mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	55,22	2,07	1,71	29,41	46,74	7,31	4,76	20,42	63,01
- 600 + 500	56,85	2,96	2,44	11,79	79,25	5,24	3,41	17,97	68,39
- 500 + 355	57,52	7,26	6,01	18,48	67,86	10,63	6,92	25,43	55,78
- 355 + 212	55,57	19,98	16,52	31,48	43,36	26,03	16,95	33,14	40,37
- 212 + 150	57,37	10,52	8,70	31,75	44,65	14,32	9,33	34,34	40,14
- 150 + 106	54,29	9,46	7,82	29,00	46,58	12,68	8,25	32,37	40,38
- 106 + 75	58,83	13,27	10,97	42,19	28,28	19,79	12,88	47,13	19,89
-75	62,92	55,40	45,81	55,56	11,71	57,58	37,49	59,77	5,01
Total		120,93	100,00			153,58	100,00		

Table A-3.5: Test 37, Details of product time fractions 7&8

Size range (µm)	Average feed ash content (%)	90-105 minutes				105-120 minutes			
		Mass (g)	Mass (%)	Ash content (%)	Upgrade (%)	Mass (g)	Mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	55,22	11,19	7,51	28,76	47,92	8,69	4,30	21,54	60,99
- 600 + 500	56,85	5,42	3,64	26,30	53,73	5,31	2,63	21,63	61,96
- 500 + 355	57,52	11,55	7,75	27,76	51,73	12,25	6,06	29,48	48,76
- 355 + 212	55,57	24,03	16,13	33,35	39,99	51,73	25,58	53,47	3,78
- 212 + 150	57,37	10,96	7,36	31,26	45,51	25,24	12,48	50,49	12,00
- 150 + 106	54,29	11,34	7,61	32,39	40,34	17,73	8,77	50,58	6,84
- 106 + 75	58,83	19,02	12,77	46,68	20,65	26,16	12,94	58,16	1,13
-75	62,92	55,44	37,22	59,12	6,04	55,11	27,25	60,92	3,18
Total		148,94	100,00			202,21	100,00		

Table A-3.6: Test 37, Underflow (Remains)

Size range (µm)	Average feed ash content (%)	Remains (Underflow)			
		Mass (g)	Mass (%)	Ash content (%)	Increase in ash content (%)
-1000 + 600	55,22	219,74	24,90	61,85	10,71
- 600 + 500	56,85	68,62	7,78	75,80	25,00
- 500 + 355	57,52	131,52	14,90	78,40	26,63
- 355 + 212	55,57	186,92	21,18	81,91	32,15
- 212 + 150	57,37	82,34	9,33	81,12	29,28
- 150 + 106	54,29	89,65	10,16	81,22	33,16
- 106 + 75	58,83	47,08	5,34	79,72	26,20
-75	62,92	56,55	6,41	82,57	23,79
Total`		882,43	100,00		

Table A-3.7: Test 38, Details of feed mass

Size range (µm)	Feed addition at 0 minutes (g)	Feed mass (%)	Feed addition after 15 minutes (g)	Feed addition after 30 minutes (g)	Feed addition after 45 minutes (g)	Feed addition after 60 minutes (g)	Feed addition after 75 minutes (g)	Feed addition after 90 minutes (g)	Feed addition after 105 minutes (g)
-1000 + 600	75,1787	14,61	38,31	38,67	37,39	39,40	38,40	38,68	38,00
- 600 + 500	32,9336	6,40	16,61	16,01	16,54	16,32	16,65	16,28	16,65
- 500 + 355	56,9609	11,07	29,54	28,96	28,24	28,79	28,68	29,03	28,79
- 355 + 212	97,1034	18,88	48,78	47,93	48,74	48,28	51,58	47,89	49,08
- 212 + 150	44,8036	8,71	24,12	23,21	25,77	24,91	22,41	20,55	22,65
- 150 + 106	60,6114	11,78	30,76	29,94	25,81	30,69	28,92	27,18	30,64
- 106 + 75	45,7326	8,89	27,74	22,69	24,70	29,32	24,97	26,37	23,12
-75	101,1259	19,66	47,22	50,45	52,80	41,49	48,36	52,03	51,12
Total (g)	514,45	100,00	263,08	257,86	259,98	259,20	259,95	258,01	260,05

Table A-3.8: Test 38, Details of product time fractions 1&2

Size range (µm)	Average feed ash content (%)	0-15 minutes				15-30 minutes			
		Mass (g)	Mass (%)	Ash content (%)	Upgrade (%)	Mass (g)	Mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	55,34	12,30	4,99	36,30	34,40	10,01	6,02	31,55	42,99
- 600 + 500	57,07	11,29	4,58	19,07	66,60	7,75	4,66	16,23	71,57
- 500 + 355	57,53	24,44	9,91	20,72	63,99	16,94	10,19	21,03	63,45
- 355 + 212	53,60	47,68	19,33	26,63	50,31	31,15	18,73	23,80	55,60
- 212 + 150	57,25	18,63	7,55	26,02	54,56	16,64	10,01	26,03	54,54
- 150 + 106	56,39	26,58	10,78	31,47	44,19	12,43	7,47	28,74	49,04
- 106 + 75	52,52	28,95	11,74	32,08	38,92	14,67	8,82	33,83	35,58
-75	58,22	76,81	31,14	50,64	13,03	56,67	34,09	54,45	6,47
Total		246,69	100,00			166,26	100,00		

Table A-3.9: Test 38, Details of product time fractions 3&4

Size range (µm)	Average feed ash content (%)	30-45 minutes				45-60 minutes			
		Mass (g)	Mass (%)	Ash content (%)	Upgrade (%)	Mass (g)	Mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	55,34	11,98	7,97	46,21	16,50	23,77	13,53	35,79	35,32
- 600 + 500	57,07	6,43	4,27	16,60	70,91	8,40	4,78	16,23	71,57
- 500 + 355	57,53	14,26	9,48	19,70	65,75	16,34	9,30	20,00	65,24
- 355 + 212	53,60	27,04	17,98	25,33	52,75	28,73	16,35	24,85	53,64
- 212 + 150	57,25	12,52	8,32	23,61	58,77	13,50	7,68	26,64	53,46
- 150 + 106	56,39	17,72	11,78	33,41	40,76	17,45	9,93	31,38	44,35
- 106 + 75	52,52	13,69	9,10	38,95	25,83	16,65	9,47	39,70	24,41
-75	58,22	46,78	31,10	52,69	9,50	50,88	28,95	53,07	8,85
Total		150,41	100,00			175,72	100,00		

Table A-3.10: Test 38, Details of product time fractions 5&6

Size range (µm)	Average feed ash content (%)	60-75 minutes				75-90 minutes			
		Mass (g)	Mass (%)	Ash content (%)	Upgrade (%)	Mass (g)	Mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	55,34	15,84	11,08	37,58	32,08	19,45	12,29	29,47	46,74
- 600 + 500	57,07	5,86	4,10	17,44	69,44	7,35	4,65	16,81	70,54
- 500 + 355	57,53	12,64	8,84	22,51	60,87	14,52	9,18	19,30	66,45
- 355 + 212	53,60	22,61	15,82	21,56	59,78	26,01	16,44	21,85	59,24
- 212 + 150	57,25	10,22	7,15	22,25	61,13	11,02	6,96	25,17	56,04
- 150 + 106	56,39	15,47	10,82	35,14	37,68	10,91	6,89	22,69	59,76
- 106 + 75	52,52	13,80	9,66	36,18	31,13	12,96	8,19	35,00	33,36
-75	58,22	46,48	32,52	54,72	6,00	55,99	35,39	55,44	4,78
Total		142,92	100,00			158,20	100,00		

Table A-3.11: Test 38, Details of product time fractions 7&8

Size range (µm)	Average feed ash content (%)	90-105 minutes				105-120 minutes			
		Mass (g)	Mass (%)	Ash content (%)	Upgrade (%)	Mass (g)	Mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	55,34	14,18	9,24	21,65	60,87	26,57	15,89	25,81	53,36
- 600 + 500	57,07	6,60	4,30	17,83	68,76	8,49	5,08	19,73	65,43
- 500 + 355	57,53	14,37	9,36	18,72	67,46	15,20	9,09	21,39	62,82
- 355 + 212	53,60	23,81	15,52	20,84	61,13	26,34	15,75	21,68	59,55
- 212 + 150	57,25	11,60	7,56	24,41	57,37	11,60	6,94	22,87	60,06
- 150 + 106	56,39	10,64	6,93	22,35	60,37	11,59	6,93	30,51	45,90
- 106 + 75	52,52	15,19	9,90	45,16	14,01	16,18	9,67	36,54	30,42
-75	58,22	57,08	37,19	55,03	5,48	51,26	30,65	55,47	4,72
Total		153,46	100,00			167,25	100,00		

Table A-3.12: Test 38, Underflow

Size range (µm)	Average feed ash content (%)	Remains (Underflow)			
		Mass (g)	Mass (%)	Ash content (%)	Increase in ash content (%)
-1000 + 600	55,34	243,14	27,98	60,18	8,05
- 600 + 500	57,07	62,12	7,15	73,33	22,17
- 500 + 355	57,53	119,88	13,79	77,12	25,40
- 355 + 212	53,60	187,04	21,52	78,35	31,59
- 212 + 150	57,25	74,79	8,61	78,42	26,99
- 150 + 106	56,39	77,64	8,93	79,63	29,18
- 106 + 75	52,52	54,87	6,31	81,44	35,51
-75	58,22	49,63	5,71	81,93	28,94
Total		869,09	100,00		

Table A-3.13: Test 39, Details of feed mass

Size range (µm)	Feed addition at 0 minutes (g)	Feed mass (%)	Feed addition after 15 minutes (g)	Feed addition after 30 minutes (g)	Feed addition after 45 minutes (g)	Feed addition after 60 minutes (g)	Feed addition after 75 minutes (g)	Feed addition after 90 minutes (g)	Feed addition after 105 minutes (g)
-1000 + 600	85,21	16,70	42,73	43,56	46,38	46,65	41,12	45,54	43,01
- 600 + 500	32,87	6,44	17,97	16,56	16,01	16,71	17,01	16,69	16,59
- 500 + 355	61,95	12,14	31,57	30,58	31,15	30,25	30,15	31,28	31,27
- 355 + 212	98,82	19,37	53,01	49,67	50,31	50,16	50,07	50,37	49,88
- 212 + 150	37,22	7,30	19,35	20,09	20,45	16,90	21,95	19,09	18,79
- 150 + 106	51,59	10,11	25,31	21,74	25,26	18,34	23,44	21,29	26,04
- 106 + 75	45,45	8,91	23,25	18,99	21,63	20,85	19,19	24,17	22,94
-75	97,13	19,04	45,45	54,91	47,82	55,68	52,54	49,22	49,03
Total (g)	510,23	100,00	258,64	256,10	259,01	255,54	255,47	257,65	257,55

Table A-3.14: Test 39, Details of product time fractions 1&2

Size range (µm)	Average feed ash content (%)	0-15 minutes				15-30 minutes			
		Mass (g)	Mass (%)	Ash content (%)	Upgrade (%)	Mass (g)	Mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	56,13	8,00	3,07	26,08	53,53	6,68	4,63	31,15	44,51
- 600 + 500	57,15	12,77	4,91	8,59	84,97	7,43	5,15	10,34	81,91
- 500 + 355	57,92	26,69	10,26	11,89	79,46	15,43	10,68	15,24	73,69
- 355 + 212	53,79	49,02	18,85	17,04	68,32	30,09	20,84	20,60	61,70
- 212 + 150	56,99	19,17	7,37	20,14	64,65	12,13	8,40	22,96	59,71
- 150 + 106	55,57	24,38	9,37	33,19	40,29	11,93	8,26	25,77	53,62
- 106 + 75	55,39	29,19	11,22	34,71	37,33	17,43	12,07	42,36	23,53
-75	60,32	90,90	34,94	53,02	12,10	43,29	29,98	55,48	8,02
Total		260,13	100,00			144,42	100,00		

Table A-3.15: Test 39, Details of product time fractions 3&4

Size range (µm)	Average feed ash content (%)	30-45 minutes				45-60 minutes			
		Mass (g)	Mass (%)	Ash content (%)	Upgrade (%)	Mass (g)	Mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	56,13	7,40	5,19	24,32	56,67	12,88	8,51	10,19	81,85
- 600 + 500	57,15	7,14	5,01	11,21	80,38	8,25	5,45	12,54	78,07
- 500 + 355	57,92	14,10	9,89	14,72	74,58	15,74	10,41	16,21	72,01
- 355 + 212	53,79	26,65	18,69	19,45	63,84	28,04	18,53	20,07	62,69
- 212 + 150	56,99	10,83	7,60	20,76	63,58	12,46	8,23	23,45	58,85
- 150 + 106	55,57	10,95	7,68	23,85	57,08	11,16	7,37	25,42	54,26
- 106 + 75	55,39	12,96	9,09	38,42	30,64	13,71	9,06	39,48	28,74
-75	60,32	52,57	36,86	54,68	9,34	49,07	32,43	55,82	7,45
Total		142,60	100,00			151,31	100,00		

Table A-3.16: Test 39, Details of product time fractions 5&6

Size range (µm)	Average feed ash content (%)	60-75 minutes				75-90 minutes			
		Mass (g)	Mass (%)	Ash content (%)	Upgrade (%)	Mass (g)	Mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	56,13	18,40	11,05	12,26	78,17	12,37	8,08	14,29	74,54
- 600 + 500	57,15	8,83	5,30	14,99	73,78	7,97	5,20	13,40	76,55
- 500 + 355	57,92	16,77	10,07	17,92	69,06	15,28	9,98	16,07	72,26
- 355 + 212	53,79	29,29	17,59	20,53	61,83	27,26	17,81	19,86	63,07
- 212 + 150	56,99	11,35	6,82	21,32	62,59	11,87	7,76	25,72	54,87
- 150 + 106	55,57	11,39	6,84	24,02	56,77	10,03	6,55	22,41	59,68
- 106 + 75	55,39	16,15	9,70	35,32	36,23	14,68	9,59	49,11	11,35
-75	60,32	54,33	32,63	56,22	6,79	53,65	35,04	55,19	8,50
Total		166,52	100,00			153,12	100,00		

Table A-3.17: Test 39, Details of product time fractions 7&8

Size range (µm)	Average feed ash content (%)	90-105 minutes				105-120 minutes			
		Mass (g)	Mass (%)	Ash content (%)	Upgrade (%)	Mass (g)	Mass (%)	Ash content (%)	Upgrade (%)
-1000 + 600	56,13	18,46	11,43	9,41	83,24	18,87	11,93	12,78	77,24
- 600 + 500	57,15	8,21	5,08	14,19	75,18	8,76	5,54	15,33	73,18
- 500 + 355	57,92	27,97	17,32	19,91	65,62	15,89	10,04	19,05	67,11
- 355 + 212	53,79	16,47	10,20	18,08	66,39	28,74	18,16	21,32	60,36
- 212 + 150	56,99	10,94	6,78	21,52	62,23	11,62	7,34	22,47	60,57
- 150 + 106	55,57	11,40	7,06	24,59	55,74	12,23	7,73	30,09	45,86
- 106 + 75	55,39	13,33	8,26	33,59	39,36	12,04	7,61	41,92	24,32
-75	60,32	54,68	33,87	55,90	7,32	50,10	31,66	58,19	3,52
Total		161,45	100,00			158,25	100,00		

Table A-3.18: Test 39, Underflow

Size range (µm)	Average feed ash content (%)	Remains (Underflow)			
		Mass (g)	Mass (%)	Ash content (%)	Increase in ash content (%)
-1000 + 600	56,13	254,90	31,51	58,30	3,72
- 600 + 500	57,15	61,05	7,55	74,03	22,79
- 500 + 355	57,92	118,46	14,65	78,48	26,20
- 355 + 212	53,79	169,38	20,94	80,44	33,13
- 212 + 150	56,99	61,47	7,60	80,78	29,45
- 150 + 106	55,57	59,12	7,31	81,54	31,84
- 106 + 75	55,39	48,04	5,94	82,72	33,04
-75	60,32	36,43	4,50	84,88	28,94
Total		808,86	100,00		

APPENDIX B: YIELD-ASH DATA

B-1: Primary batch tests

Table B-1.1: Tests 1, 2 & 3, Time fractions 1 & 2

Time	After 0 minutes						After 15 minutes						After 30 minutes					
Size (µm)	Maximum Yield (%)			Feed Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
-1000 + 600	100,00	100,00	100,00	60,41	57,95	58,96	1,27	2,03	0,97	47,50	53,26	55,44	4,12	2,18	1,55	56,23	52,75	55,10
- 600 + 500	100,00	100,00	100,00	59,46	60,38	59,14	2,19	1,50	1,45	45,51	45,00	52,72	3,33	1,84	1,93	48,48	45,86	50,28
- 500 + 355	100,00	100,00	100,00	60,95	59,16	58,40	3,21	1,49	0,87	46,94	43,55	44,94	3,90	2,00	1,32	47,64	45,43	39,69
- 355 + 212	100,00	100,00	100,00	56,58	58,60	58,76	3,51	15,72	18,78	43,37	57,45	58,42	7,18	17,70	19,79	51,13	57,37	57,94
- 212 + 150	100,00	100,00	100,00	59,84	57,21	58,42	6,18	23,10	20,50	51,19	55,44	56,97	22,16	24,35	22,19	57,53	55,55	57,15
- 150 + 106	100,00	100,00	100,00	58,05	59,01	58,06	8,71	14,94	25,76	49,82	52,72	56,25	13,85	16,66	30,72	53,74	53,19	57,06
- 106 + 75	100,00	100,00	100,00	58,47	57,49	59,67	5,73	28,89	11,48	49,60	50,25	55,73	13,21	31,74	18,91	55,12	50,94	57,79
-75	100,00	100,00	100,00	58,61	57,82	58,30	19,97	47,61	29,94	48,82	53,68	54,28	35,12	52,04	41,03	52,10	53,83	54,56

Table B-1.2: Tests 1, 2 & 3, Time fractions 2 & 3

Time	After 45 minutes						After 60 minutes					
Size (µm)	Cumulative Yield (%)			Cumulative Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	1	2	3	1	2	3	1	2	3	1	2	3
-1000+600	8,11	2,23	1,56	58,99	53,05	55,07	8,15	2,28	1,71	59.11	53.24	57.87
- 600 + 500	4,83	1,92	2,13	52,54	47,13	50,53	4,92	1,99	2,37	52,71	47,16	54,90
- 500 + 355	5,36	2,09	1,49	51,70	45,56	42,78	5,45	2,15	1,69	51,81	45,75	47,80
- 355 + 212	8,94	17,81	19,95	53,38	57,24	58,00	9,15	17,87	20,07	53,44	57,19	58,18
- 212 + 150	29,53	24,46	22,28	58,63	55,50	57,21	29,90	24,52	22,34	58,61	55,48	57,26
- 150 + 106	16,87	16,99	31,02	54,62	53,17	57,19	17,57	17,18	31,16	54,70	53,19	57,27
- 106 + 75	18,72	32,32	19,19	56,96	51,06	58,01	20,22	32,58	19,29	57,04	51,10	58,08
-75	37,01	54,67	42,72	52,32	53,88	55,22	40,58	56,13	44,21	52,22	53,91	55,25

Table B-1.3: Tests 1, 2 & 3, Overall feed

Overall Feed						
	Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	**1**	**2**	**3**	**1**	**2**	**3**
Theoretical maximum	100,00	100,00	100,00	58,76	58,20	58,72
After 15 min	6,71	19,16	15,71	48,77	53,90	56,48
After 30 min	14,29	20,95	19,10	54,10	54,13	56,71
After 45 min	17,96	21,41	19,41	55,54	54,12	56,93
After 60 min	18,83	21,67	19,66	55,48	54,12	57,06

Table B-1.4: Tests 4, 5 & 6, Time fractions 1 & 2

Time	After 0 minutes						After 15 minutes						After 30 minutes					
Size (μm)	Maximum Yield (%)			Feed Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6	4	5	6
-1000 + 600	100,00	100,00	100,00	61,49	59,55	60,66	6,41	13,06	14,99	59,57	58,36	59,15	15,04	38,59	20,37	59,87	58,86	59,04
- 600 + 500	100,00	100,00	100,00	61,66	60,71	59,84	2,19	3,83	4,07	59,38	57,90	59,05	4,48	8,46	5,04	60,63	59,15	58,79
- 500 + 355	100,00	100,00	100,00	61,34	59,90	59,88	2,29	8,87	6,97	58,58	58,97	59,75	4,11	10,76	8,15	59,96	59,14	59,58
- 355 + 212	100,00	100,00	100,00	60,34	59,98	59,51	16,46	7,98	17,83	58,89	57,95	59,22	18,44	10,21	20,01	59,17	58,49	59,08
- 212 + 150	100,00	100,00	100,00	59,32	59,03	58,76	14,39	13,06	15,61	58,05	57,75	58,33	21,46	15,47	19,09	58,78	58,02	58,41
- 150 + 106	100,00	100,00	100,00	59,58	59,03	59,34	7,08	11,86	11,81	54,65	56,25	57,59	14,25	17,69	13,14	57,38	57,44	57,67
- 106 + 75	100,00	100,00	100,00	59,90	57,30	58,29	8,18	11,97	8,38	55,78	56,74	56,89	14,46	14,43	14,61	57,24	57,02	57,47
-75	100,00	100,00	100,00	60,28	57,68	58,15	4,54	9,91	6,22	52,81	55,47	55,62	9,86	11,99	13,21	54,42	55,53	54,67

Table B-1.5: Tests 4, 5 & 6, Time fractions 3 & 4

Time	After 45 minutes						After 60 minutes					
Size (µm)	Cumulative Yield (%)			Cumulative Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	**4**	**5**	**6**	**4**	**5**	**6**	**4**	**5**	**6**	**4**	**5**	**6**
-1000+600	15,18	38,88	20,38	59,89	58,94	59,04	15,27	38,90	20,38	60,07	58,93	59,04
- 600 + 500	4,66	8,74	5,08	60,74	59,22	58,76	4,73	8,76	5,08	61,16	59,19	58,76
- 500 + 355	4,27	11,01	8,18	59,79	59,33	59,55	4,35	11,03	8,18	60,36	59,30	59,55
- 355 + 212	18,64	10,59	20,21	59,19	59,04	59,06	18,69	10,63	20,22	59,14	58,97	59,06
- 212 + 150	21,73	15,92	19,43	58,78	58,42	58,42	21,76	16,00	19,48	58,79	58,39	58,41
- 150 + 106	15,00	18,99	13,58	57,47	57,79	57,65	15,13	19,11	13,72	57,50	57,75	57,62
- 106 + 75	16,73	15,92	15,35	57,38	57,08	57,25	17,10	16,30	15,46	57,49	57,03	57,22
-75	17,66	15,35	14,75	52,91	53,87	54,15	20,04	17,44	16,18	52,48	52,63	53,34

Table B-1.6: Tests 4, 5 & 6, Overall feed

Overall Feed						
	Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	**1**	**2**	**3**	**1**	**2**	**3**
Theoretical maximum	100,00	100,00	100,00	60,20	59,04	59,13
After 15 min	10,01	10,73	11,79	57,74	57,38	58,32
After 30 min	15,28	15,58	15,63	58,43	57,96	58,02
After 45 min	16,59	16,54	16,13	58,07	57,94	57,86
After 60 min	16,93	16,88	16,40	57,98	57,70	57,67

Table B-1.7: Tests 7, 8 & 9, Time fractions 1 & 2

Time	After 0 minutes						After 15 minutes						After 30 minutes					
Size (μm)	Maximum Yield (%)			Feed Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	**7**	**8**	**9**	**7**	**8**	**9**	**7**	**8**	**9**	**7**	**8**	**9**	**7**	**8**	**9**	**7**	**8**	**9**
-1000 + 600	100,00	100,00	100,00	61,22	59,22	59,91	15,37	11,19	15,49	58,90	58,55	59,49	18,23	22,56	17,51	58,84	58,22	59,09
- 600 + 500	100,00	100,00	100,00	59,05	58,73	59,63	4,36	2,49	4,45	58,36	56,43	59,32	5,73	4,75	6,16	58,35	57,18	58,20
- 500 + 355	100,00	100,00	100,00	59,13	59,95	58,84	3,81	3,23	2,83	56,29	55,47	57,89	7,70	4,63	3,41	54,68	56,26	57,50
- 355 + 212	100,00	100,00	100,00	59,61	59,50	59,00	10,23	12,12	5,08	57,73	59,04	58,71	12,15	15,84	7,78	57,66	58,74	57,87
- 212 + 150	100,00	100,00	100,00	59,22	58,15	59,51	7,74	12,92	14,15	57,95	57,38	59,19	9,65	13,98	16,78	58,07	57,47	58,85
- 150 + 106	100,00	100,00	100,00	58,22	58,91	59,24	4,44	4,42	7,10	55,72	55,69	58,63	8,22	7,37	9,64	57,72	57,00	57,77
- 106 + 75	100,00	100,00	100,00	59,66	57,86	57,38	8,02	7,56	4,86	58,64	55,99	51,14	10,87	12,54	12,91	58,80	56,41	53,45
-75	100,00	100,00	100,00	58,92	57,65	57,99	11,44	8,49	1,57	58,03	56,12	55,90	25,03	14,89	5,87	56,88	55,32	52,10

Table B-1.8: Tests 7, 8 & 9, Time fractions 3 & 4

Time	**After 45 minutes**						**After 60 minutes**					
Size (µm)	Cumulative Yield (%)			Cumulative Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	**7**	**8**	**9**	**7**	**8**	**9**	**7**	**8**	**9**	**7**	**8**	**9**
-1000+600	18,95	22,99	17,56	58,57	58,09	59,05	18,97	23,06	17,60	58,57	58,02	59,01
- 600 + 500	6,41	5,36	6,22	57,51	56,38	58,01	6,46	5,41	6,28	57,38	56,36	57,81
- 500 + 355	8,25	4,94	3,44	54,35	55,97	57,38	8,35	4,99	3,47	54,28	55,81	57,37
- 355 + 212	12,77	16,38	8,12	57,41	58,67	57,66	13,09	16,46	8,19	57,31	58,62	57,58
- 212 + 150	10,01	14,26	17,19	57,92	57,45	58,82	10,32	14,38	17,33	57,84	57,41	58,77
- 150 + 106	9,59	8,83	10,59	57,38	56,43	58,28	10,07	9,00	11,14	57,36	56,36	58,01
- 106 + 75	12,22	15,53	15,86	58,11	55,55	52,73	13,15	17,14	17,87	57,89	55,23	52,29
-75	34,39	21,53	12,65	54,34	52,56	48,59	43,20	27,15	15,69	52,42	51,25	47,17

Table B-1.9: Tests 7, 8 & 9, Overall feed

Overall Feed						
	Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	**7**	**8**	**9**	**7**	**8**	**9**
Theoretical maximum	100,00	100,00	100,00	59,41	58,69	58,98
After 15 min	8,41	9,05	7,62	57,98	57,46	58,52
After 30 min	11,73	12,85	10,63	57,80	57,43	57,53
After 45 min	13,11	14,31	11,92	57,03	56,70	56,60
After 60 min	14,07	15,11	12,56	56,44	56,24	56,03

Table B-1.10: Tests 10, 11 & 12, Time fractions 1 & 2

Time	After 0 minutes						After 15 minutes						After 30 minutes					
Size (µm)	Maximum Yield (%)			Feed Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	**10**	**11**	**12**	**10**	**11**	**12**	**10**	**11**	**12**	**10**	**11**	**12**	**10**	**11**	**12**	**10**	**11**	**12**
-1000 + 600	100,00	100,00	100,00	59,49	58,33	61,25	0,79	1,27	1,22	52,46	54,86	57,36	0,89	1,39	1,25	54,26	56,46	57,02
- 600 + 500	100,00	100,00	100,00	57,32	56,98	56,85	4,03	1,73	1,55	52,85	51,20	52,28	4,21	1,80	1,56	51,81	50,71	52,14
- 500 + 355	100,00	100,00	100,00	58,84	56,78	59,53	2,39	2,15	2,02	58,49	51,22	58,78	2,42	2,21	2,04	58,02	50,82	58,68
- 355 + 212	100,00	100,00	100,00	61,29	53,40	61,33	11,77	15,66	12,47	60,31	53,13	60,18	11,84	15,80	12,51	60,22	53,12	60,14
- 212 + 150	100,00	100,00	100,00	59,29	57,39	59,39	28,06	27,95	32,53	58,05	55,54	57,51	28,10	28,03	32,57	58,03	55,55	57,51
- 150 + 106	100,00	100,00	100,00	60,11	60,30	62,52	12,38	36,83	11,51	58,43	54,59	57,51	12,45	36,93	11,60	58,39	54,59	57,48
- 106 + 75	100,00	100,00	100,00	57,25	58,85	56,90	22,22	21,48	19,78	52,89	54,18	53,15	22,51	21,74	20,00	52,74	54,00	52,86
-75	100,00	100,00	100,00	58,45	58,79	61,37	82,12	81,61	81,44	53,81	57,53	61,08	85,35	85,16	83,66	53,69	57,28	60,87

Table B-1.11: Tests 10, 11 & 12, Time fractions 3 & 4

Time	After 45 minutes						After 60 minutes					
Size (µm)	Cumulative Yield (%)			Cumulative Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	10	11	12	10	11	12	10	11	12	10	11	12
-1000+600	0,99	1,41	1,34	54,83	56,15	57,25	1,01	1,43	1,47	54,90	55,59	59,31
- 600 + 500	4,32	1,83	1,65	51,57	50,43	52,34	4,44	1,84	1,69	51,94	50,49	52,55
- 500 + 355	2,45	2,22	2,09	57,90	50,72	58,72	2,47	2,24	2,11	57,89	50,73	58,67
- 355 + 212	11,87	15,82	12,55	60,22	53,11	60,14	11,90	15,85	12,57	60,20	53,12	60,14
- 212 + 150	28,14	28,06	32,62	58,03	55,54	57,51	28,16	28,08	32,64	58,03	55,54	57,51
- 150 + 106	12,50	36,98	11,69	58,39	54,58	57,39	12,54	37,00	11,76	58,41	54,59	57,47
- 106 + 75	22,66	21,81	20,37	52,65	53,96	52,32	22,70	21,87	20,49	52,63	53,94	52,30
-75	86,98	86,92	86,39	53,65	57,13	60,65	87,89	87,41	86,98	53,62	57,10	60,61

Table B-1.12: Tests 10, 11 & 12, Overall feed

Overall Feed						
	Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	10	11	12	10	11	12
Theoretical maximum	100,00	100,00	100,00	59,37	57,43	60,11
After 15 min	25,16	25,74	26,00	55,65	55,63	59,00
After 30 min	25,71	26,28	26,40	55,52	55,54	58,88
After 45 min	26,00	26,52	26,91	55,48	55,48	58,74
After 60 min	26,15	26,60	27,04	55,45	55,47	58,73

Table B-1.13: Tests 13, 14 & 15, Time fractions 1 & 2

Time	After 0 minutes						After 15 minutes						After 30 minutes					
Size (µm)	Maximum Yield (%)			Feed Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	**13**	**14**	**15**	**13**	**14**	**15**	**13**	**14**	**15**	**13**	**14**	**15**	**13**	**14**	**15**	**13**	**14**	**15**
-1000 + 600	100,00	100,00	100,00	63,68	60,79	63,49	0,51	1,34	1,99	63,65	59,08	56,93	0,55	1,35	2,38	62,17	58,97	62,13
- 600 + 500	100,00	100,00	100,00	56,60	60,67	59,87	1,66	5,85	4,68	56,45	60,00	58,94	1,70	5,90	4,84	56,04	59,79	59,04
- 500 + 355	100,00	100,00	100,00	62,91	62,74	62,11	2,52	8,29	5,63	60,07	61,46	60,22	2,54	8,37	5,77	59,93	61,26	60,34
- 355 + 212	100,00	100,00	100,00	61,09	61,00	59,96	25,14	15,94	25,28	56,47	60,19	58,70	25,22	16,02	25,45	56,47	60,14	58,76
- 212 + 150	100,00	100,00	100,00	57,74	59,08	59,57	28,42	30,46	23,96	57,39	58,15	56,69	28,49	30,60	24,28	57,39	58,15	56,76
- 150 + 106	100,00	100,00	100,00	59,37	59,64	59,49	9,39	43,40	15,66	56,14	56,45	57,71	9,56	43,76	16,61	56,10	56,43	57,65
- 106 + 75	100,00	100,00	100,00	58,33	56,83	58,09	15,90	18,81	31,18	55,36	55,82	54,67	16,20	19,61	32,79	55,28	55,77	54,59
-75	100,00	100,00	100,00	57,90	58,72	58,08	45,38	36,77	34,77	53,69	54,15	54,00	50,48	46,68	42,75	53,25	52,85	53,07

Table B-1.14: Tests 13, 14 & 15, Time fractions 3 & 4

Time	After 45 minutes						After 60 minutes					
Size (µm)	Cumulative Yield (%)			Cumulative Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	13	14	15	13	14	15	13	14	15	13	14	15
-1000+600	0,64	1,42	2,51	60,32	58,80	61,57	0,67	1,46	2,55	59,27	58,28	61,37
- 600 + 500	1,75	5,94	4,91	56,25	59,72	58,99	1,77	5,97	4,94	56,20	59,59	58,97
- 500 + 355	2,58	8,40	5,84	59,73	61,22	60,16	2,60	8,44	5,86	59,63	61,19	60,13
- 355 + 212	25,26	16,08	25,63	56,45	60,12	58,75	25,30	16,11	25,65	56,45	60,13	58,74
- 212 + 150	28,53	30,64	24,39	57,38	58,14	56,76	28,61	30,67	24,44	57,37	58,13	56,74
- 150 + 106	9,84	43,89	16,96	55,78	56,38	57,60	10,14	43,99	17,20	55,73	56,38	57,56
- 106 + 75	16,37	19,69	33,88	55,12	55,70	54,80	16,56	19,79	34,10	54,97	55,62	54,68
-75	54,11	50,75	48,19	52,86	52,09	52,96	56,87	53,47	50,47	52,65	51,82	52,88

Table B-1.15: Tests 13, 14 & 15, Overall feed

Overall Feed						
	Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	13	14	15	13	14	15
Theoretical maximum	100,00	100,00	100,00	59,73	59,69	60,00
After 15 min	19,47	21,21	20,45	56,02	57,22	56,47
After 30 min	20,10	22,49	21,83	55,83	56,76	56,22
After 45 min	20,55	22,99	22,72	55,64	56,47	56,13
After 60 min	20,91	23,33	23,05	55,51	56,34	56,04

Table B-1.16: Tests 16, 17 & 18, Time fractions 1 & 2

Time	After 0 minutes						After 15 minutes						After 30 minutes					
Size (µm)	Maximum Yield (%)			Feed Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	**16**	**17**	**18**	**16**	**17**	**18**	**16**	**17**	**18**	**16**	**17**	**18**	**16**	**17**	**18**	**16**	**17**	**18**
-1000 + 600	100,00	100,00	100,00	55,79	57,05	59,01	1,21	8,98	6,01	48,29	53,20	53,25	1,39	9,07	6,11	49,52	53,18	53,20
- 600 + 500	100,00	100,00	100,00	57,74	58,36	58,25	1,83	3,33	4,82	32,20	41,81	43,04	2,78	3,66	5,09	23,61	39,68	41,41
- 500 + 355	100,00	100,00	100,00	57,32	57,67	58,09	10,02	14,56	11,24	23,47	35,21	25,05	14,10	16,86	13,17	19,25	31,47	22,69
- 355 + 212	100,00	100,00	100,00	61,29	54,05	58,66	13,23	30,90	25,69	25,51	41,30	45,13	19,14	34,69	28,78	21,52	38,09	41,45
- 212 + 150	100,00	100,00	100,00	56,28	57,94	58,48	17,60	17,04	21,72	48,40	47,03	46,60	19,93	18,76	23,20	44,15	43,97	44,34
- 150 + 106	100,00	100,00	100,00	59,71	59,14	60,07	15,77	32,03	18,39	35,56	45,22	36,82	22,59	37,37	29,86	29,15	41,00	27,51
- 106 + 75	100,00	100,00	100,00	56,28	58,69	57,22	34,22	31,95	35,42	47,57	43,94	48,28	38,81	36,67	40,12	44,84	42,45	46,12
-75	100,00	100,00	100,00	57,83	56,77	57,52	64,12	41,75	54,12	49,02	44,29	49,13	79,98	62,64	70,07	50,01	45,17	48,36

Table B-1.17: Tests 16, 17 & 18, Time fractions 3 & 4

Time	After 45 minutes						After 60 minutes					
Size (µm)	Cumulative Yield (%)			Cumulative Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	16	17	18	16	17	18	16	17	18	16	17	18
-1000+600	1,55	9,22	6,19	51,18	53,20	53,29	1,81	9,23	6,35	52,42	53,19	53,05
- 600 + 500	3,29	4,11	5,36	21,38	37,17	39,94	3,70	4,52	6,26	20,32	36,12	35,38
- 500 + 355	16,03	19,36	14,81	18,10	28,59	21,25	17,14	21,42	17,31	17,74	26,03	19,75
- 355 + 212	22,43	38,41	31,02	20,56	35,64	39,35	25,76	41,85	33,21	20,02	34,69	37,78
- 212 + 150	21,41	20,34	24,12	42,19	41,60	43,07	22,31	21,65	24,92	41,44	40,84	42,18
- 150 + 106	27,00	41,73	36,71	27,29	38,34	25,08	29,89	45,26	44,03	27,66	38,00	24,22
- 106 + 75	41,91	40,74	43,34	43,61	40,73	44,33	43,66	44,28	44,89	43,47	40,98	43,87
-75	87,56	78,76	79,33	50,80	47,92	49,07	91,11	90,50	90,23	51,33	50,37	49,68

Table B-1.18: Tests 16, 17 & 18, Overall feed

Overall Feed						
	Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	16	17	18	16	17	18
Theoretical maximum	100,00	100,00	100,00	57,91	57,14	58,39
After 15 min	22,32	23,09	23,73	43,89	43,89	45,95
After 30 min	27,82	27,25	27,61	41,16	41,61	43,35
After 45 min	30,85	30,85	30,10	40,26	40,39	42,17
After 60 min	32,82	33,77	32,68	39,87	40,41	41,43

Table B-1.19: Tests 19, 20 & 21, Time fractions 1 & 2

Time	After 0 minutes						After 15 minutes						After 30 minutes					
Size (µm)	Maximum Yield (%)			Feed Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	19	20	21	19	20	21	19	20	21	19	20	21	19	20	21	19	20	21
-1000 + 600	100,00	100,00	100,00	55,62	59,62	52,38	2,96	8,35	0,20	44,73	57,36	30,49	3,09	8,42	0,24	44,75	57,17	34,67
- 600 + 500	100,00	100,00	100,00	57,30	58,30	53,44	2,40	4,52	0,38	31,69	50,34	28,57	2,54	4,71	0,45	31,61	49,56	29,61
- 500 + 355	100,00	100,00	100,00	57,94	56,43	55,91	3,83	7,07	0,48	33,25	52,18	21,40	4,11	7,31	0,57	32,14	51,24	22,37
- 355 + 212	100,00	100,00	100,00	56,15	53,49	52,90	9,63	11,25	2,44	47,08	50,12	52,95	10,13	11,61	2,58	46,21	49,50	51,43
- 212 + 150	100,00	100,00	100,00	56,64	59,67	59,74	9,84	26,76	15,85	50,15	59,59	59,23	10,36	27,01	16,00	49,90	59,42	58,98
- 150 + 106	100,00	100,00	100,00	59,57	61,48	57,07	25,98	18,56	41,61	47,13	41,23	54,50	27,35	19,18	42,45	46,58	41,07	53,91
- 106 + 75	100,00	100,00	100,00	56,85	55,52	55,66	42,75	42,48	50,24	41,17	42,68	47,02	44,22	43,64	51,55	40,82	42,21	46,40
-75	100,00	100,00	100,00	58,99	58,97	58,58	90,20	92,47	95,97	56,43	56,89	56,40	93,67	94,61	97,77	56,47	56,93	56,48

Table B-1.20: Tests 19, 20 & 21, Time fractions 3 & 4

Time	After 45 minutes						After 60 minutes					
Size (µm)	Cumulative Yield (%)			Cumulative Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	19	20	21	19	20	21	19	20	21	19	20	21
-1000+600	3,15	8,48	0,24	44,56	57,20	34,86	3,24	8,54	0,27	44,70	57,23	36,94
- 600 + 500	2,67	4,77	0,48	31,21	49,45	30,29	2,76	4,84	0,50	31,59	49,41	29,22
- 500 + 355	4,53	7,35	0,62	30,96	51,15	23,41	4,64	7,44	0,63	31,24	50,94	23,37
- 355 + 212	10,66	11,65	2,64	44,91	49,49	51,26	10,86	11,77	2,66	44,90	49,37	50,87
- 212 + 150	10,52	27,04	16,05	49,60	59,40	58,93	10,63	27,08	16,08	49,52	59,38	58,90
- 150 + 106	27,98	19,34	42,79	46,24	40,96	53,75	28,46	19,50	43,07	46,03	40,87	53,51
- 106 + 75	45,11	44,08	52,17	40,50	42,00	46,14	45,91	44,43	52,64	40,39	41,84	45,91
-75	95,84	95,41	98,39	56,56	56,98	56,54	97,62	95,96	98,88	56,63	57,04	56,61

Table B-1.21: Tests 19, 20 & 21, Overall

Overall Feed						
	Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	**19**	**20**	**21**	**19**	**20**	**21**
Theoretical maximum	100,00	100,00	100,00	57,26	57,67	55,81
After 15 min	27,69	30,56	29,13	51,88	53,75	54,89
After 30 min	28,83	31,25	29,73	51,71	53,55	54,73
After 45 min	29,55	31,48	29,96	51,54	53,52	54,70
After 60 min	30,09	31,67	30,13	51,55	53,50	54,66

Table B-1.22: Tests 22, 23 & 24, Time fractions 1 & 2

Time	After 0 minutes						After 15 minutes						After 30 minutes					
Size (µm)	Maximum Yield (%)			Feed Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	22	23	24	22	23	24	22	23	24	22	23	24	22	23	24	22	23	24
-1000 + 600	100,00	100,00	100,00	55,84	57,91	59,59	0,83	0,33	9,65	54,81	35,57	56,81	0,87	0,40	9,89	54,82	34,02	56,70
- 600 + 500	100,00	100,00	100,00	54,68	57,48	60,49	1,07	0,44	19,64	51,15	25,89	60,04	1,11	0,55	19,80	51,03	24,83	60,00
- 500 + 355	100,00	100,00	100,00	53,72	57,28	61,92	0,94	0,49	11,20	50,44	18,48	60,73	1,00	0,66	11,59	50,06	19,82	60,75
- 355 + 212	100,00	100,00	100,00	60,42	56,29	60,11	13,36	1,63	14,30	59,76	44,82	58,25	13,43	1,92	14,61	59,70	43,07	58,20
- 212 + 150	100,00	100,00	100,00	59,55	60,83	60,43	30,12	4,85	29,81	58,42	58,73	56,02	30,23	5,18	30,23	58,40	57,51	55,97
- 150 + 106	100,00	100,00	100,00	57,07	60,06	60,94	11,97	16,47	10,80	55,59	54,49	52,79	12,70	17,72	12,96	54,92	52,47	51,05
- 106 + 75	100,00	100,00	100,00	58,12	55,15	60,62	53,39	47,31	46,29	53,07	50,48	48,55	55,85	52,23	51,64	51,90	47,21	46,83
-75	100,00	100,00	100,00	58,50	57,86	57,71	78,24	81,04	65,40	53,61	56,53	54,05	81,53	83,01	71,51	53,77	56,55	54,42

Table B-1.23: Tests 22, 23 & 24, Time fractions 3 & 4

Time	**After 45 minutes**						**After 60 minutes**					
Size (µm)	Cumulative Yield (%)			Cumulative Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	**22**	**23**	**24**	**22**	**23**	**24**	**22**	**23**	**24**	**22**	**23**	**24**
-1000+600	0,93	0,45	9,95	55,51	34,51	56,53	0,94	0,47	11,83	55,09	34,31	59,44
- 600 + 500	1,18	0,61	19,87	51,96	25,26	59,95	1,21	0,63	20,60	51,62	25,07	60,44
- 500 + 355	1,12	0,74	11,64	52,76	21,76	60,65	1,15	0,80	12,54	52,43	22,07	61,73
- 355 + 212	13,56	2,03	14,69	59,80	42,78	58,16	13,61	2,04	15,73	59,75	42,66	59,67
- 212 + 150	30,34	5,33	30,42	58,37	56,70	56,05	30,41	5,38	32,11	58,33	56,34	57,52
- 150 + 106	13,46	19,41	14,50	53,44	49,13	50,99	14,10	19,96	18,07	51,82	48,13	57,81
- 106 + 75	58,82	58,45	54,31	50,32	46,71	46,43	61,48	60,23	56,98	48,86	45,72	47,97
-75	84,52	85,12	74,55	53,84	56,65	54,67	86,28	85,52	82,71	53,95	56,65	57,79

Table B-1.24: Tests 22, 23 & 24, Overall feed

Overall Feed						
	Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	**22**	**23**	**24**	**22**	**23**	**24**
Theoretical maximum	100,00	100,00	100,00	57,86	57,94	60,12
After 15 min	21,49	26,24	25,31	55,88	55,85	54,98
After 30 min	22,08	27,18	26,86	55,72	55,42	54,65
After 45 min	22,67	28,14	27,62	55,50	55,25	54,60
After 60 min	23,06	28,37	30,02	55,25	55,09	56,86

Table B-1.25: Tests 25, 26 & 27, Time fractions 1 & 2

Time	After 0 minutes						After 15 minutes						After 30 minutes					
Size (µm)	Maximum Yield (%)			Feed Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	25	26	27	25	26	27	25	26	27	25	26	27	25	26	27	25	26	27
-1000 + 600	100,00	100,00	100,00	59,00	58,19	58,97	2,93	1,75	13,32	18,36	11,84	50,32	3,17	2,03	13,68	17,54	11,15	49,30
- 600 + 500	100,00	100,00	100,00	57,22	57,02	57,42	8,04	6,31	12,85	9,02	8,47	30,57	8,66	7,15	13,87	9,24	8,64	29,20
- 500 + 355	100,00	100,00	100,00	60,69	59,77	60,56	39,14	34,21	46,26	15,75	13,99	24,41	41,51	37,80	49,28	16,25	14,63	24,87
- 355 + 212	100,00	100,00	100,00	59,63	58,76	59,52	50,72	46,15	46,95	23,82	24,92	31,26	55,12	52,68	53,92	24,60	26,30	33,25
- 212 + 150	100,00	100,00	100,00	61,58	60,61	62,12	79,56	73,10	67,87	37,00	33,82	41,63	84,60	80,82	78,38	37,15	34,46	42,35
- 150 + 106	100,00	100,00	100,00	63,26	62,42	62,00	63,03	61,41	64,05	40,56	37,89	34,96	69,89	70,70	72,41	41,22	38,86	37,06
- 106 + 75	100,00	100,00	100,00	62,73	61,82	62,63	46,07	48,70	43,08	54,81	38,84	40,48	50,48	54,94	51,73	55,27	41,12	43,61
-75	100,00	100,00	100,00	61,06	60,17	60,91	78,56	84,05	77,90	36,81	55,34	53,10	86,49	91,41	88,79	38,86	57,12	54,21

Table B-1.26: Tests 25, 26 & 27, Time fractions 3 & 4

Time	After 45 minutes						After 60 minutes					
Size (µm)	Cumulative Yield (%)			Cumulative Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	25	26	27	25	26	27	25	26	27	25	26	27
-1000+600	3,50	2,23	13,79	17,32	11,72	49,02	3,84	2,79	13,88	18,85	23,05	48,87
- 600 + 500	9,05	7,48	14,07	9,47	8,99	28,99	9,28	8,00	14,25	9,79	11,68	29,00
- 500 + 355	42,51	39,15	49,85	16,61	14,97	24,94	43,02	41,34	50,19	16,94	16,94	25,17
- 355 + 212	56,68	55,99	56,29	25,26	27,38	34,15	57,48	59,26	57,45	25,70	28,85	34,65
- 212 + 150	86,86	85,80	82,83	37,57	35,41	43,11	88,16	89,64	85,79	37,86	36,37	43,63
- 150 + 106	73,52	76,52	76,43	41,92	40,25	38,00	75,89	81,09	78,90	42,59	41,37	38,63
- 106 + 75	53,75	58,83	55,32	55,24	41,93	44,37	55,87	61,90	58,64	55,58	42,92	45,09
-75	90,90	95,42	92,64	39,56	56,97	54,35	94,12	98,34	96,34	40,47	57,03	54,52

Table B-1.27: Tests 25, 26 & 27, Overall feed

Overall Feed						
	Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	25	26	27	25	26	27
Theoretical maximum	100,00	100,00	100,00	60,31	59,58	60,18
After 15 min	43,74	43,76	43,71	34,29	39,98	39,65
After 30 min	47,60	48,69	49,54	35,33	41,21	41,05
After 45 min	49,63	51,46	51,72	35,94	41,68	41,61
After 60 min	50,97	53,87	53,33	36,59	42,41	42,10

Table B-1.28: Tests 28, 29 & 30, Time fractions 1 & 2

Time	After 0 minutes						After 15 minutes						After 30 minutes					
Size (µm)	Maximum Yield (%)			Feed Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	**28**	**29**	**30**	**28**	**29**	**30**	**28**	**29**	**30**	**28**	**29**	**30**	**28**	**29**	**30**	**28**	**29**	**30**
-1000 + 600	100,00	100,00	100,00	65,40	61,19	58,91	2,42	2,02	3,03	64,25	60,64	56,59	2,50	2,05	3,31	64,16	60,51	56,40
- 600 + 500	100,00	100,00	100,00	62,63	57,93	54,99	0,67	1,03	0,84	59,10	56,13	33,42	0,88	1,06	1,04	61,69	56,45	39,48
- 500 + 355	100,00	100,00	100,00	62,68	55,59	58,61	1,17	0,80	4,52	58,32	53,04	57,14	1,39	0,85	4,65	61,78	54,01	56,70
- 355 + 212	100,00	100,00	100,00	63,35	55,54	50,83	5,26	3,57	4,59	62,76	55,10	40,69	5,47	3,66	5,38	62,96	54,93	36,38
- 212 + 150	100,00	100,00	100,00	54,82	54,56	53,51	13,16	16,22	14,10	51,17	42,15	37,66	13,65	16,82	17,55	50,81	41,15	30,54
- 150 + 106	100,00	100,00	100,00	54,66	54,65	55,67	32,65	18,53	32,46	33,26	16,33	37,75	34,74	19,95	37,07	33,18	16,53	36,12
- 106 + 75	100,00	100,00	100,00	57,78	57,48	58,80	47,56	51,50	47,98	50,19	41,66	41,75	48,81	52,97	52,37	50,19	41,96	42,90
-75	100,00	100,00	100,00	65,08	58,41	59,45	88,45	89,69	87,74	64,42	57,32	57,53	89,74	90,50	90,48	64,58	57,50	58,12

Table B-1.29: Tests 28, 29 & 30, Time fractions 3 & 4

Time	**After 45 minutes**						**After 60 minutes**					
Size (µm)	Cumulative Yield (%)			Cumulative Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	**28**	**29**	**30**	**28**	**29**	**30**	**28**	**29**	**30**	**28**	**29**	**30**
-1000+600	2,58	2,08	3,34	64,20	60,67	56,39	2,64	2,10	3,36	64,26	60,37	56,19
- 600 + 500	0,95	1,15	1,09	61,97	57,80	39,46	1,08	1,18	1,19	61,62	57,81	43,14
- 500 + 355	1,47	0,88	4,69	61,88	54,17	56,71	1,69	0,90	4,71	59,66	54,26	56,81
- 355 + 212	5,57	3,73	5,45	62,37	54,37	36,53	5,93	3,77	5,48	61,85	54,36	36,54
- 212 + 150	14,44	17,55	17,75	49,97	39,88	30,43	14,83	17,81	17,90	49,91	39,47	30,35
- 150 + 106	37,39	21,36	37,52	32,75	16,52	35,93	38,56	21,95	37,89	33,14	16,54	35,82
- 106 + 75	50,19	53,99	52,83	50,15	41,99	42,92	50,93	54,47	53,15	50,38	42,04	42,93
-75	90,90	91,27	90,97	64,74	57,65	58,20	91,78	91,64	91,32	64,91	57,72	58,00

Table B-1.30: Tests 28, 29 & 30, Overall feed

Overall Feed						
	Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	**28**	**29**	**30**	**28**	**29**	**30**
Theoretical maximum	100,00	100,00	100,00	61,97	57,22	56,37
After 15 min	32,47	32,31	31,18	59,79	52,62	52,29
After 30 min	33,19	32,85	33,18	59,81	52,61	51,74
After 45 min	33,91	33,34	33,42	59,70	52,53	51,75
After 60 min	34,42	33,56	33,59	59,80	52,51	51,59

Table B-1.31: Tests 31, 32 & 33, Time fractions 1 & 2

Time	After 0 minutes						After 15 minutes						After 30 minutes					
Size (µm)	Maximum Yield (%)			Feed Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	31	32	33	31	32	33	31	32	33	31	32	33	31	32	33	31	32	33
-1000 + 600	100,00	100,00	100,00	58,89	58,89	52,23	3,68	14,59	1,97	49,56	57,28	51,80	4,01	14,84	2,20	49,32	57,18	50,99
- 600 + 500	100,00	100,00	100,00	58,19	58,19	58,27	1,52	2,36	1,58	20,43	42,05	23,26	1,98	3,00	2,42	21,79	47,11	37,60
- 500 + 355	100,00	100,00	100,00	58,84	58,84	54,22	1,45	3,30	2,46	13,14	39,03	32,31	2,05	5,19	3,79	13,09	53,64	44,21
- 355 + 212	100,00	100,00	100,00	57,92	57,92	52,41	4,94	6,45	9,41	42,80	49,78	49,13	6,10	8,09	10,95	36,79	49,72	46,90
- 212 + 150	100,00	100,00	100,00	58,42	58,42	53,41	9,20	33,04	40,68	40,02	45,63	49,26	11,34	41,40	45,81	34,43	41,38	46,08
- 150 + 106	100,00	100,00	100,00	59,35	59,35	56,36	26,92	29,78	25,61	21,11	32,74	20,98	33,79	36,63	32,74	19,76	31,41	21,27
- 106 + 75	100,00	100,00	100,00	58,22	58,22	58,84	78,85	75,80	36,20	40,89	40,50	42,88	84,02	83,39	39,28	40,18	40,82	42,71
-75	100,00	100,00	100,00	58,66	58,66	57,66	88,38	86,56	87,43	56,55	56,17	56,59	91,24	89,53	90,35	56,85	56,68	57,02

Table B-1.32: Tests 31, 32 & 33, Time fractions 3 & 4

Time	After 45 minutes						After 60 minutes					
Size (µm)	Cumulative Yield (%)			Cumulative Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	31	32	33	31	32	33	31	32	33	31	32	33
-1000+600	4,09	14,94	2,33	49,11	57,01	49,07	4,25	15,05	2,55	48,48	57,00	48,26
- 600 + 500	2,12	3,18	2,71	21,44	45,82	34,63	2,30	3,27	3,24	21,72	45,47	31,42
- 500 + 355	2,23	5,47	4,39	13,17	51,78	39,32	2,45	5,60	5,25	13,14	51,04	35,38
- 355 + 212	6,61	8,81	12,10	34,93	46,63	43,39	7,08	9,12	13,45	33,98	45,50	40,43
- 212 + 150	12,59	45,94	48,97	31,86	38,26	43,81	13,48	47,94	52,04	30,43	37,12	42,02
- 150 + 106	37,53	40,11	37,66	19,19	30,17	20,74	40,04	41,67	41,31	18,97	29,75	20,80
- 106 + 75	86,31	86,70	40,95	39,98	40,73	42,46	87,95	88,28	42,07	39,85	40,71	42,43
-75	92,30	91,18	92,16	57,02	56,98	57,35	93,29	92,00	93,36	57,16	57,12	57,57

Table B-1.33: Tests 31, 32 & 33, Overall feed

Overall Feed						
	Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	31	32	33	31	32	33
Theoretical maximum	100,00	100,00	100,00	58,47	58,49	55,21
After 15 min	32,04	33,92	32,36	50,77	51,47	51,69
After 30 min	34,21	36,80	34,77	49,66	51,22	51,15
After 45 min	35,19	38,17	36,27	49,16	50,63	50,41
After 60 min	35,98	38,81	37,58	48,85	50,42	49,75

Table B-1.34: Tests 34, 35 & 36, Time fractions 1 & 2

Time	After 0 minutes						After 15 minutes						After 30 minutes					
Size (µm)	Maximum Yield (%)			Feed Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	34	35	36	34	35	36	34	35	36	34	35	36	34	35	36	34	35	36
-1000 + 600	100,00	100,00	100,00	58,89	60,04	56,77	15,96	15,48	53,18	22,89	16,18	53,11	16,38	16,23	53,84	23,21	16,56	52,74
- 600 + 500	100,00	100,00	100,00	58,19	59,72	56,74	40,76	21,43	29,33	12,04	15,00	20,80	41,73	22,08	30,02	12,71	15,45	20,97
- 500 + 355	100,00	100,00	100,00	58,84	59,30	57,35	56,65	43,60	39,74	19,33	22,38	26,26	58,92	45,50	40,79	20,86	23,58	26,81
- 355 + 212	100,00	100,00	100,00	57,92	56,80	56,72	70,06	47,42	50,46	33,73	34,01	33,63	77,27	54,00	55,82	36,94	38,60	37,03
- 212 + 150	100,00	100,00	100,00	58,42	55,03	57,13	57,10	52,93	32,08	37,65	43,48	30,21	65,21	60,60	38,83	41,44	46,98	37,05
- 150 + 106	100,00	100,00	100,00	59,35	60,80	58,00	38,03	39,79	36,39	41,27	36,93	35,61	43,03	44,64	41,31	44,69	40,62	39,88
- 106 + 75	100,00	100,00	100,00	58,22	57,79	56,55	49,20	45,58	44,74	42,62	38,52	38,49	54,78	52,31	51,98	45,89	43,12	43,75
-75	100,00	100,00	100,00	58,66	58,30	59,79	87,38	92,25	87,63	55,93	56,51	55,86	92,42	96,25	93,75	57,22	57,57	57,55

Table B-1.35: Tests 34, 35 & 36, Time fractions 3 & 4

Time	**After 45 minutes**						**After 60 minutes**					
Size (µm)	Cumulative Yield (%)			Cumulative Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	**34**	**35**	**36**	**34**	**35**	**36**	**34**	**35**	**36**	**34**	**35**	**36**
-1000+600	16,54	16,35	54,09	23,60	16,60	52,58	16,59	16,41	54,30	23,70	16,72	52,43
- 600 + 500	41,90	22,18	30,31	12,81	15,51	21,01	41,96	22,24	30,58	12,84	15,56	21,07
- 500 + 355	59,33	45,96	41,29	21,03	23,88	27,06	59,49	46,21	41,81	21,13	24,07	27,34
- 355 + 212	79,94	58,76	59,70	38,23	41,54	39,40	81,48	60,89	64,08	38,99	42,82	41,98
- 212 + 150	69,55	65,99	44,21	43,74	49,39	41,68	72,18	70,37	49,71	45,11	51,30	45,86
- 150 + 106	46,17	48,60	45,62	47,06	43,63	43,32	48,16	51,99	50,13	48,49	46,10	46,76
- 106 + 75	57,89	57,59	57,84	47,77	46,59	47,47	59,70	61,15	62,12	48,81	48,72	49,94
-75	93,98	97,85	96,46	57,62	57,99	58,25	94,88	98,66	97,86	57,84	58,19	58,59

Table B-1.36: Tests 34, 35 & 36, Overall feed

Overall Feed						
	Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	**34**	**35**	**36**	**34**	**35**	**36**
Theoretical maximum	100,00	100,00	100,00	58,59	58,26	57,71
After 15 min	55,40	55,91	51,94	40,23	44,96	42,96
After 30 min	60,21	60,70	56,77	42,67	47,18	45,53
After 45 min	62,36	63,80	60,06	43,88	48,66	47,22
After 60 min	63,63	65,82	63,02	44,61	49,65	48,72

B-2: Semi-continuous tests

Table B-2.1: Tests 37, 38 & 39, Time fractions 1 & 2

Time	After 0 minutes						After 15 minutes						After 30 minutes					
Size (µm)	Maximum Yield (%)			Feed Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	37	38	39	37	38	39	37	38	39	37	38	39	37	38	39	37	38	39
-1000 + 600	100,00	100,00	100,00	55,22	55,34	56,13	11,32	16,36	9,38	39,26	36,30	26,08	9,97	19,66	11,48	42,18	34,17	28,38
- 600 + 500	100,00	100,00	100,00	56,85	57,07	57,15	20,90	34,28	38,85	13,09	19,07	8,59	15,44	38,42	39,74	13,81	17,91	9,23
- 500 + 355	100,00	100,00	100,00	57,52	57,53	57,92	28,42	42,91	43,09	17,80	20,72	11,89	24,07	47,84	45,04	16,40	20,84	13,12
- 355 + 212	100,00	100,00	100,00	55,57	53,60	53,79	34,35	49,10	49,61	25,19	26,63	17,04	30,51	54,04	52,11	24,32	25,51	18,39
- 212 + 150	100,00	100,00	100,00	57,37	57,25	56,99	59,41	41,57	51,51	43,69	26,02	20,14	49,12	51,17	55,34	40,53	26,02	21,23
- 150 + 106	100,00	100,00	100,00	54,29	56,39	55,57	43,57	43,86	47,26	52,01	31,47	33,19	35,84	42,69	47,22	47,14	30,60	30,75
- 106 + 75	100,00	100,00	100,00	58,83	52,52	55,39	34,86	63,31	64,24	39,51	32,08	34,71	33,40	59,37	67,87	41,07	32,67	37,57
-75	100,00	100,00	100,00	62,92	58,22	60,32	98,58	75,96	93,58	55,32	50,64	53,02	91,39	89,99	94,11	53,62	52,26	53,81

Table B-2.2: Tests 37, 38 & 39, Time fractions 3, 4 & 5

Time	After 45 minutes						After 60 minutes						After 75 minutes					
Size (µm)	Cumulative Yield (%)			Feed Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	37	38	39	37	38	39	37	38	39	37	38	39	37	38	39	37	38	39
-1000 + 600	13,72	22,54	12,87	37,72	38,38	27,03	16,36	30,64	16,04	33,37	37,32	20,82	14,89	32,29	20,17	33,03	37,37	17,87
- 600 + 500	23,26	38,84	40,57	16,81	17,58	9,75	26,68	41,25	42,68	17,15	17,24	10,40	25,75	40,37	44,38	16,42	17,27	11,31
- 500 + 355	32,07	48,19	45,31	19,94	20,55	13,52	34,28	50,09	46,36	20,65	20,43	14,11	33,45	49,05	47,84	20,33	20,74	14,83
- 355 + 212	40,75	54,63	52,49	29,06	25,46	18,66	42,55	55,49	53,14	28,76	25,33	18,96	42,30	54,05	54,01	29,20	24,79	19,24
- 212 + 150	52,94	51,87	54,97	37,32	25,39	21,11	54,43	51,98	56,22	36,51	25,66	21,64	53,27	50,07	57,84	35,80	25,18	21,59
- 150 + 106	38,06	46,76	47,91	41,38	31,48	29,15	41,37	50,42	47,15	43,21	31,45	28,44	39,58	50,41	49,07	41,37	32,09	27,72
- 106 + 75	38,99	59,60	67,95	41,49	34,17	37,76	45,70	61,19	67,05	44,19	35,42	38,08	44,66	58,44	68,72	43,90	35,54	37,58
-75	99,27	90,68	94,56	55,46	52,37	54,06	99,80	91,87	96,13	56,22	52,52	54,42	99,29	94,72	96,40	56,11	52,89	54,76

Table B-2.3: Tests 37, 38 & 39, Time fractions 6, 7 & 8

Time	**After 90 minutes**						**After 105 minutes**						**After 120 minutes**					
Size (µm)	Cumulative Yield (%)			Feed Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)			Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	**37**	**38**	**39**	**37**	**38**	**39**	**37**	**38**	**39**	**37**	**38**	**39**	**37**	**38**	**39**	**37**	**38**	**39**
-1000 + 600	16,58	34,92	21,50	30,14	35,73	17,20	19,63	35,14	23,97	29,78	33,87	15,49	20,98	38,99	26,14	28,39	32,28	14,99
- 600 + 500	27,46	40,92	44,73	16,72	17,20	11,63	28,91	40,87	45,29	18,33	17,28	11,97	29,95	42,02	46,12	18,80	17,61	12,40
- 500 + 355	34,82	49,28	48,23	21,23	20,53	15,01	36,33	49,31	53,45	22,28	20,30	16,05	37,82	49,70	53,15	23,33	20,43	16,37
- 355 + 212	43,95	53,51	54,07	29,89	24,37	19,33	44,68	53,04	51,40	30,37	23,97	19,23	51,61	53,11	52,08	35,68	23,71	19,48
- 212 + 150	54,94	49,95	57,24	35,56	25,18	22,22	54,32	50,67	57,25	35,07	25,08	22,13	61,01	50,73	57,74	38,28	24,84	22,17
- 150 + 106	39,83	48,64	48,19	40,04	31,07	27,05	39,49	47,53	48,80	39,14	30,24	26,74	41,53	46,41	48,57	40,91	30,26	27,14
- 106 + 75	46,72	57,51	69,72	44,48	35,47	39,21	48,01	57,52	67,69	44,81	36,74	38,57	51,38	58,80	65,92	47,06	36,71	38,88
-75	99,55	97,71	97,25	56,64	53,32	54,83	99,33	99,29	98,94	56,95	53,57	54,97	99,08	99,40	99,29	57,38	53,79	55,33

Table B-2.4: Tests 37, 38 & 39, Overall feed

Overall Feed						
	Cumulative Yield (%)			Cumulative Ash (%)		
Test no.	**37**	**38**	**39**	**37**	**38**	**39**
Theoretical maximum	100,00	100,00	100,00	57,84	55,97	56,70
After 15 min	48,13	47,95	50,98	44,69	34,77	32,67
After 30 min	42,97	53,11	52,62	43,47	35,09	33,04
After 45 min	49,55	54,41	53,38	43,30	35,50	33,28
After 60 min	52,07	57,06	54,40	43,55	35,58	33,10
After 75 min	51,18	56,74	56,18	43,35	35,81	32,97
After 90 min	52,39	57,33	56,72	43,34	35,77	33,20
After 105 min	53,10	57,59	57,46	43,35	35,81	33,04
After 120 min	55,94	58,34	57,91	44,67	35,67	33,12

APPENDIX C: STANDARD DEVIATION DATA

C-1: Primary batch tests

Table C-1.1: Standard deviation in product ash (%) and upgrade (%) between triplicate repeats for 0-15 min, 3 l/min & 6 l/min

Standard deviation												
Flowrate (l/min)	3						6					
No. of channels	6 (Tests 1,2,3)		8 (Tests 4,5,6)		12 (Tests 7,8,9)		6 (Tests 10,11,12)		8 (Tests 13,14,15)		12 (Tests 16,17,18)	
Size range (µm)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)
-1000 + 600	3,35	6,81	0,50	0,45	0,39	1,37	2,00	2,68	2,80	4,34	2,33	2,74
- 600 + 500	3,53	6,48	0,63	1,39	1,20	1,48	0,68	1,05	1,48	0,54	4,85	8,07
- 500 + 355	1,39	1,59	0,49	1,79	1,00	2,40	3,50	4,19	0,62	1,01	5,21	9,02
- 355 + 212	6,88	10,42	0,54	1,21	0,56	1,19	3,35	0,59	1,53	2,77	8,49	16,52
- 212 + 150	2,45	5,51	0,24	0,67	0,76	0,66	1,08	0,52	0,59	1,80	0,77	2,70
- 150 + 106	2,63	4,61	1,20	2,22	1,38	1,88	1,64	2,86	0,68	1,13	4,29	7,59
- 106 + 75	2,75	3,59	0,50	2,52	3,10	4,01	0,56	0,57	0,48	1,79	1,90	4,52
-75	2,45	4,56	1,29	3,92	0,96	0,86	2,97	3,21	0,19	0,32	2,26	3,35

Table C-1.2: Standard deviation in product ash (%) and upgrade (%) between triplicate repeats for 0-15 min, 9 l/min & 12 l/min

Standard deviation												
Flowrate (l/min)	9						12					
No. of channels	6 (Tests 19,20,21)		8 (Tests 22,23,24)		12 (Tests 25,26,27)		6 (Tests 28,29,30)		8 (Tests 31,32,33)		12 (Tests 34,35,36)	
Size range (µm)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)
-1000 + 600	10,98	15,59	9,57	16,69	16,81	28,44	3,13	1,28	3,24	6,67	16,06	29,00
- 600 + 500	9,61	15,09	14,47	24,33	10,29	17,89	11,47	16,47	9,59	16,49	3,64	6,73
- 500 + 355	12,67	22,43	17,99	30,09	4,55	7,44	2,26	1,82	10,97	19,35	2,84	5,34
- 355 + 212	2,39	6,68	6,72	8,66	3,28	5,44	9,15	9,00	3,15	8,17	0,16	0,68
- 212 + 150	4,37	5,18	1,21	2,27	3,21	4,62	5,62	9,62	3,80	9,74	5,43	10,69
- 150 + 106	5,43	11,65	1,15	4,44	2,29	3,16	9,22	16,49	5,51	8,87	2,42	4,00
- 106 + 75	2,48	4,98	1,85	5,34	7,17	11,17	4,00	7,15	1,04	1,43	1,94	2,82
-75	0,23	0,34	1,29	2,52	8,26	13,95	3,30	0,91	0,19	1,01	0,29	1,44

Table C-1.3: Standard deviation in product ash (%) and upgrade (%) between triplicate repeats for 15-30 min, 3 l/min & 6 l/min

Standard deviation												
Flowrate (l/min)	3						6					
No. of channels	6 (Tests 1,2,3)		8 (Tests 4,5,6)		12 (Tests 7,8,9)		6 (Tests 10,11,12)		8 (Tests 13,14,15)		12 (Tests 16,17,18)	
Size range (µm)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)
-1000 + 600	5,94	8,58	0,56	1,00	1,06	1,74	12,07	22,12	24,33	37,63	3,41	7,85
- 600 + 500	4,57	7,48	1,69	1,60	1,35	2,83	5,22	9,35	11,63	19,05	4,64	7,90
- 500 + 355	9,99	16,02	1,26	1,16	2,03	2,93	7,40	12,32	11,01	18,06	0,55	0,96
- 355 + 212	4,18	8,41	1,48	1,92	0,61	0,68	2,61	10,10	7,04	12,36	0,72	1,46
- 212 + 150	1,00	0,49	0,61	0,65	0,73	2,03	6,48	11,62	0,84	1,18	1,05	1,87
- 150 + 106	1,72	3,70	0,78	1,36	2,00	4,05	0,80	0,78	1,15	1,91	1,27	2,27
- 106 + 75	1,24	0,56	0,40	1,29	1,80	1,62	6,61	11,13	1,43	3,44	3,29	4,95
-75	0,49	0,58	0,94	2,00	2,17	3,34	1,03	0,45	0,54	1,43	3,67	5,97

Table C-1.4: Standard deviation in product ash (%) and upgrade (%) between triplicate repeats for 15-30 min, 9 l/min & 12 l/min

Standard deviation												
Flowrate (l/min)	9						12					
No. of channels	6 (Tests 19,20,21)		8 (Tests 22,23,24)		12 (Tests 25,26,27)		6 (Tests 28,29,30)		8 (Tests 31,32,33)		12 (Tests 34,35,36)	
Size range (µm)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)
-1000 + 600	10,17	22,59	12,67	22,45	2,10	3,53	4,13	4,24	3,21	3,41	5,58	9,27
- 600 + 500	2,47	6,65	15,02	25,47	0,99	1,69	2,38	2,40	18,33	31,47	5,51	9,38
- 500 + 355	4,20	7,97	15,36	24,09	4,66	7,54	16,06	25,90	28,67	50,41	4,85	7,61
- 355 + 212	2,22	3,57	9,52	14,14	5,67	9,44	23,48	36,14	15,76	27,61	1,49	3,49
- 212 + 150	5,08	10,11	6,14	10,66	3,29	4,88	16,68	30,40	6,01	10,81	1,21	5,16
- 150 + 106	5,21	7,45	8,21	14,59	3,31	5,73	5,24	9,62	4,67	8,13	0,32	2,69
- 106 + 75	3,28	5,36	6,70	10,08	0,49	0,52	2,11	2,98	6,22	10,58	0,88	3,08
-75	1,39	2,68	0,50	1,23	8,03	13,99	0,74	7,05	2,32	4,25	0,99	1,98

Table C-1.5: Standard deviation in product ash (%) and upgrade (%) between triplicate repeats for 30-45 min, 3 l/min & 6 l/min

Standard deviation												
Flowrate (l/min)	3						6					
No. of channels	6 (Tests 1,2,3)		8 (Tests 4,5,6)		12 (Tests 7,8,9)		6 (Tests 10,11,12)		8 (Tests 13,14,15)		12 (Tests 16,17,18)	
Size range (µm)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)
-1000 + 600	8,54	14,82	5,98	10,77	4,17	6,78	9,48	14,63	2,80	6,22	4,59	9,38
- 600 + 500	9,31	14,62	3,83	5,23	6,63	11,62	9,82	17,36	5,74	12,60	3,00	5,07
- 500 + 355	8,18	14,09	6,92	11,88	4,99	7,93	10,09	15,77	2,13	3,24	0,26	0,45
- 355 + 212	13,54	23,85	7,26	11,94	1,78	2,90	7,25	6,98	5,45	9,55	1,11	1,42
- 212 + 150	12,62	20,78	6,30	10,71	1,49	2,65	4,22	5,84	5,79	8,96	1,99	3,82
- 150 + 106	7,91	14,14	2,19	3,98	4,29	6,84	4,61	8,73	6,27	10,58	1,34	2,28
- 106 + 75	6,51	9,44	2,30	3,95	1,29	1,37	8,42	13,92	9,98	16,87	2,52	4,76
-75	7,42	12,64	1,26	1,01	0,82	0,95	1,49	1,43	3,56	6,47	2,08	3,82

Table C-1.6: Standard deviation in product ash (%) and upgrade (%) between triplicate repeats for 30-45 min, 9 l/min & 12 l/min

Standard deviation												
Flowrate (l/min)	9						12					
No. of channels	6 (Tests 19,20,21)		8 (Tests 22,23,24)		12 (Tests 25,26,27)		6 (Tests 28,29,30)		8 (Tests 31,32,33)		12 (Tests 34,35,36)	
Size range (µm)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)
-1000 + 600	12,15	18,32	15,66	29,41	2,17	3,84	6,83	10,03	9,11	13,93	21,28	35,99
- 600 + 500	8,05	15,01	15,76	30,44	1,06	1,92	14,94	23,39	6,03	10,38	4,05	6,74
- 500 + 355	7,97	14,72	16,68	34,29	3,15	4,92	2,51	2,90	4,12	6,49	2,82	4,27
- 355 + 212	12,14	23,69	13,54	20,72	4,18	6,68	10,23	23,42	1,29	1,54	0,85	1,02
- 212 + 150	6,25	9,21	15,74	26,23	2,32	2,93	10,02	18,19	1,00	2,42	1,33	3,17
- 150 + 106	2,02	4,90	14,87	24,15	0,90	1,64	4,39	8,08	1,49	2,94	1,32	2,64
- 106 + 75	1,18	1,85	9,58	17,40	0,80	0,78	2,27	4,12	2,46	4,17	0,22	1,37
-75	2,79	5,06	2,29	4,52	1,89	2,97	1,91	4,35	1,08	2,70	0,82	2,19

Table C-1.7: Standard deviation in product ash (%) and upgrade (%) between triplicate repeats for 45-60 min, 3 l/min & 6 l/min

Standard deviation												
Flowrate (l/min)	3						6					
No. of channels	6 (Tests 1,2,3)		8 (Tests 4,5,6)		12 (Tests 7,8,9)		6 (Tests 10,11,12)		8 (Tests 13,14,15)		12 (Tests 16,17,18)	
Size range (µm)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)
-1000 + 600	10,47	16,41	37,36	60,67	8,27	12,66	26,96	43,74	6,22	10,20	8,90	17,08
- 600 + 500	18,92	32,63	36,69	59,48	7,18	12,54	3,39	5,73	7,88	14,48	7,50	12,81
- 500 + 355	14,34	25,60	20,78	33,06	7,71	13,59	1,12	2,10	4,28	6,91	4,69	8,15
- 355 + 212	18,26	30,63	4,22	7,47	2,52	3,91	1,14	8,14	7,56	11,88	3,87	8,50
- 212 + 150	10,89	18,39	6,64	10,92	0,94	1,71	4,64	6,64	3,06	6,10	5,54	9,75
- 150 + 106	9,37	16,55	3,87	6,18	1,98	4,02	4,52	5,67	0,86	1,28	6,05	10,39
- 106 + 75	6,89	10,18	4,38	6,05	2,56	3,05	3,00	5,67	1,73	3,04	5,40	8,98
-75	2,06	3,88	2,42	2,59	2,09	3,68	2,10	1,63	1,82	3,46	5,49	9,95

Table C-1.8: Standard deviation in product ash (%) and upgrade (%) between triplicate repeats for 45-60 min, 9 l/min & 12 l/min

Standard deviation												
Flowrate (l/min)	9						12					
No. of channels	6 (Tests 19,20,21)		8 (Tests 22,23,24)		12 (Tests 25,26,27)		6 (Tests 28,29,30)		8 (Tests 31,32,33)		12 (Tests 34,35,36)	
Size range (µm)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)
-1000 + 600	4,80	7,56	21,60	35,18	17,90	31,07	19,74	28,53	9,92	16,50	17,70	29,31
- 600 + 500	16,94	28,65	22,43	35,88	12,09	21,28	11,40	25,22	7,32	12,59	5,90	9,41
- 500 + 355	8,46	14,11	20,91	31,71	6,01	10,04	11,73	22,31	2,91	4,88	4,01	5,55
- 355 + 212	17,68	31,86	24,34	39,61	1,92	2,67	7,19	8,64	3,15	5,01	0,64	0,53
- 212 + 150	3,39	5,26	27,23	45,05	0,49	0,97	15,03	27,26	1,36	3,34	0,72	3,07
- 150 + 106	7,08	11,08	33,20	54,00	2,17	2,66	12,00	22,06	2,37	4,78	0,07	2,70
- 106 + 75	6,66	11,33	30,38	49,31	3,03	4,91	9,49	16,73	3,67	6,08	0,59	2,62
-75	3,75	6,61	13,48	23,72	3,31	5,06	34,28	55,22	1,75	3,82	0,63	2,00

C-2: Semi-continuous tests

Table C-2.1: Standard deviation in product ash (%) and upgrade (%) between triplicate repeats for 0-60 min

Standard deviation								
Flowrate (l/min)	9							
No. of channels	12							
Time (min)	0-15		15-30		30-45		45-60	
Size range (μm)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)
-1000 + 600	5,65	10,56	9,26	17,02	9,03	16,55	10,48	19,05
- 600 + 500	4,29	7,52	3,99	7,06	3,53	6,25	2,25	4,00
- 500 + 355	3,67	6,44	3,97	6,90	3,98	6,99	2,68	4,75
- 355 + 212	4,22	7,67	1,32	2,69	6,45	11,07	3,19	5,34
- 212 + 150	10,01	17,35	2,02	3,41	3,88	6,66	4,28	7,36
- 150 + 106	9,30	18,00	1,21	1,96	3,93	6,67	9,69	18,48
- 106 + 75	3,07	2,57	4,62	5,52	1,69	1,96	4,90	5,72
-75	1,91	0,44	2,67	6,77	2,87	1,90	2,49	1,17

Table C-2.2: Standard deviation in product ash (%) and upgrade (%) between triplicate repeats for 60-120 min

Standard deviation								
Flowrate (l/min)	9							
No. of channels	12							
Time (min)	60-75		75-90		90-105		105-120	
Size range (μm)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)	Product ash (%)	Product upgrade (%)
-1000 + 600	10,55	19,22	6,24	11,40	7,99	14,59	5,43	9,96
- 600 + 500	2,31	4,01	1,94	3,46	5,08	8,99	2,64	4,69
- 500 + 355	2,04	3,61	3,88	6,82	4,01	7,02	4,47	7,84
- 355 + 212	4,94	8,27	5,85	9,92	6,65	11,41	15,07	26,49
- 212 + 150	4,71	8,13	4,20	7,23	4,08	7,02	13,12	22,78
- 150 + 106	4,55	7,80	4,63	9,11	4,30	8,56	9,56	18,40
- 106 + 75	3,06	3,29	6,24	9,06	5,85	10,73	9,19	12,62
-75	0,61	2,52	2,10	1,70	1,76	0,77	2,22	0,66

APPENDIX D: ADDITIONAL PLOTS

D-1: Preliminary batch tests

D-1.1 Product ash (%) and upgrade (%) curves for -500 µm tests (Tests 7A-9A)

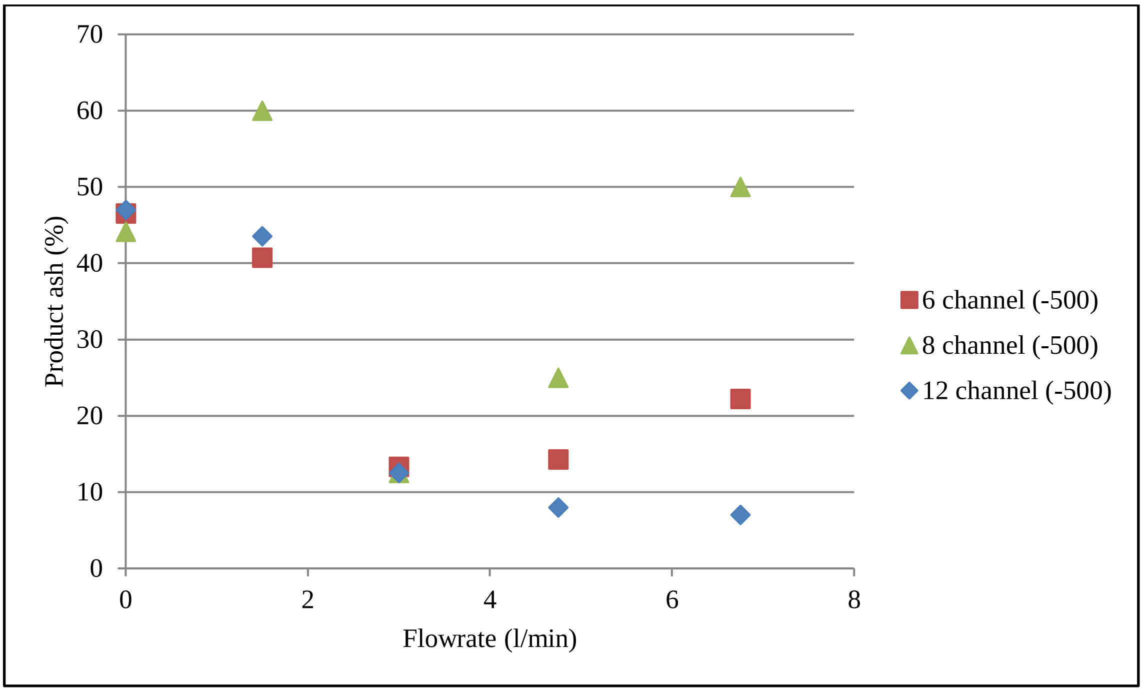

Figure D-1.1: Effect of fluidisation rate on product ash content (-500 + 355 micron fraction)

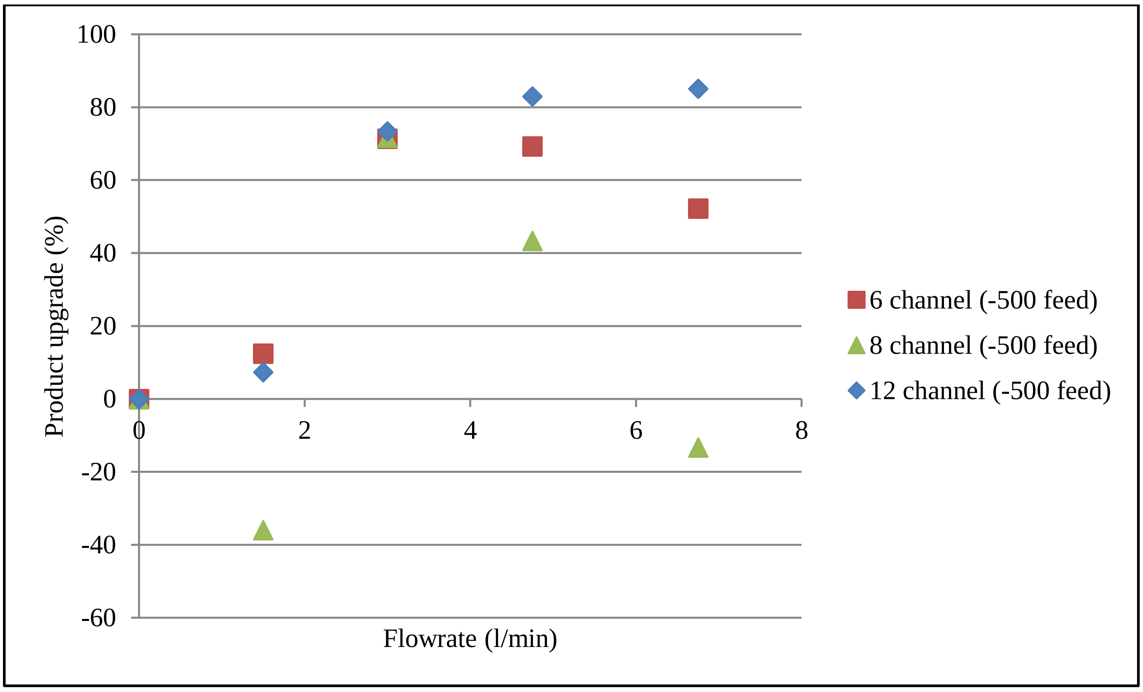

Figure D-1.2: Effect of fluidisation rate on upgrade (-500 + 355 micron fraction)

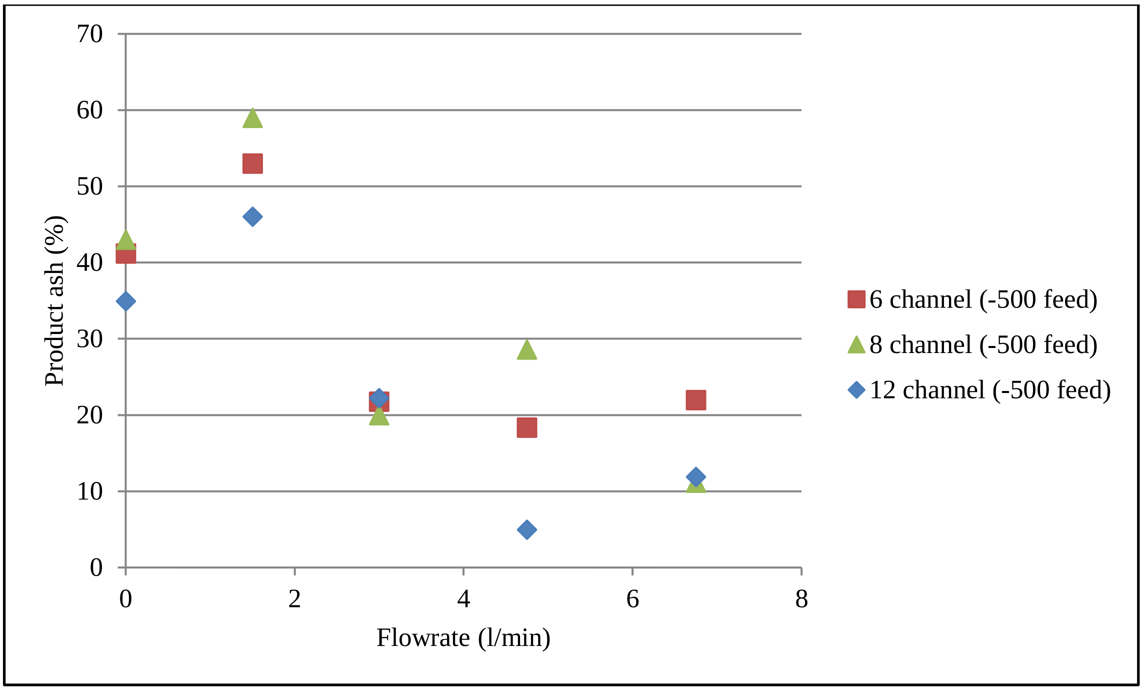

Figure D-1.3: Effect of fluidisation rate on product ash content (-355 + 212 micron fraction)

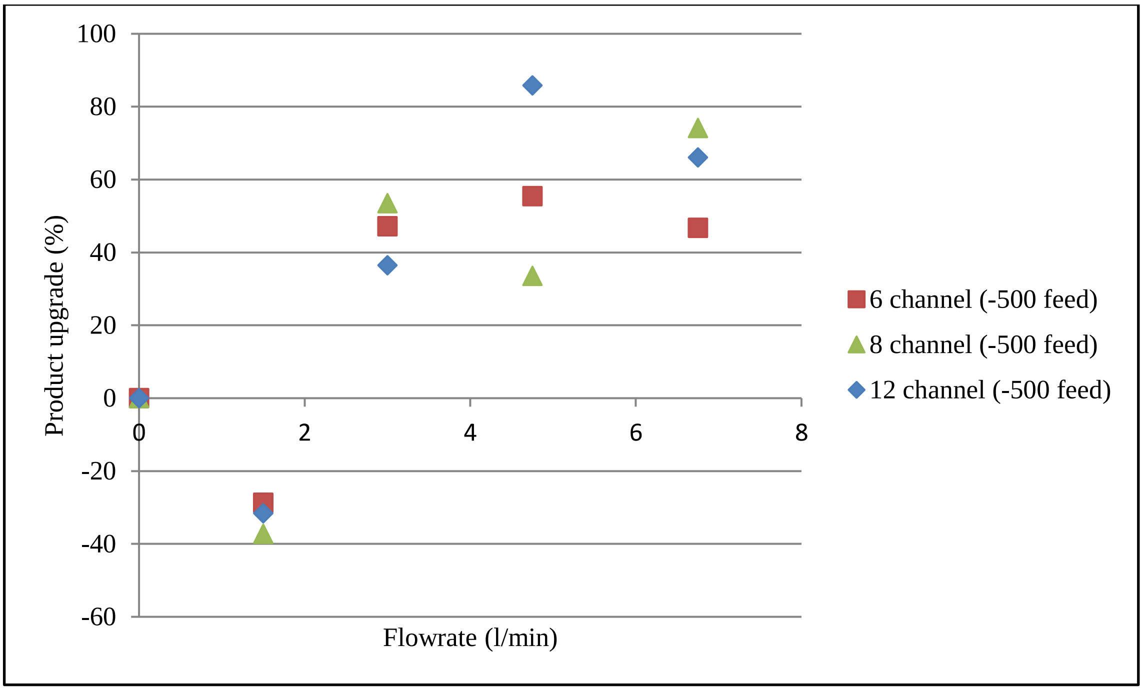

Figure D-1.4: Effect of fluidisation rate on upgrade (-355 + 212 micron fraction)

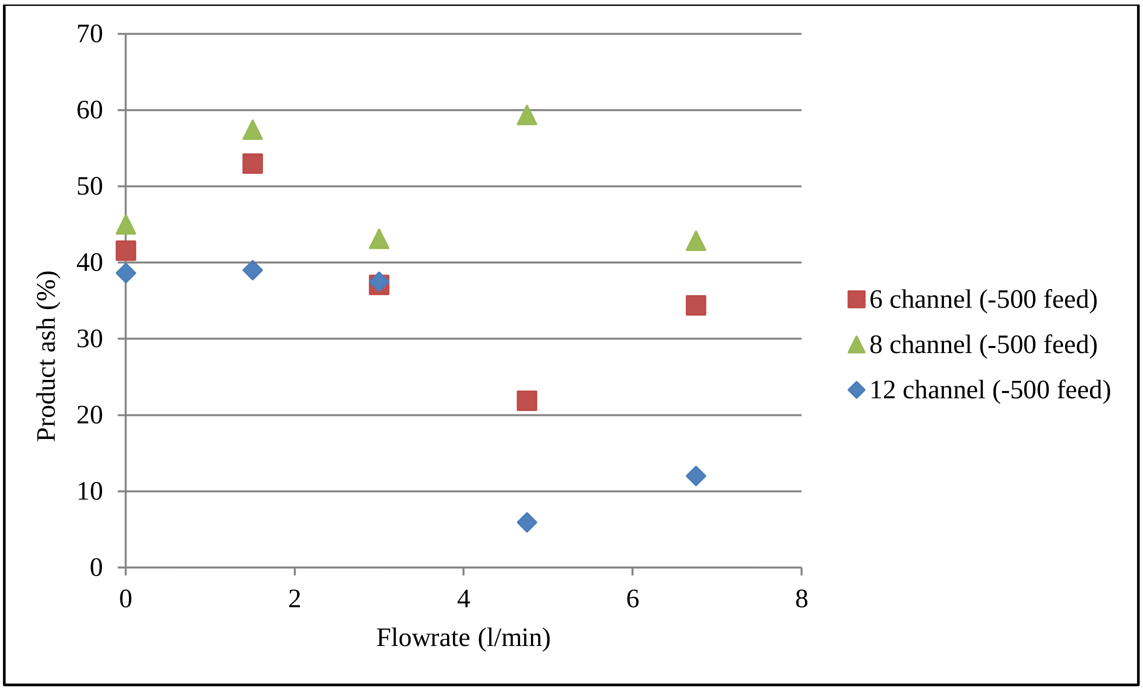

Figure D-1.5: Effect of fluidisation rate on product ash content (-212 + 150 micron fraction)

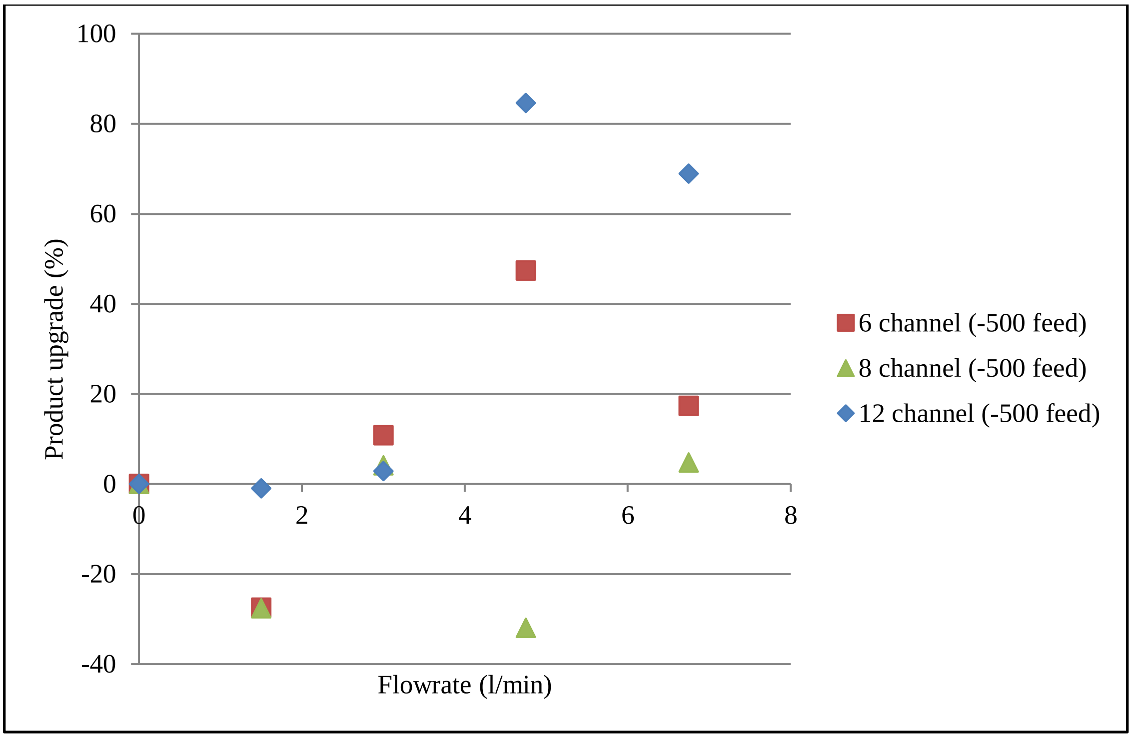

Figure D-1.6: Effect of fluidisation rate on upgrade (-212 + 150 micron fraction)

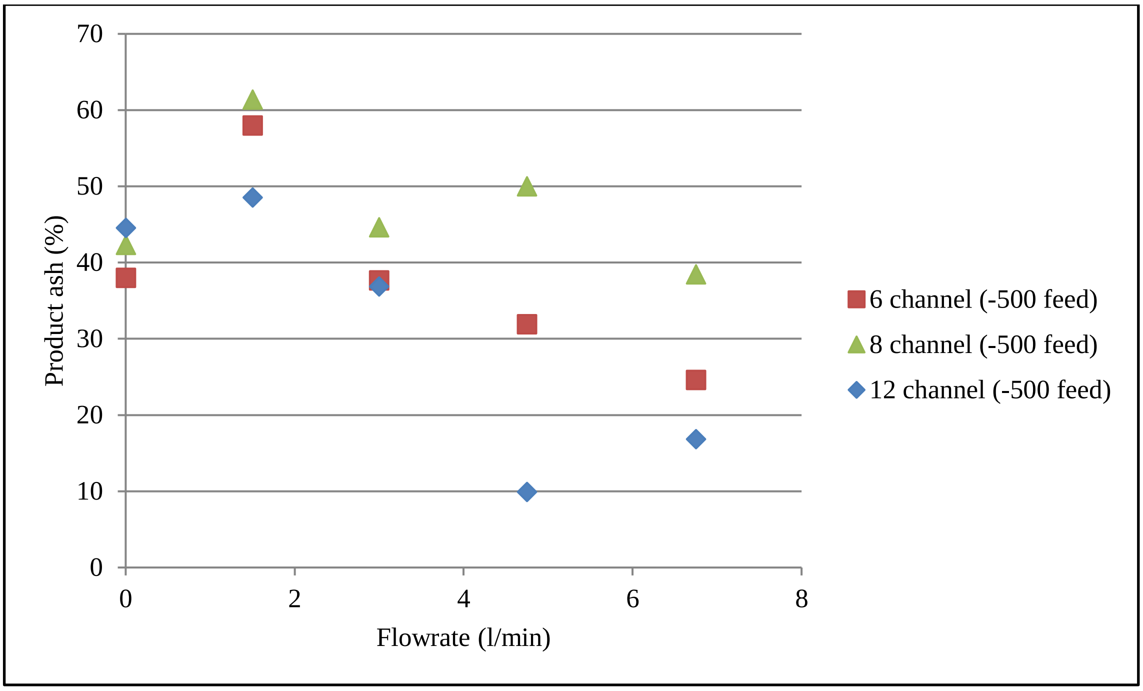

Figure D-1.7: Effect of fluidisation rate on product ash content (-150 + 106 micron fraction)

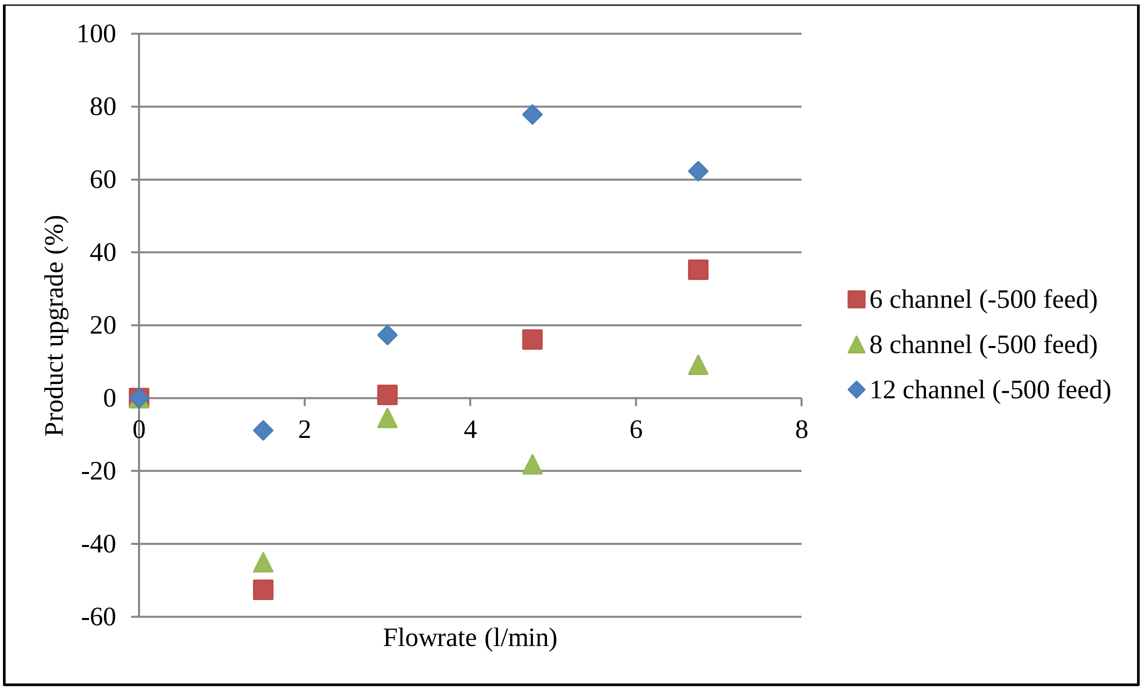

Figure D-1.8: Effect of fluidisation rate on upgrade (-150 + 106 micron fraction)

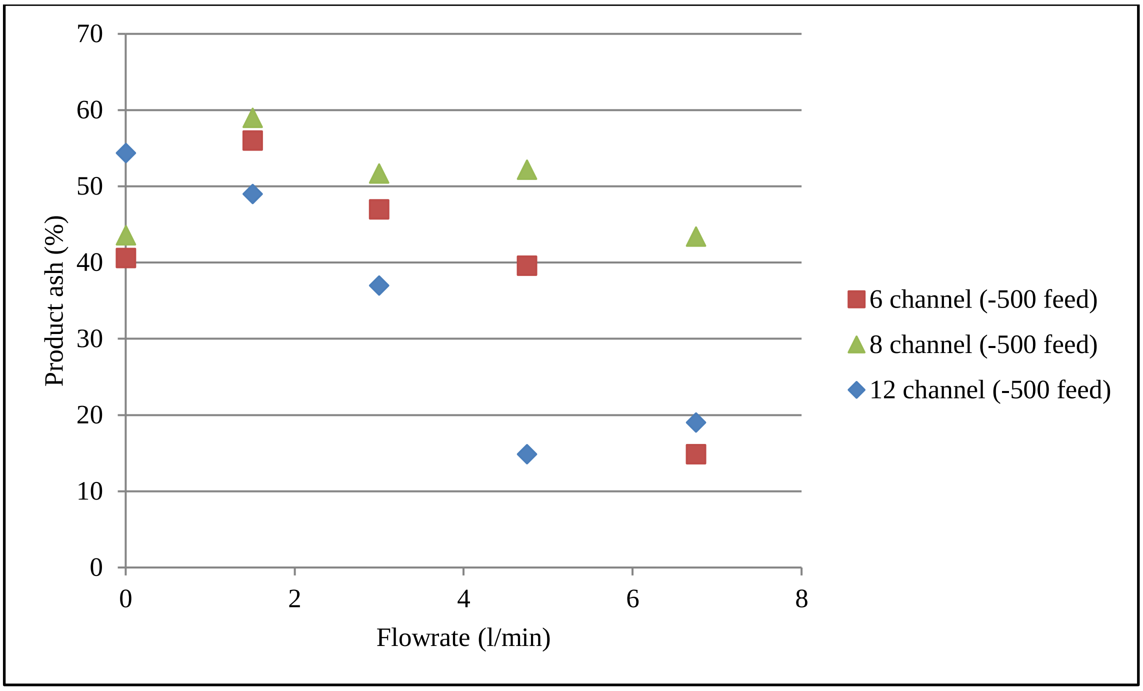

Figure D-1.9: Effect of fluidisation rate on product ash content (-106 + 75 micron fraction)

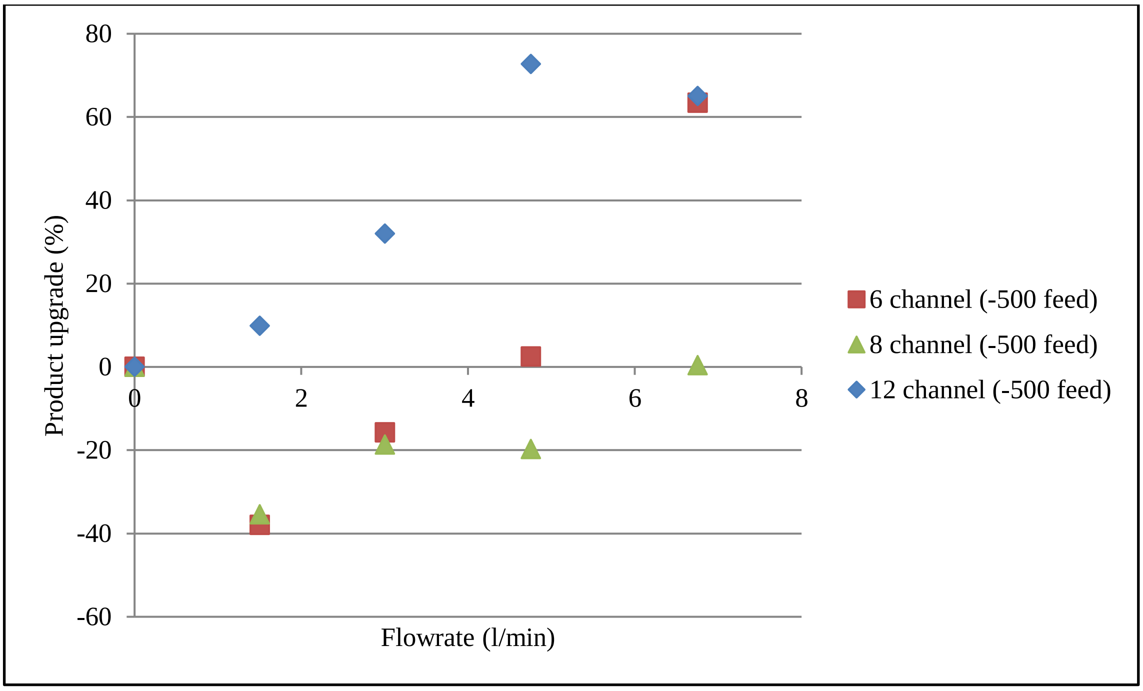

Figure D-1.10: Effect of fluidisation rate on upgrade (-106 + 75 micron fraction)

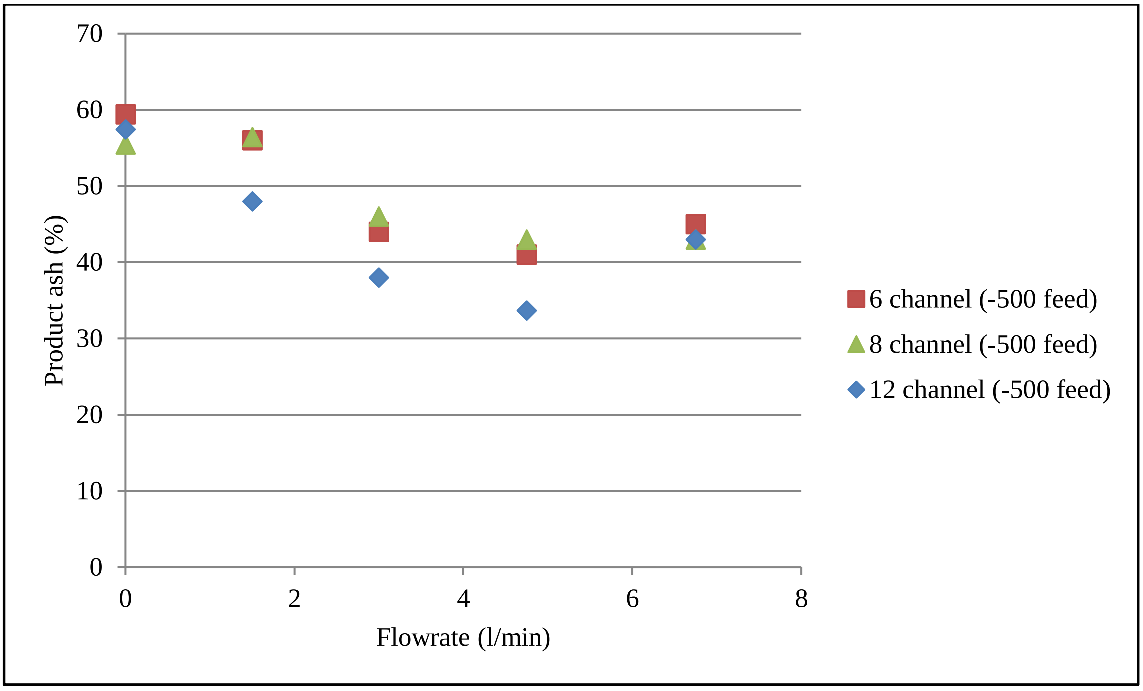

Figure D-1.11: Effect of fluidisation rate on product ash content (-75 micron fraction)

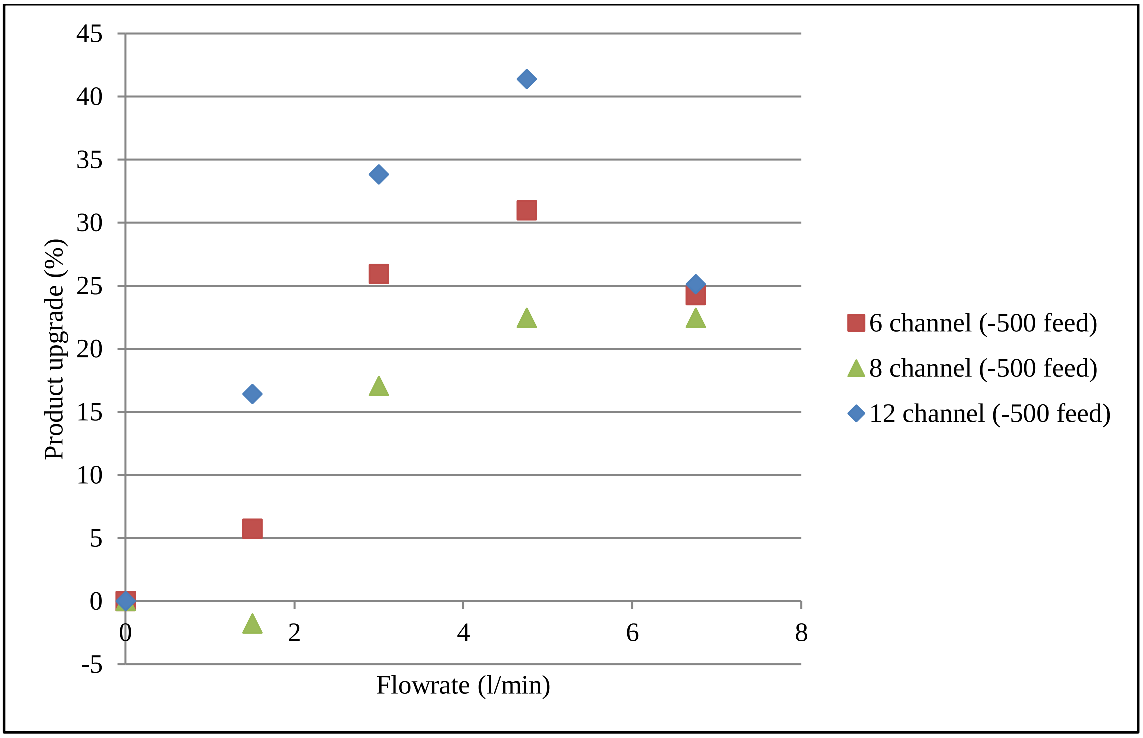

Figure D-1.12: Effect of fluidisation rate on upgrade (-75 micron fraction)

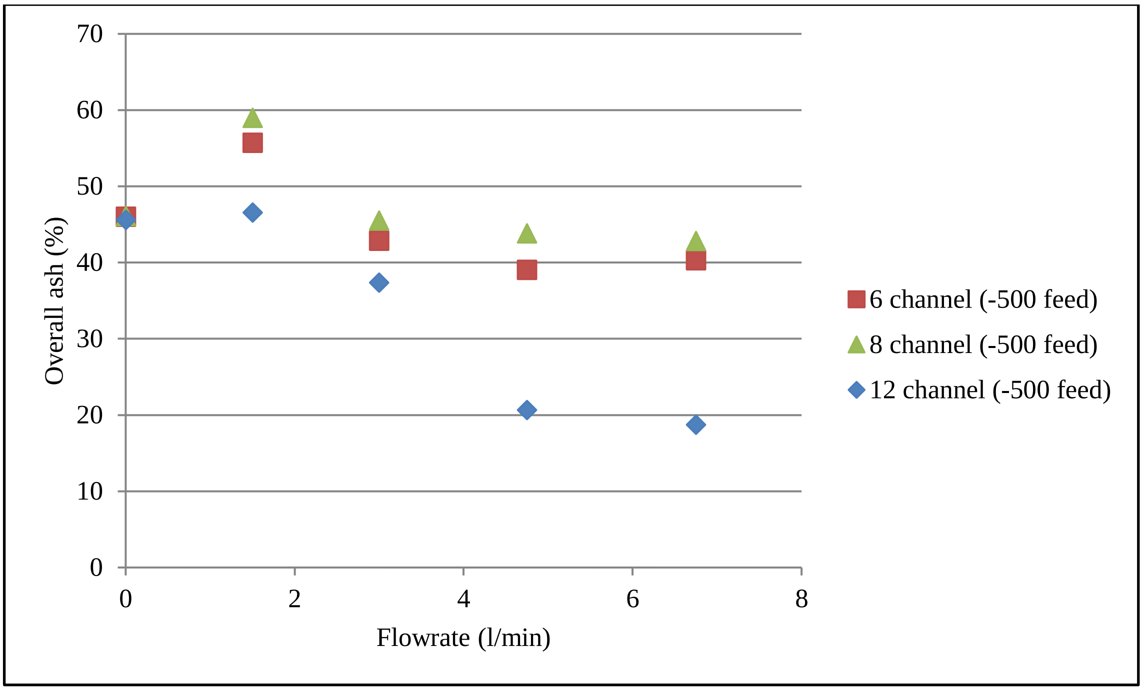

Figure D-1.13: Effect of fluidisation rate on overall product ash content

D-1.2 Product ash (%) and upgrade (%) plots for -355 µm tests (Tests 10A-12A)

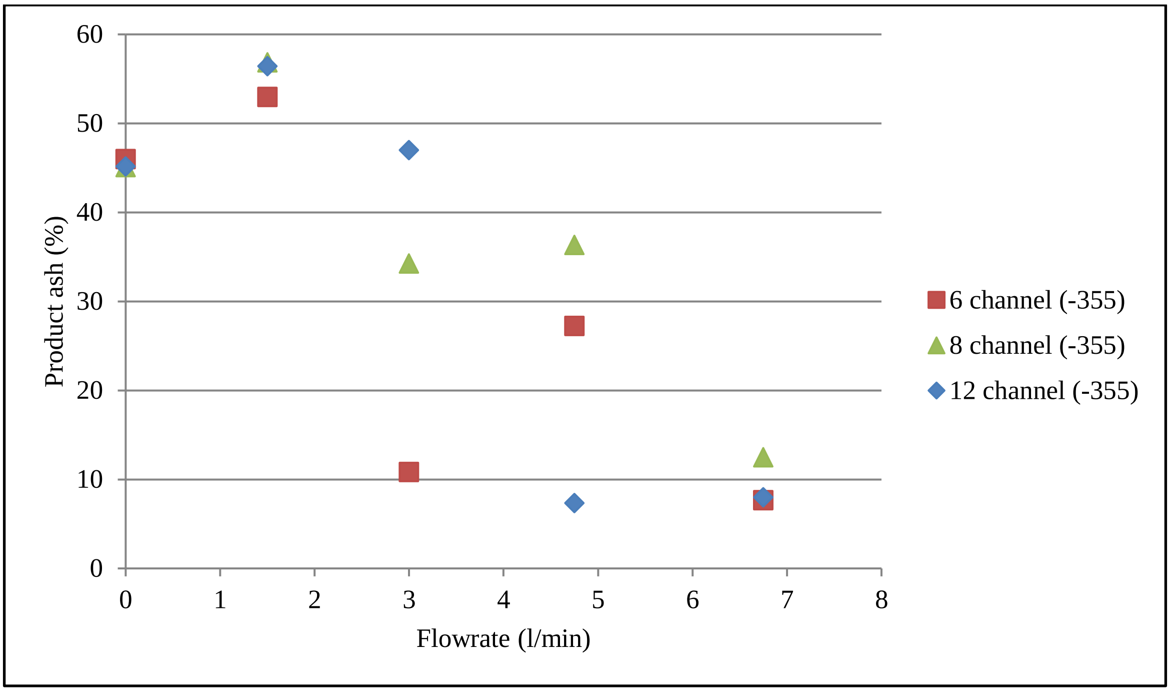

Figure D-1.14: Effect of fluidisation rate on product ash content (-355 + 212 micron fraction)

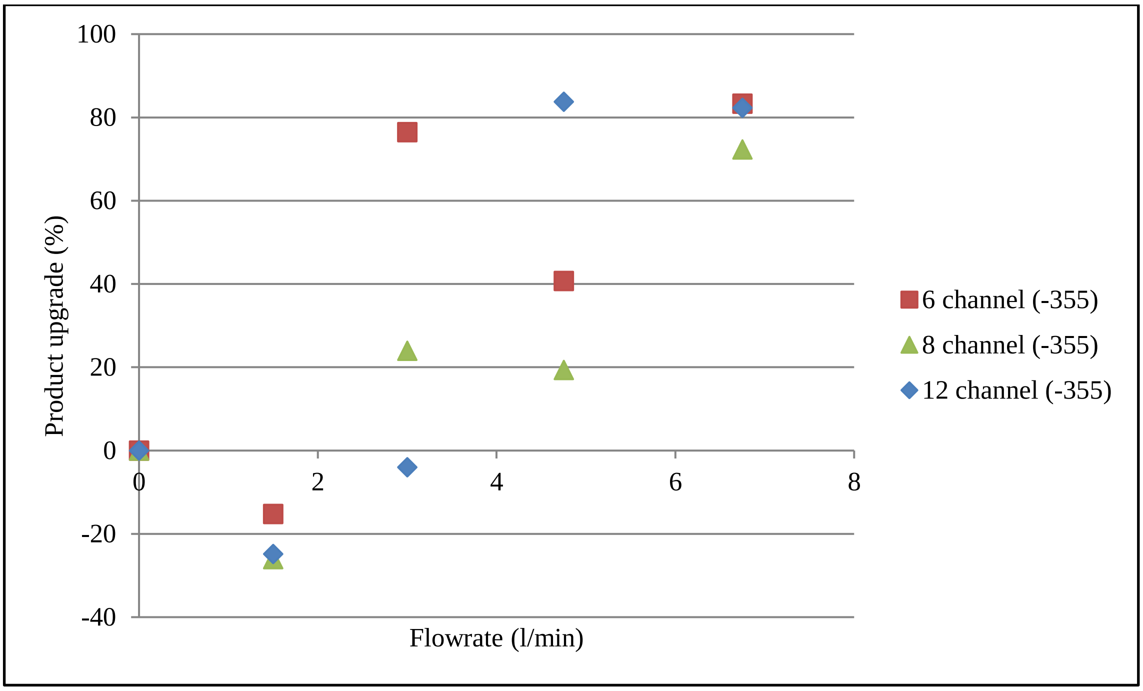

Figure D-1.15: Effect of fluidisation rate on upgrade (-355 + 212 micron fraction)

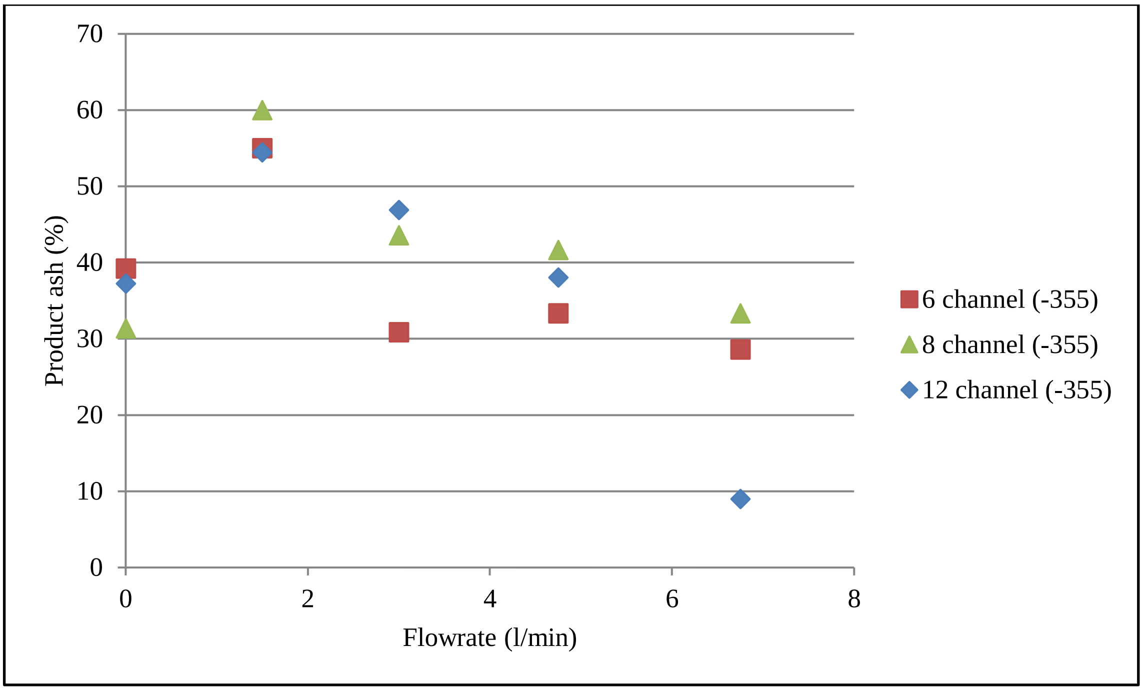

Figure D-1.16: Effect of fluidisation rate on product ash content (-212 + 150 micron fraction)

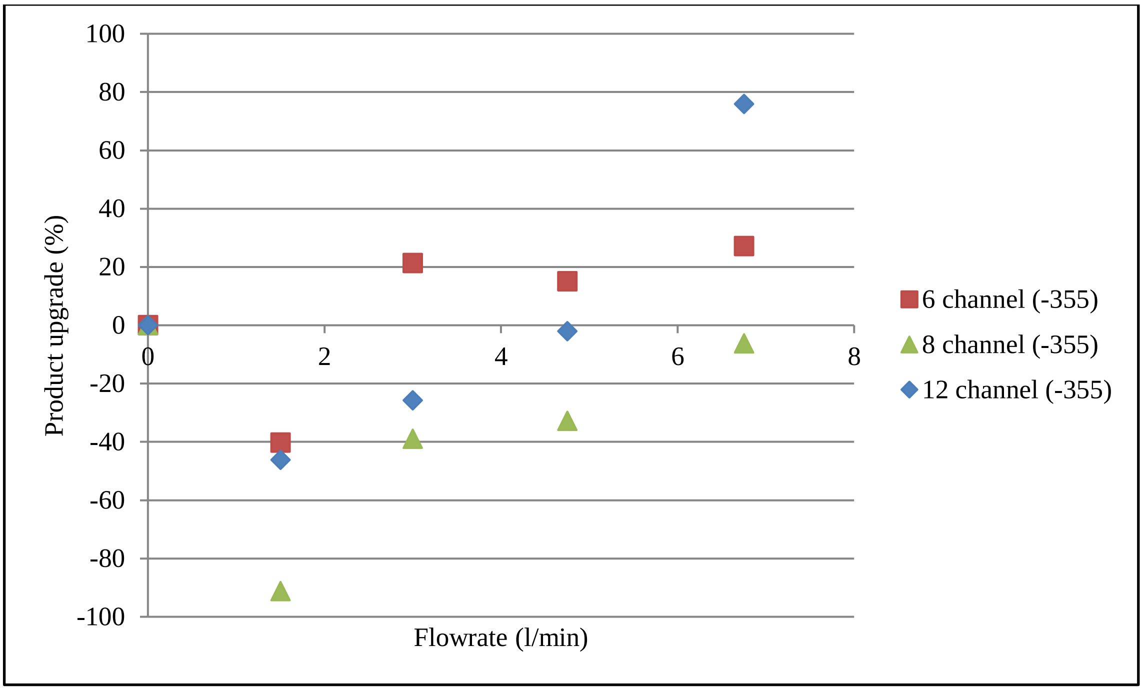

Figure D-1.17: Effect of fluidisation rate on upgrade (-212 + 150 micron fraction)

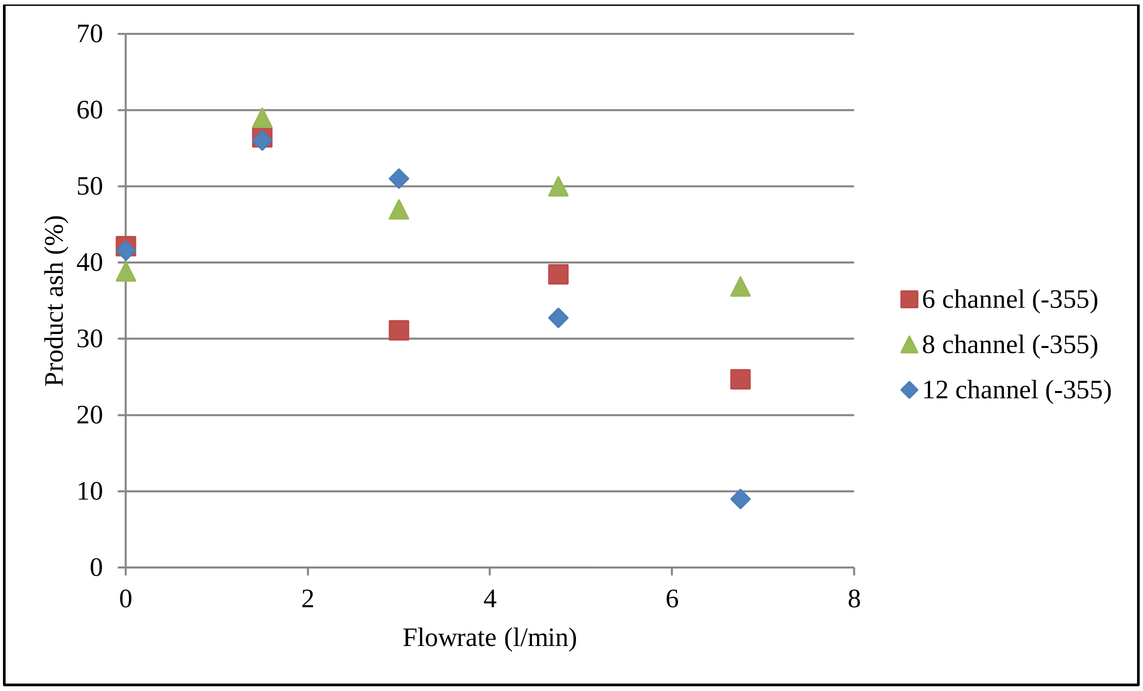

Figure D-1.18: Effect of fluidisation rate on product ash content (-150 + 106 micron fraction)

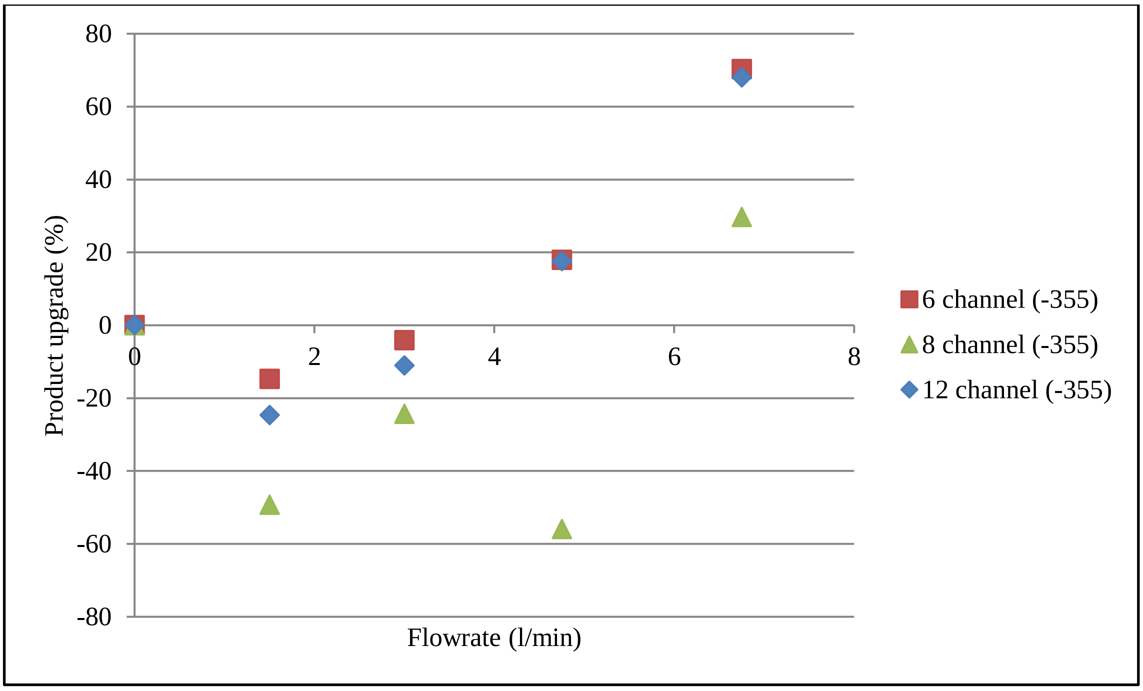

Figure D-1.19: Effect of fluidisation rate on upgrade (-150 + 106 micron fraction)

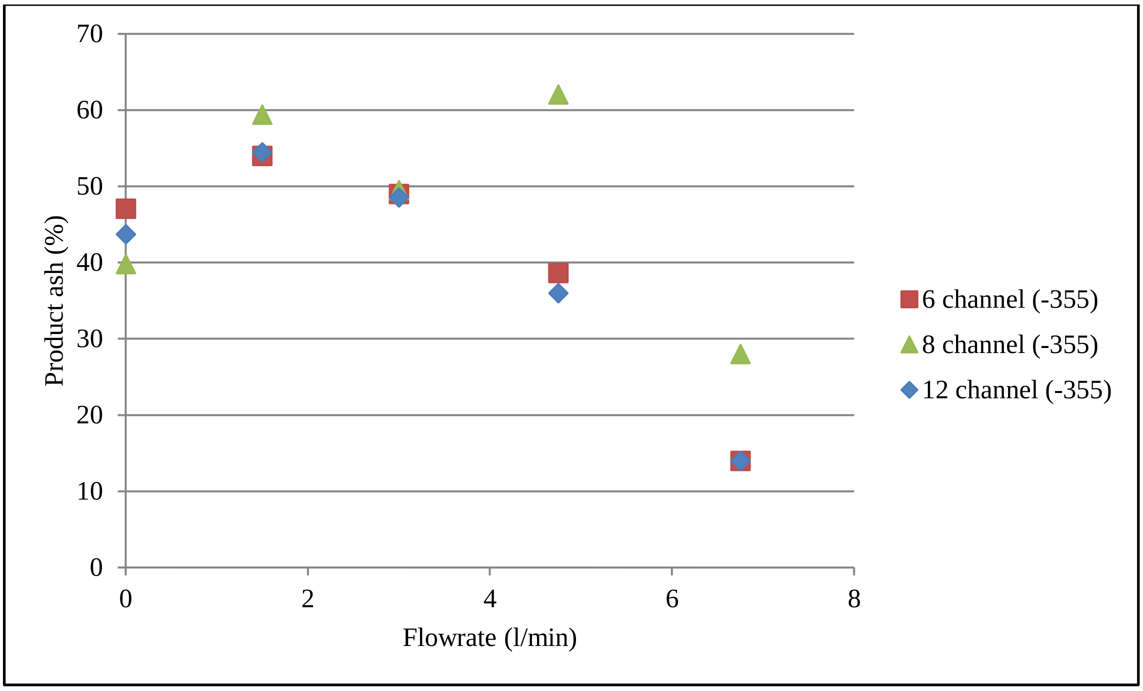

Figure D-1.20: Effect of fluidisation rate on product ash content (-106 + 75 micron fraction)

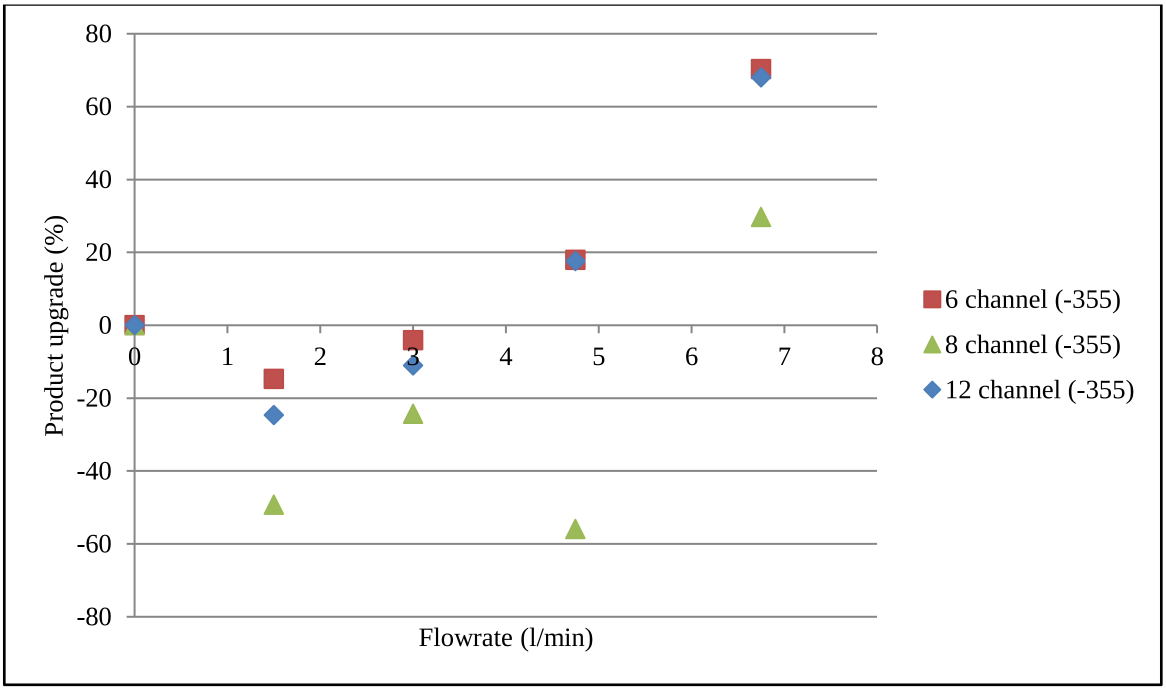

Figure D-1.21: Effect of fluidisation rate on upgrade (-106 + 75 micron fraction)

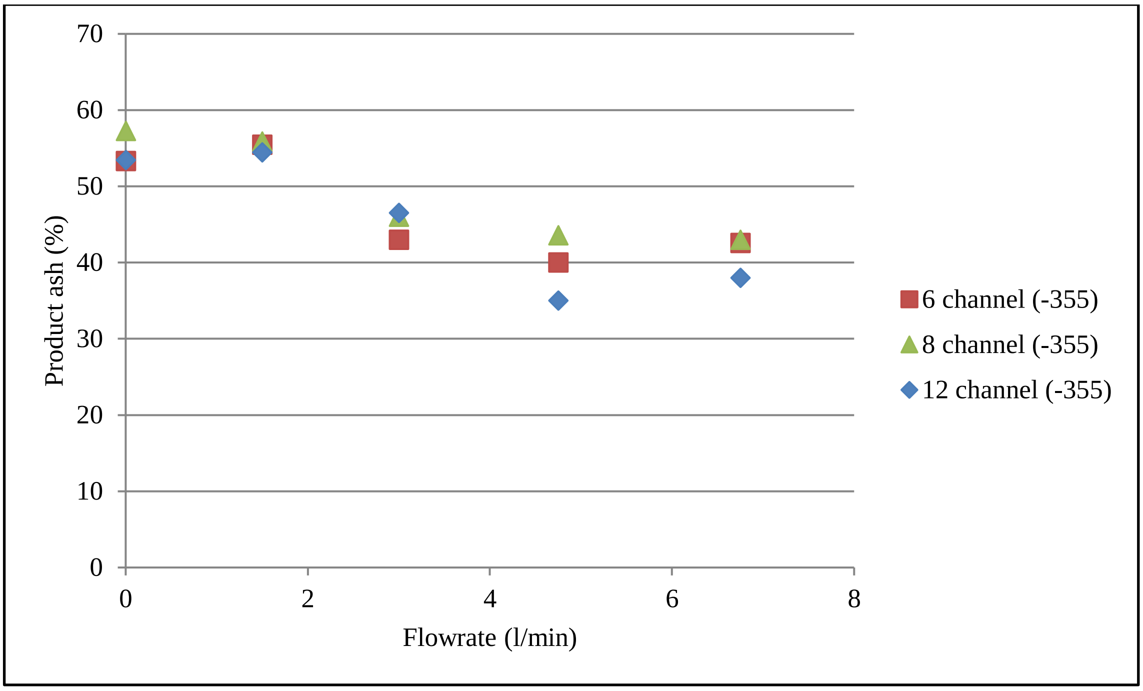

Figure D-1.22: Effect of fluidisation rate on product ash content (-75 micron fraction)

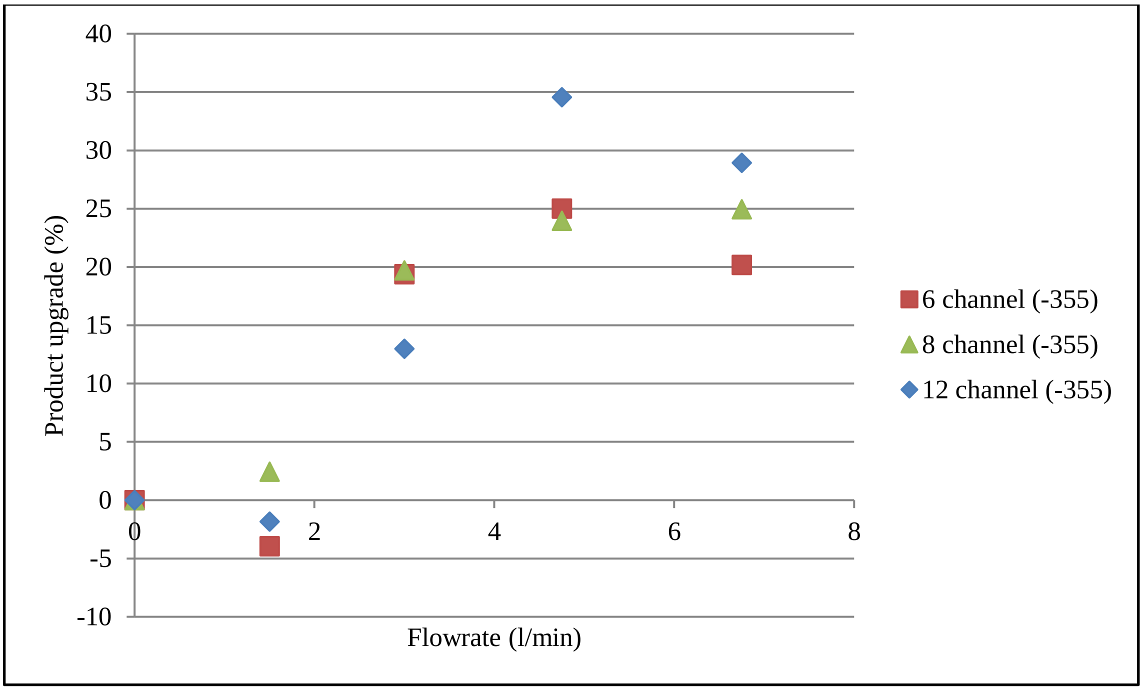

Figure D-1.23: Effect of fluidisation rate on product ash content (-75 micron fraction)

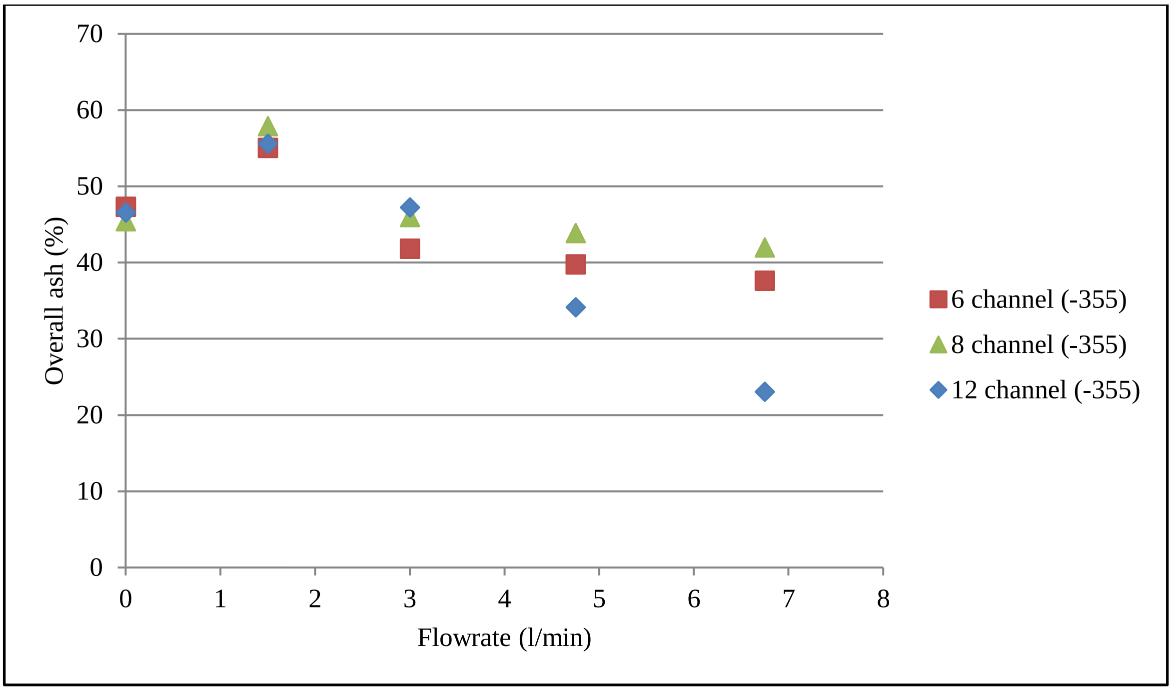

Figure D-1.24: Effect of fluidisation rate on overall ash content

D-1.3 Product ash (%) and upgrade (%) plots for -212 µm tests (Tests 13A-15A)

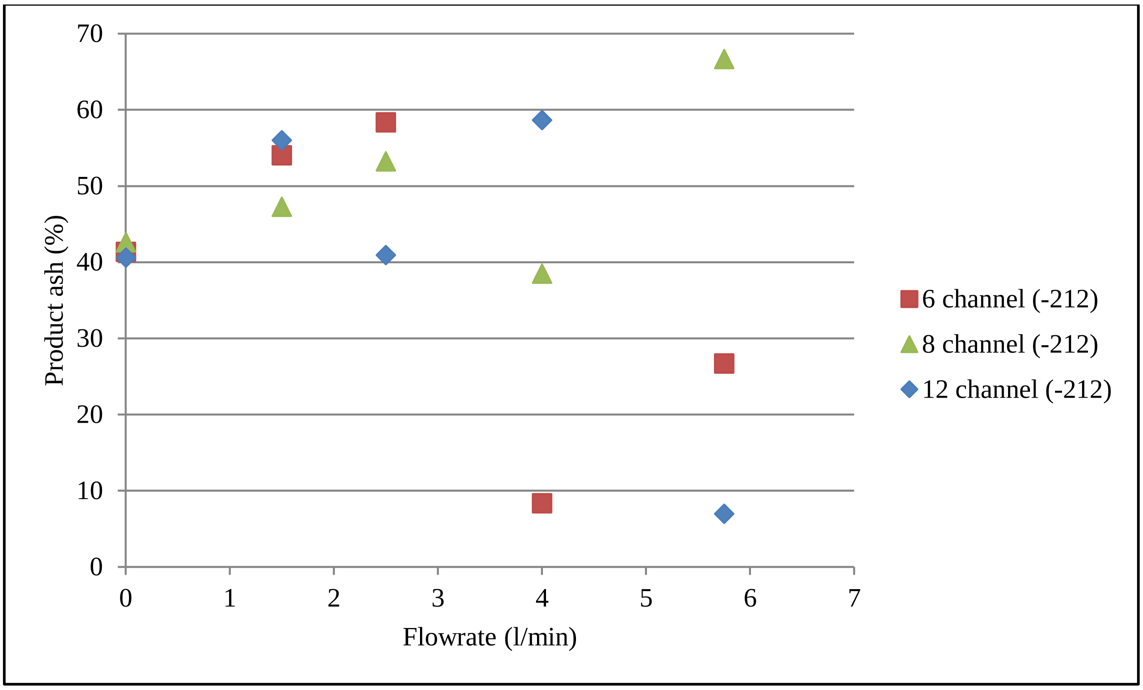

Figure D-1.25: Effect of fluidisation rate on product ash content (-212 + 150 micron fraction)

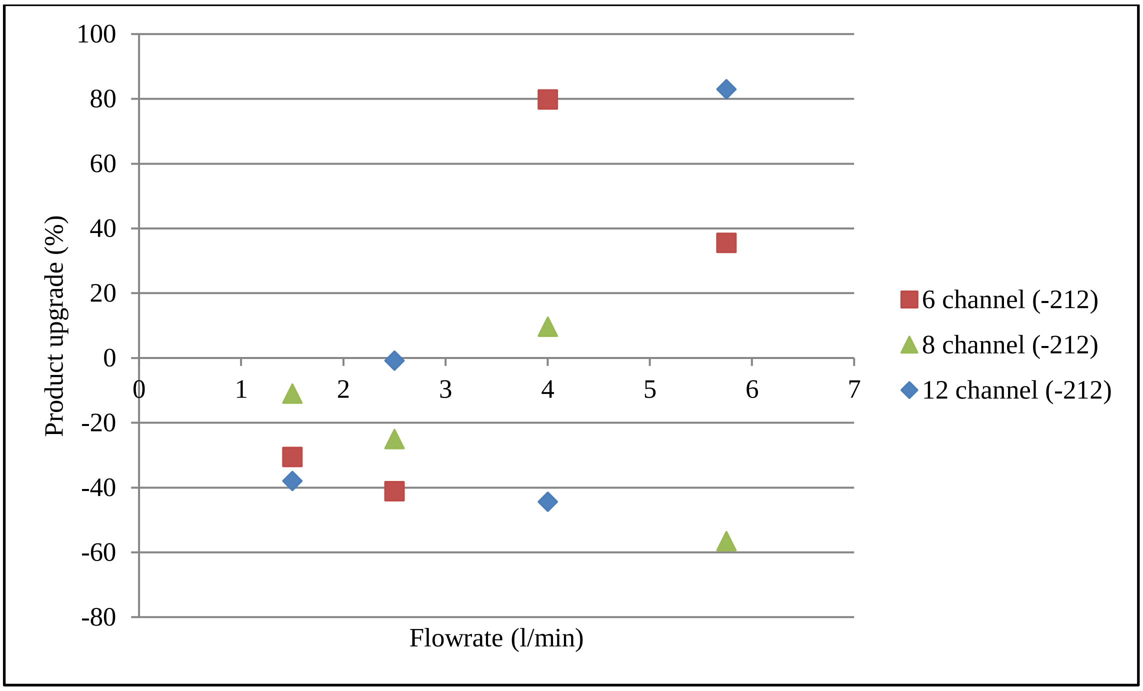

Figure D-1.26: Effect of fluidisation rate on upgrade (-212 + 150 micron fraction)

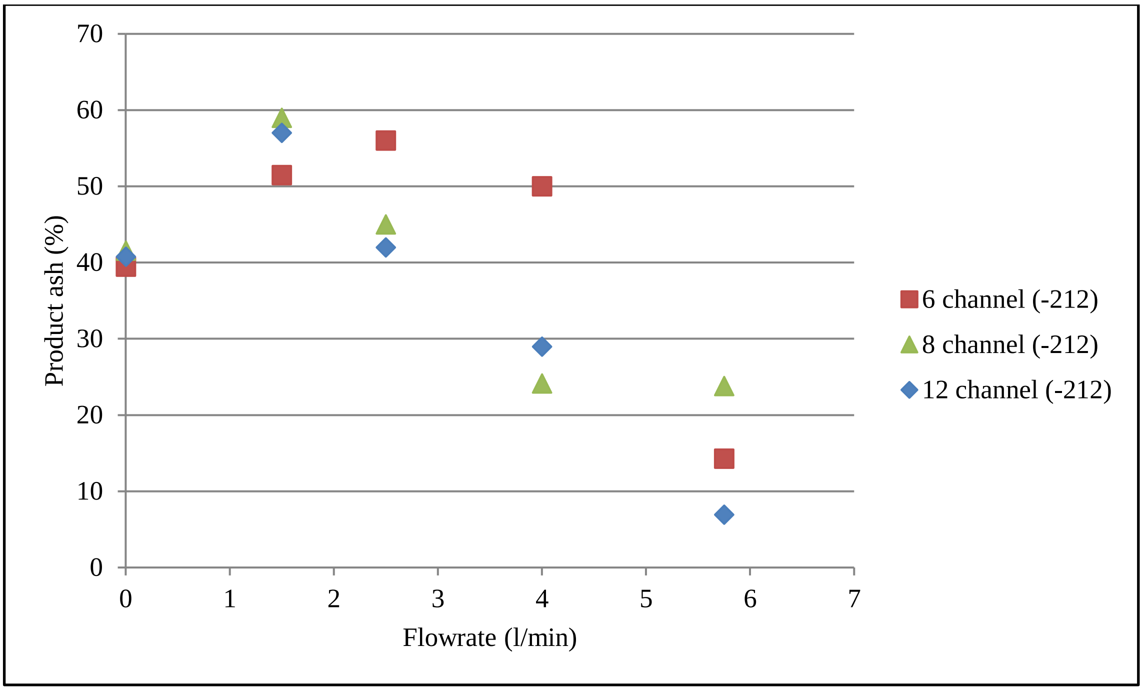

Figure D-1.27: Effect of fluidisation rate on product ash content (-150 + 106 micron fraction)

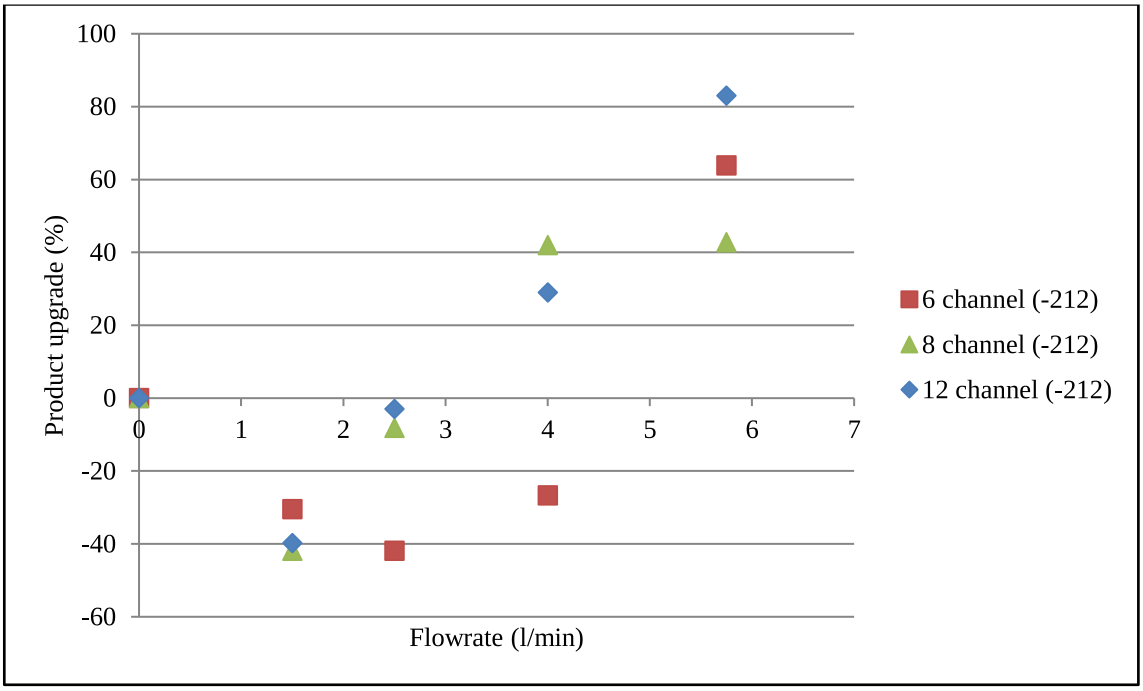

Figure D-1.28: Effect of fluidisation rate on upgrade (-150 + 106 micron fraction)

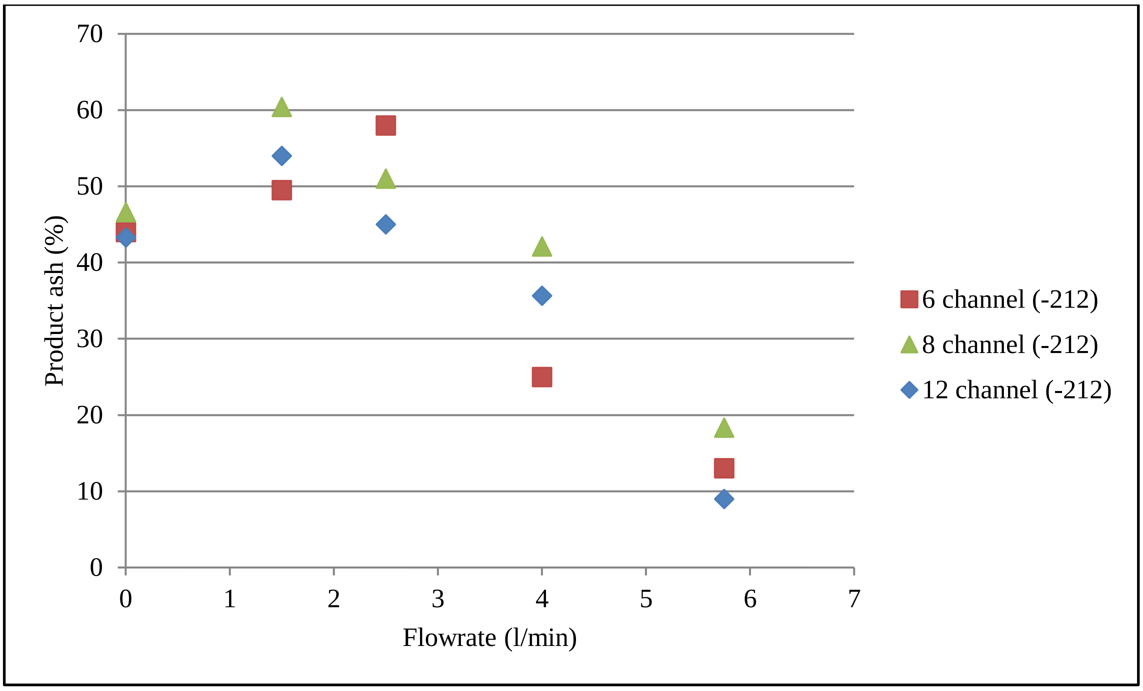

Figure D-1.29: Effect of fluidisation rate on product ash content (-106 + 75 micron fraction)

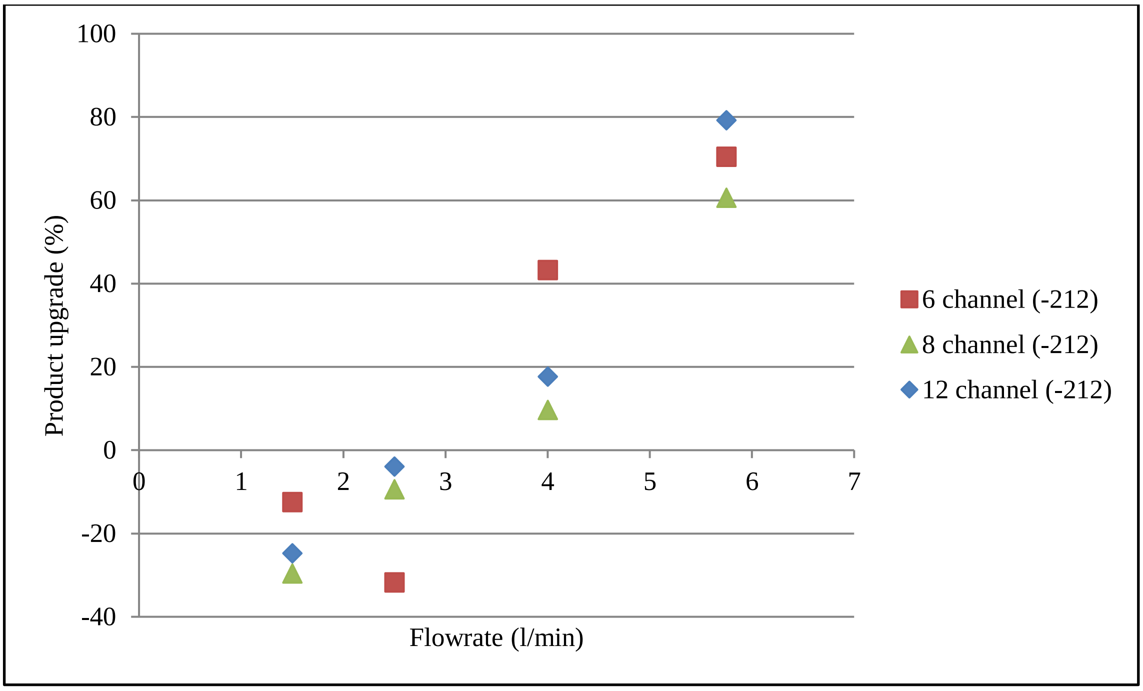

Figure D-1.30: Effect of fluidisation rate on upgrade (-106 + 75 micron fraction)

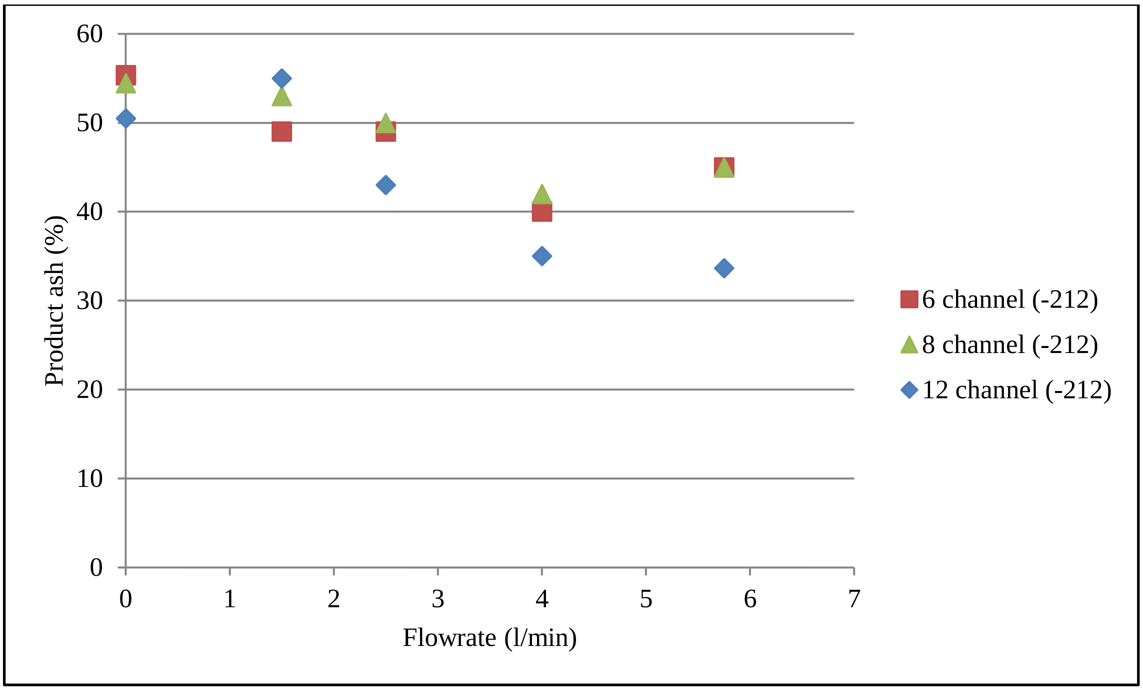

Figure D-1.31: Effect of fluidisation rate on product ash content (-75 micron fraction)

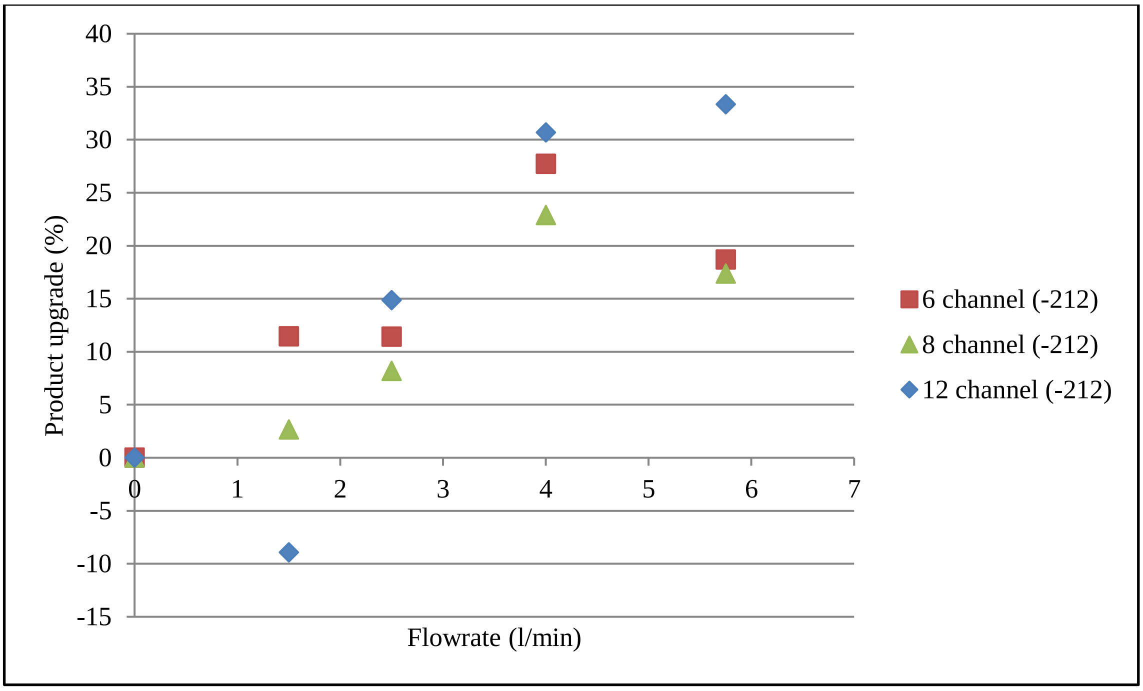

Figure D-1.32: Effect of fluidisation rate on upgrade (-75 micron fraction)

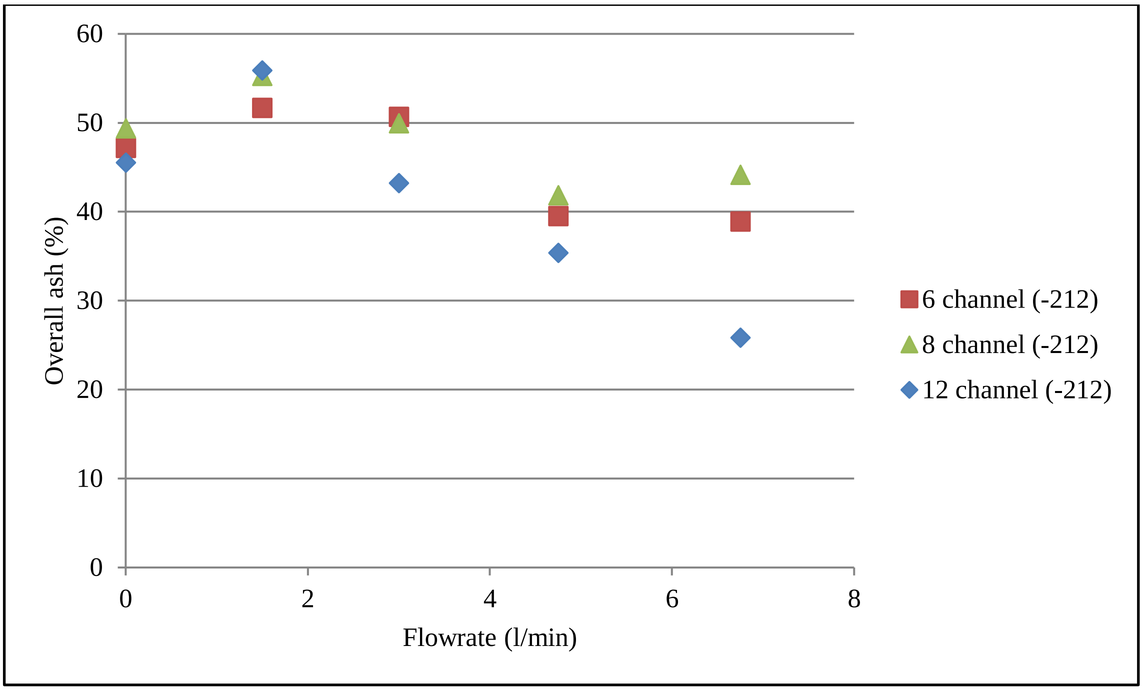

Figure D-1.33: Effect of fluidisation rate on overall product ash content

D-2: Primary batch tests

D-2.1 Product ash (%) curves

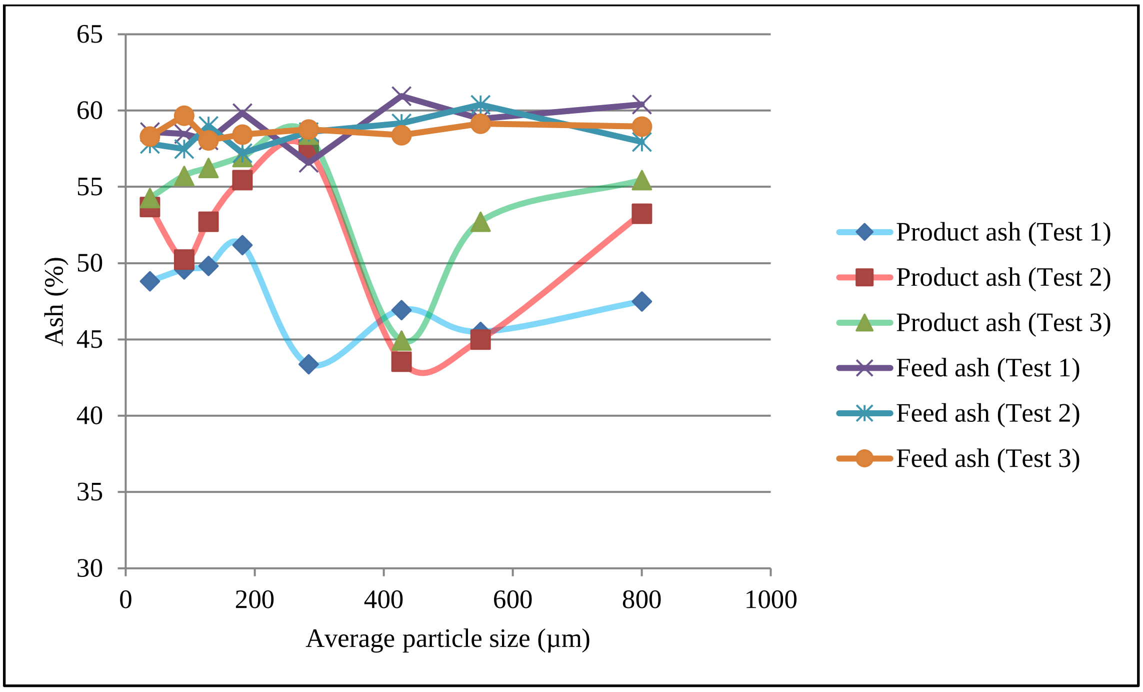

Figure D-2.1: Variation of ash with particle size using 6 channels at 3 l/min (0-15 minutes)

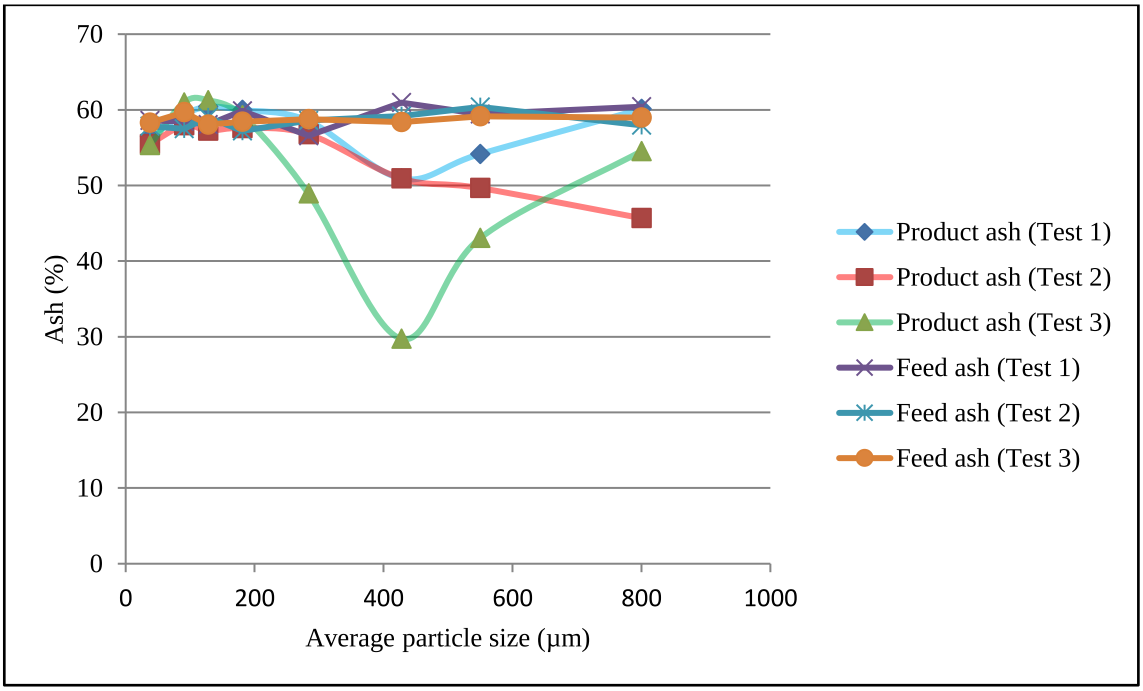

Figure D-2.2: Variation of ash with particle size using 6 channels at 3 l/min (15-30 minutes)

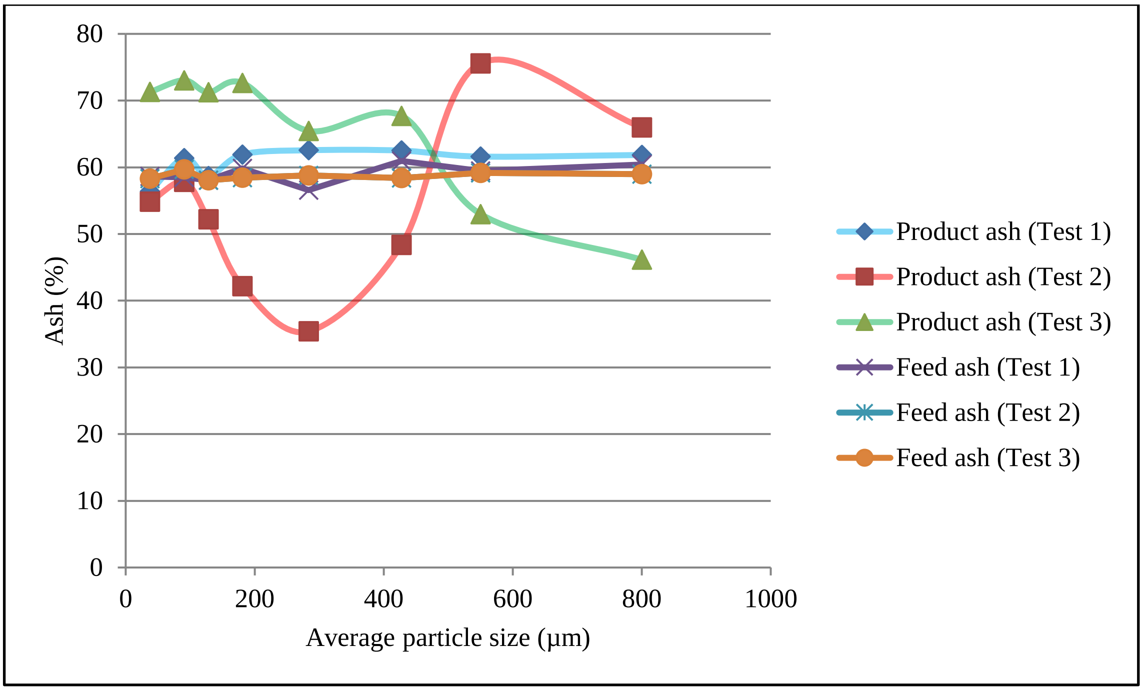

Figure D-2.3: Variation of ash with particle size using 6 channels at 3 l/min (30-45 minutes)

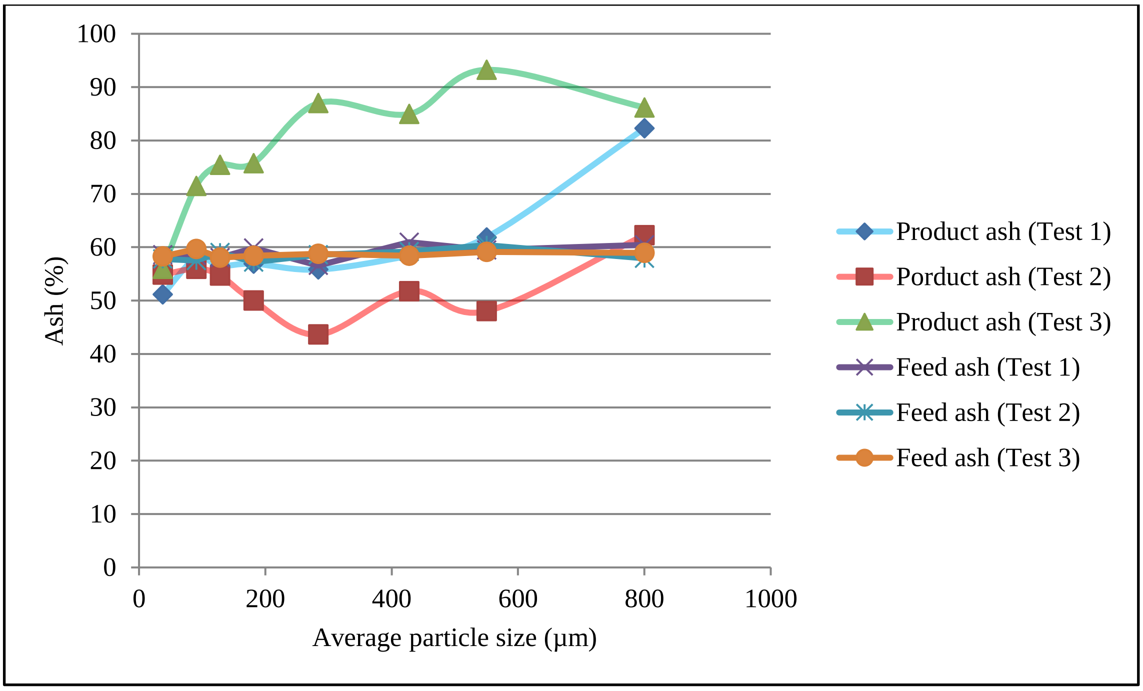

Figure D-2.4: Variation of ash with particle size using 6 channels at 3 l/min (45-60 minutes)

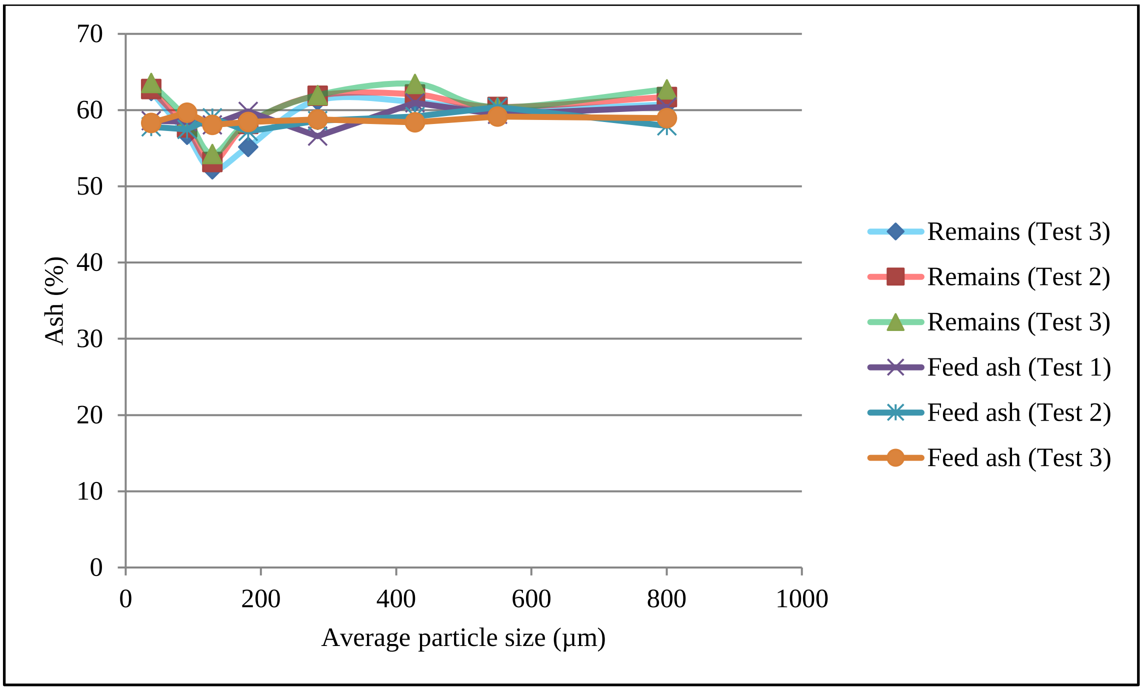

Figure D-2.5: Variation of ash with particle size using 6 channels at 3 l/min (Underflow)

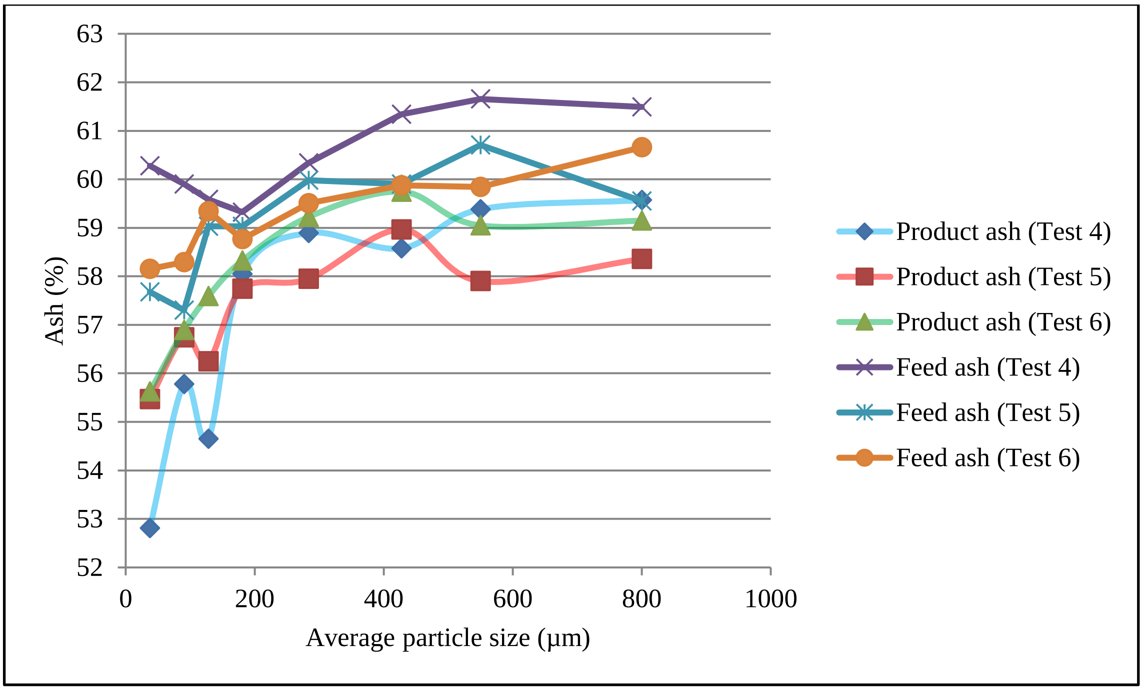

Figure D-2.6: Variation of ash with particle size using 8 channels at 3 l/min (0-15 minutes)

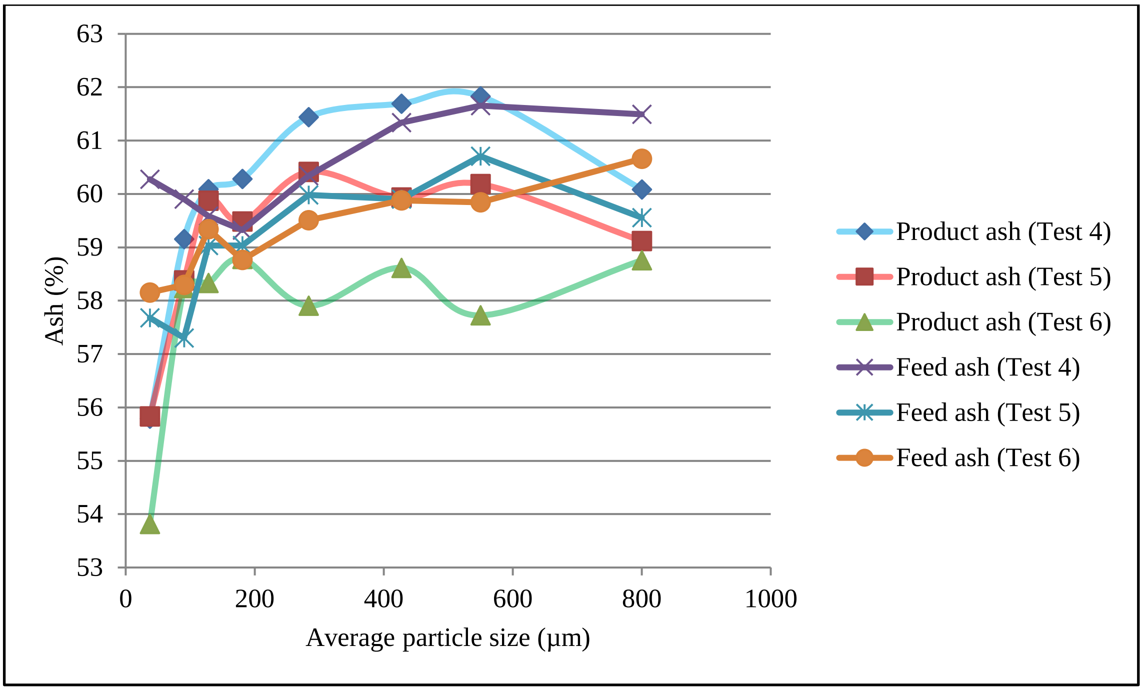

Figure D-2.7: Variation of ash with particle size using 8 channels at 3 l/min (15-30 minutes)

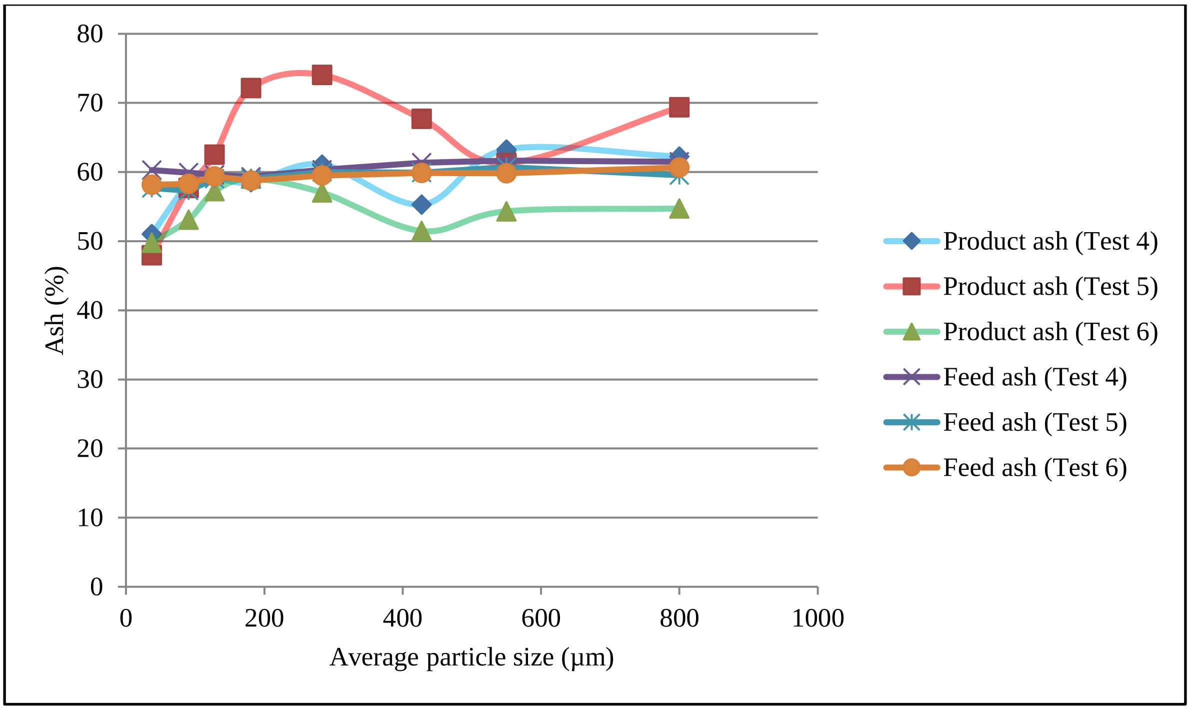

Figure D-2.8: Variation of ash with particle size using 8 channels at 3 l/min (30-45 minutes)

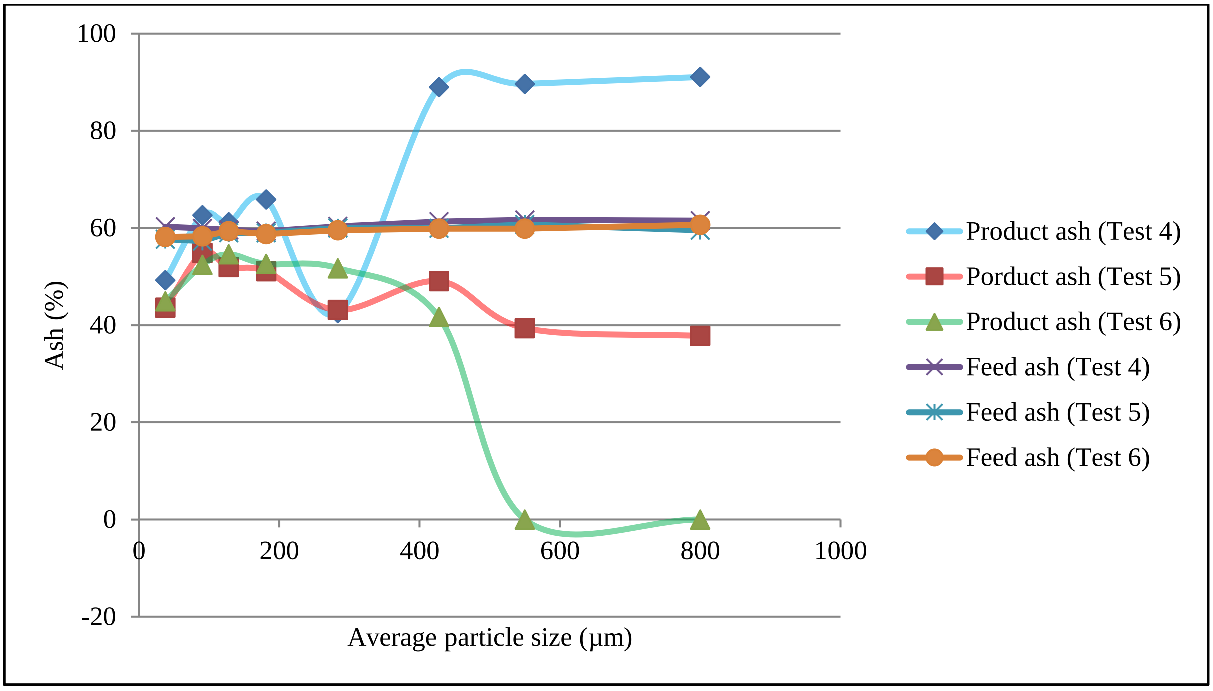

Figure D-2.9: Variation of ash with particle size using 8 channels at 3 l/min (45-60 minutes)

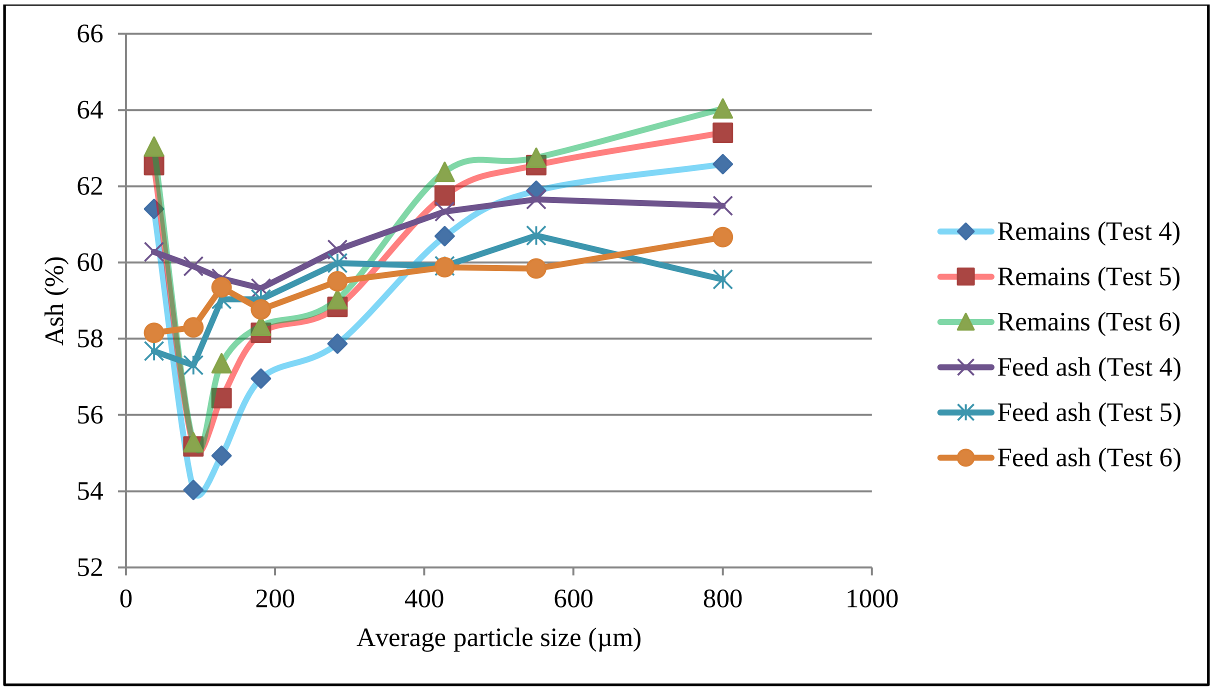

Figure D-2.10: Variation of ash with particle size using 8 channels at 3 l/min (Underflow)

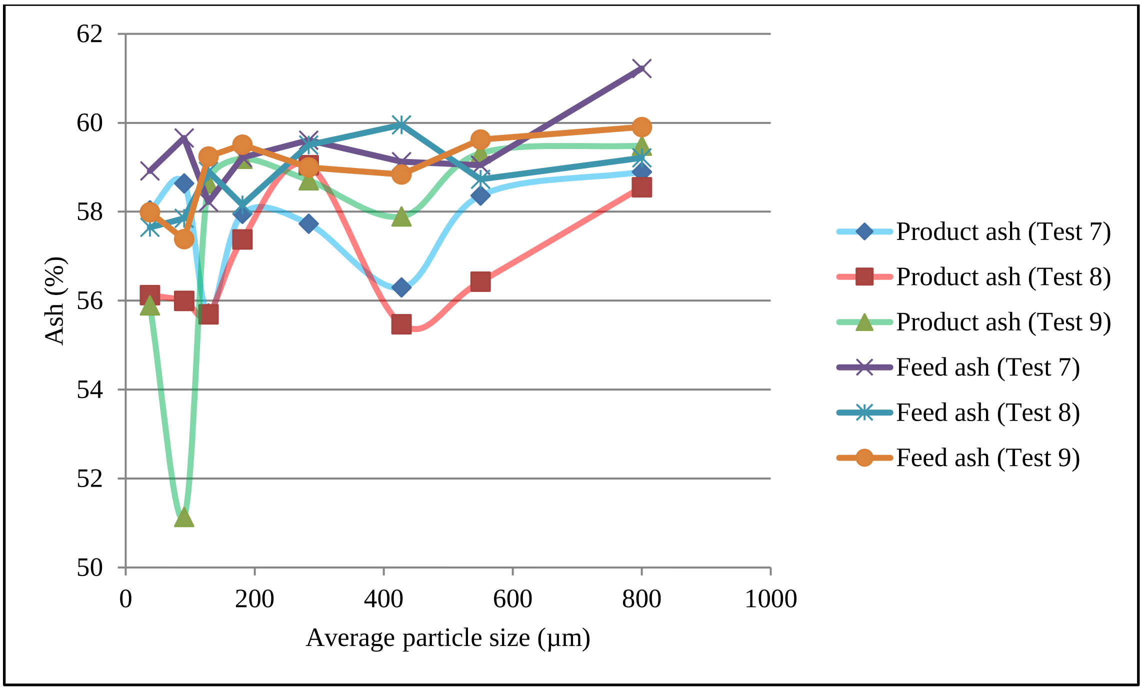

Figure D-2.11: Variation of ash with particle size using 12 channels at 3 l/min (0-15 minutes)

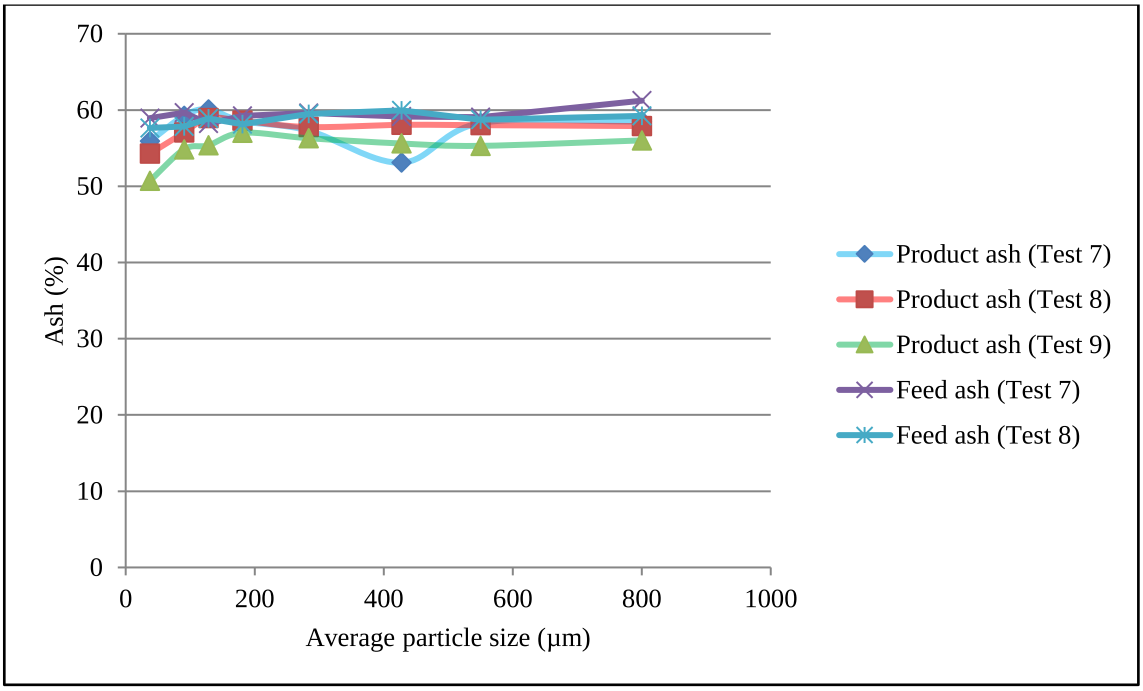

Figure D-2.12: Variation of ash with particle size using 12 channels at 3 l/min (15-30 minutes)

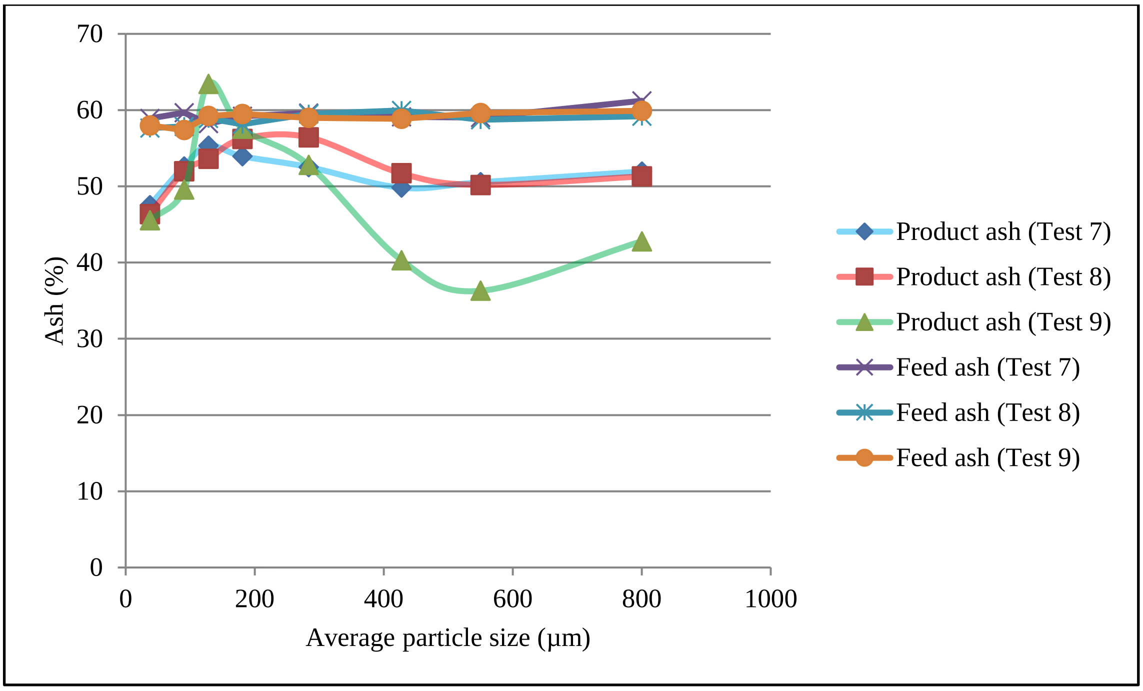

Figure D-2.13: Variation of ash with particle size using 12 channels at 3 l/min (30-45 minutes)

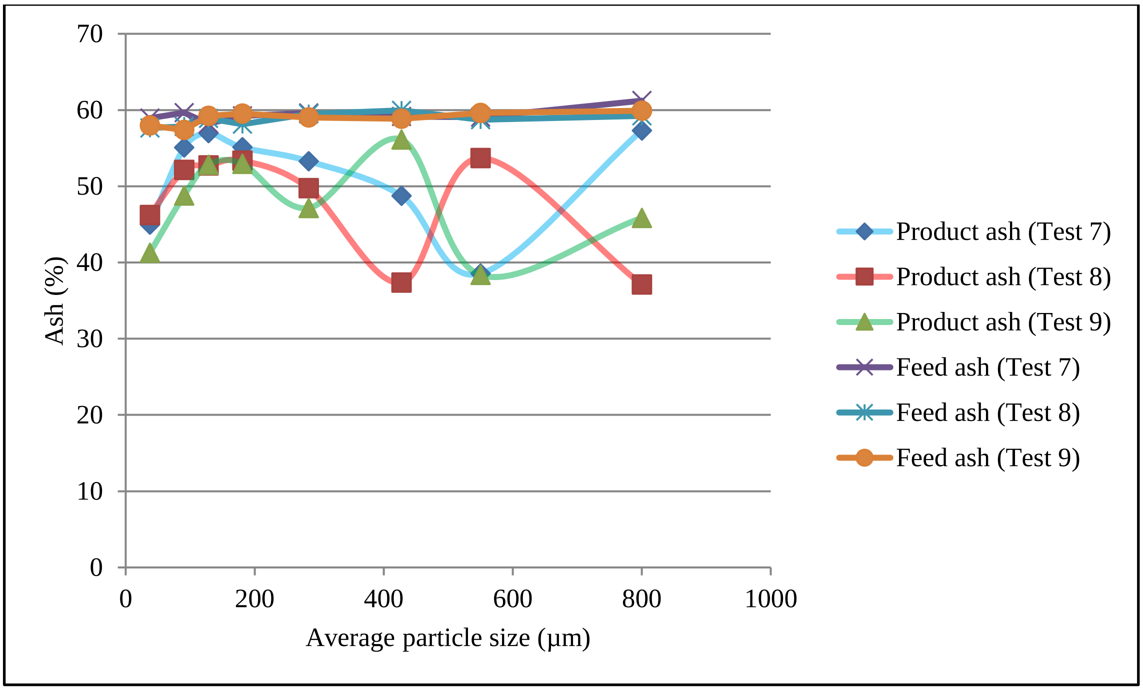

Figure D-2.14: Variation of ash with particle size using 12 channels at 3 l/min (45-60 minutes)

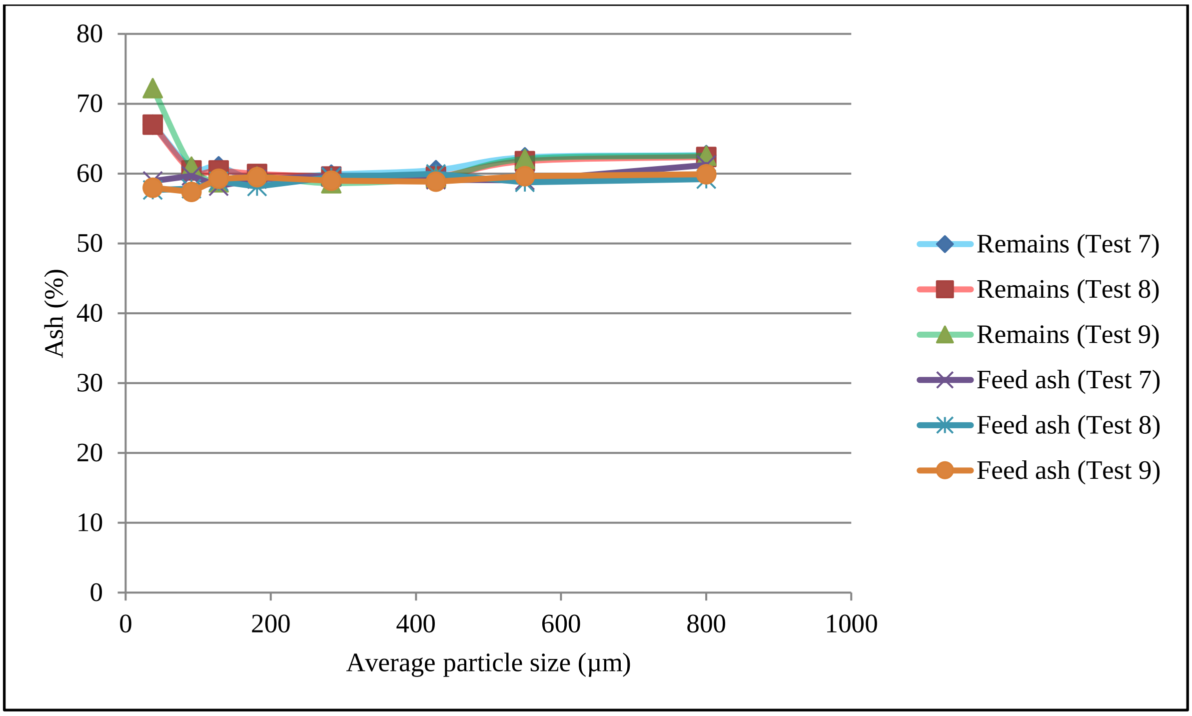

Figure D-2.15: Variation of ash with particle size using 12 channels at 3 l/min (Underflow)

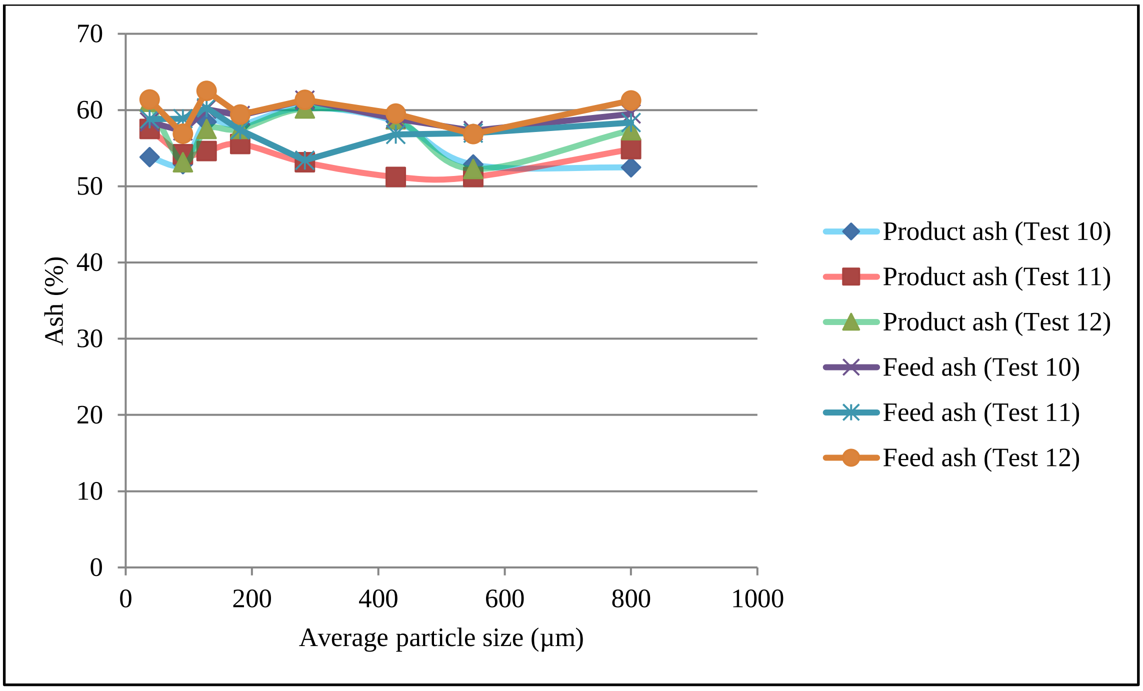

Figure D-2.16: Variation of ash with particle size using 6 channels at 6 l/min (0-15 minutes)

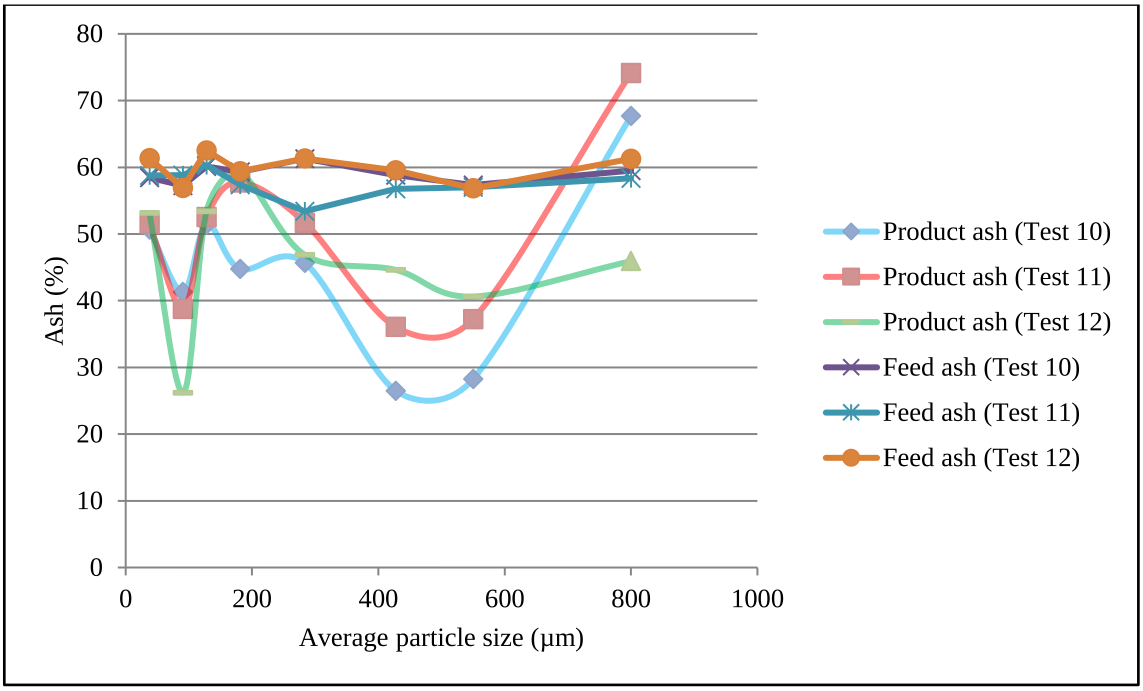

Figure D-2.17: Variation of ash with particle size using 6 channels at 6 l/min (15-30 minutes)

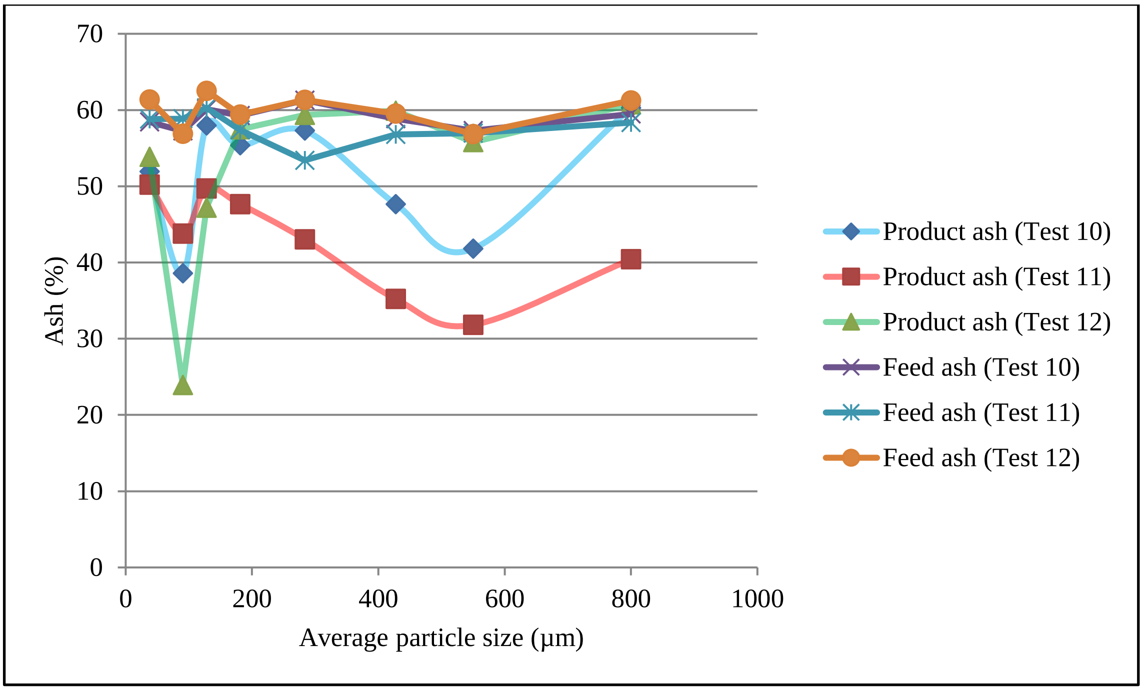

Figure D-2.18: Variation of ash with particle size using 6 channels at 6 l/min (30-45 minutes)

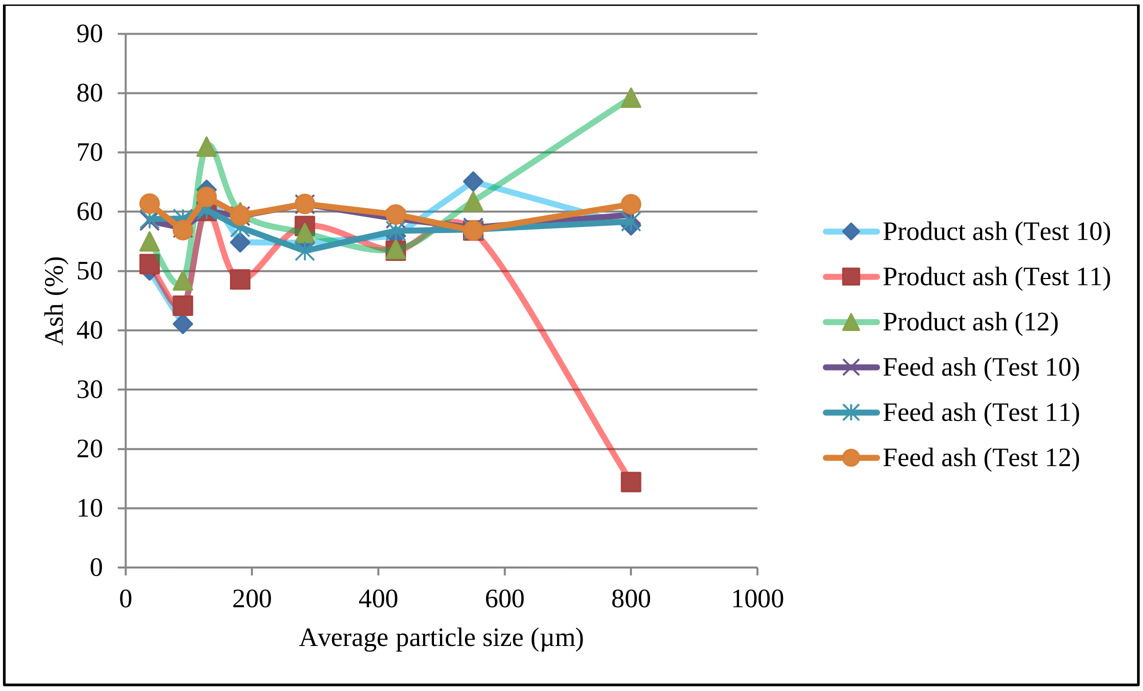

Figure D-2.19: Variation of ash with particle size using 6 channels at 6 l/min (45-60 minutes)

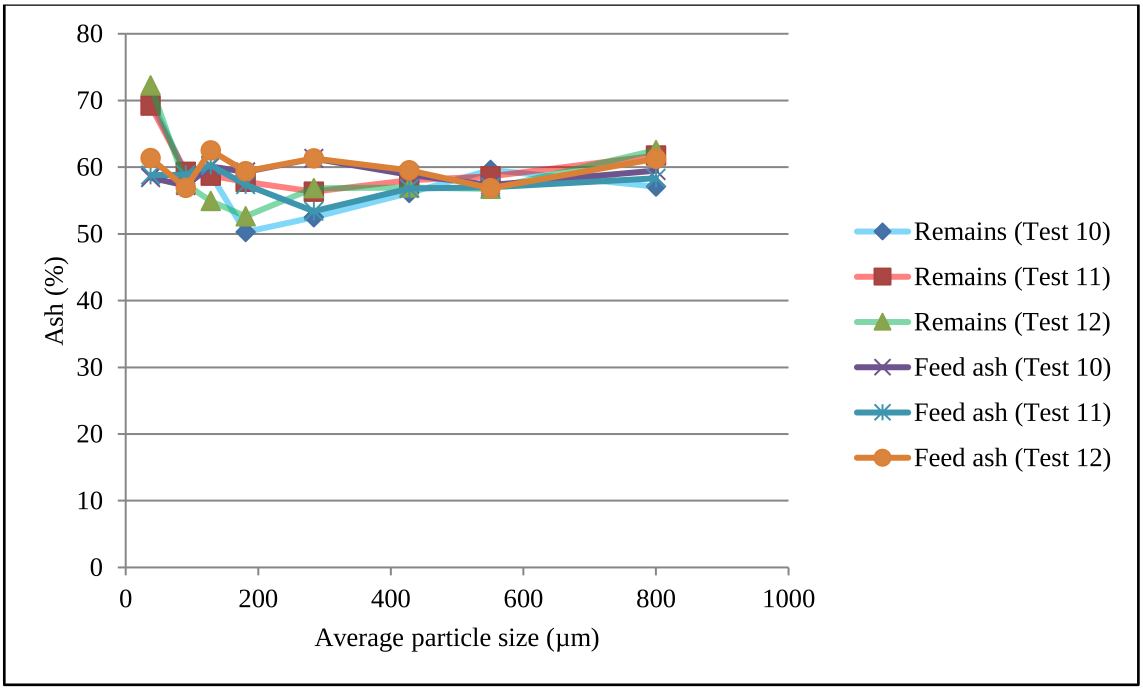

Figure D-2.20: Variation of ash with particle size using 6 channels at 6 l/min (Underflow)

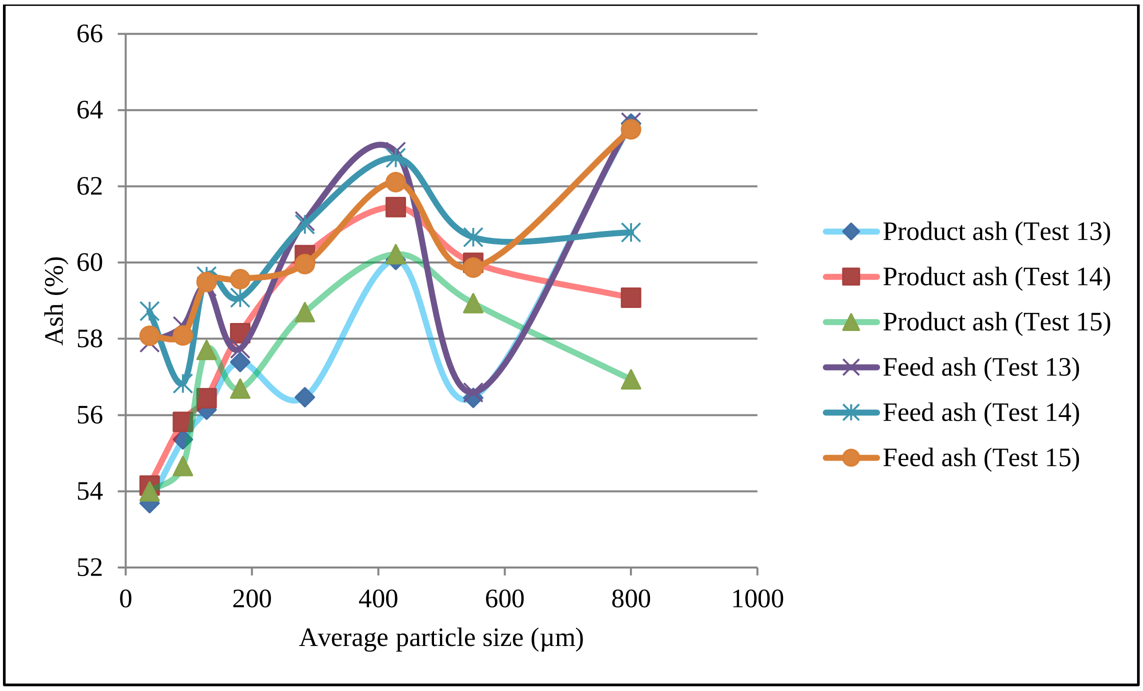

Figure D-2.21: Variation of ash with particle size using 8 channels at 6 l/min (0-15 minutes)

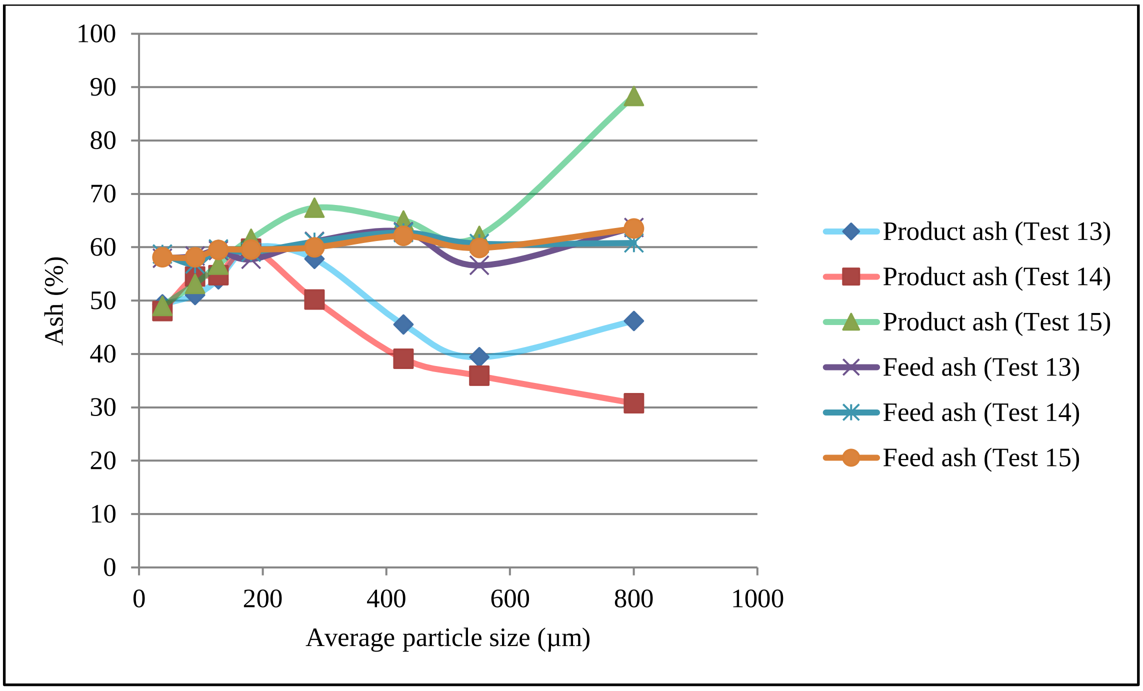

Figure D-2.22: Variation of ash with particle size using 8 channels at 6 l/min (15-30 minutes)

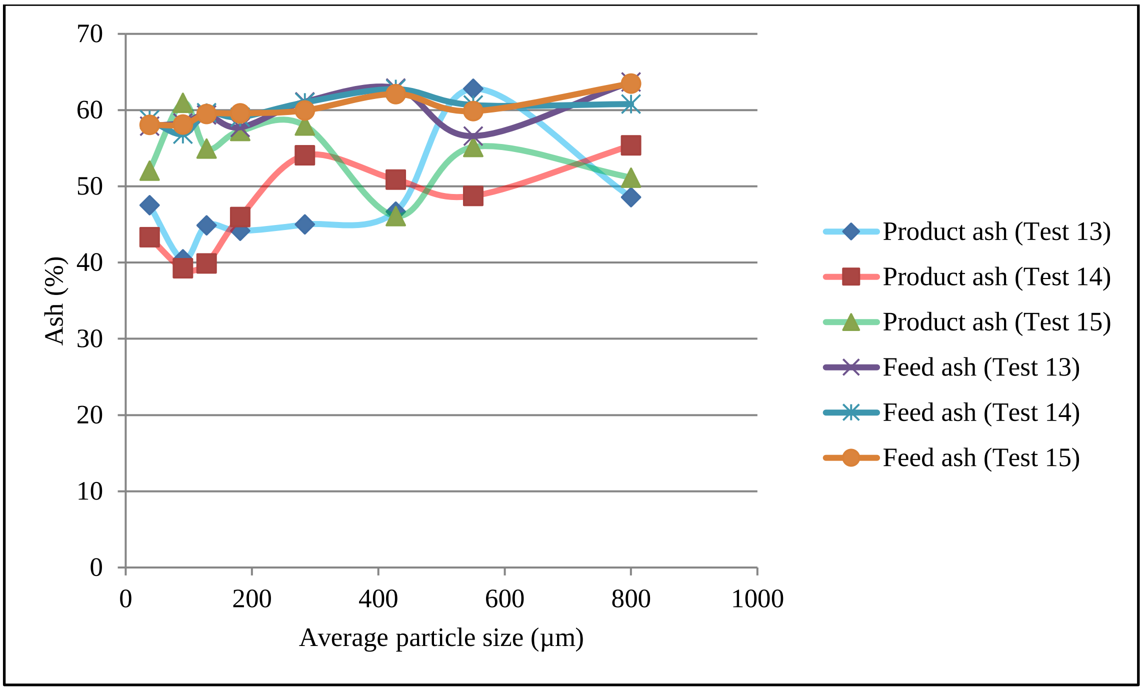

Figure D-2.23: Variation of ash with particle size using 8 channels at 6 l/min (30-45minutes)

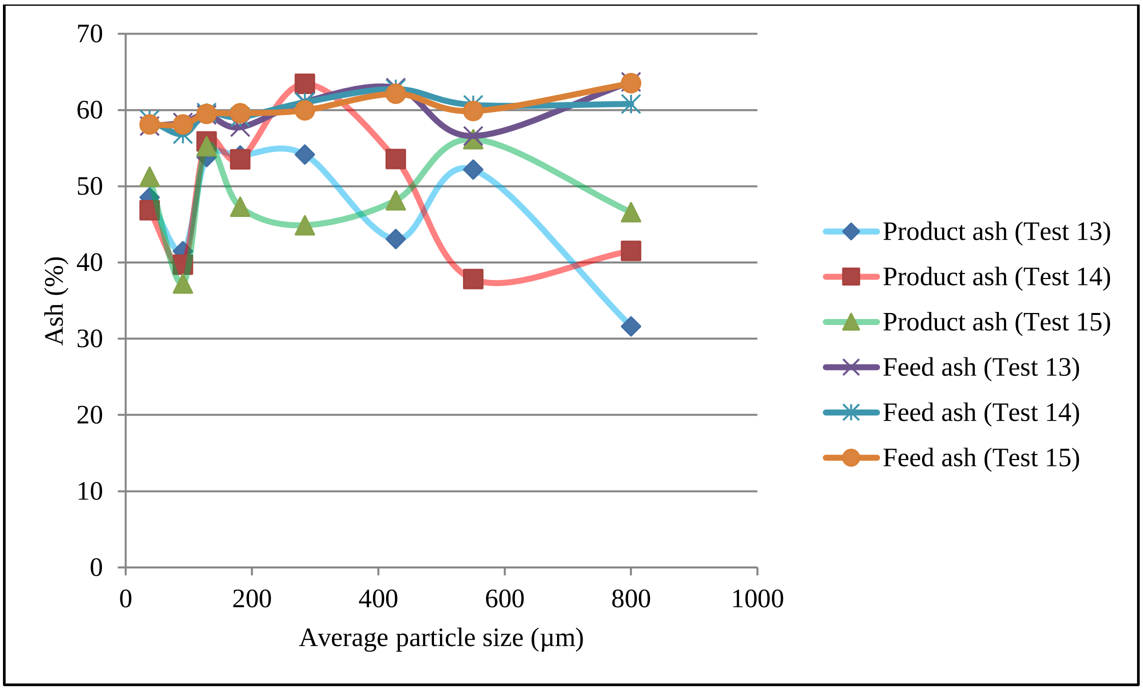

Figure D-2.24: Variation of ash with particle size using 8 channels at 6 l/min (45-60 minutes)

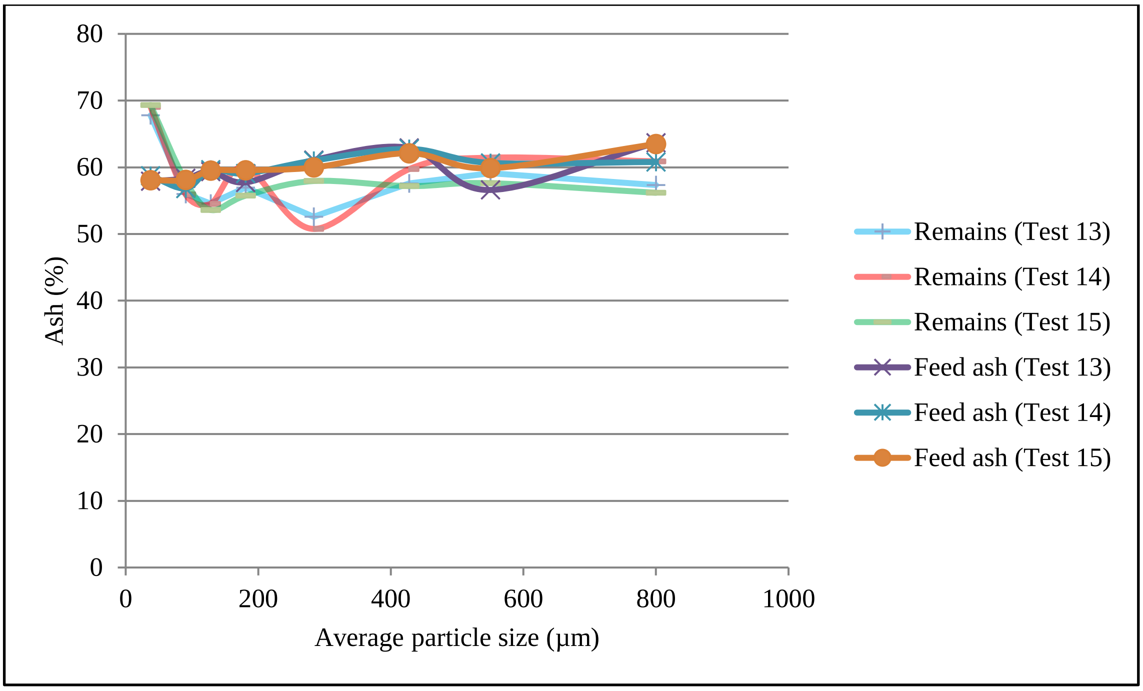

Figure D-2.25: Variation of ash with particle size using 8 channels at 6 l/min (Underflow)

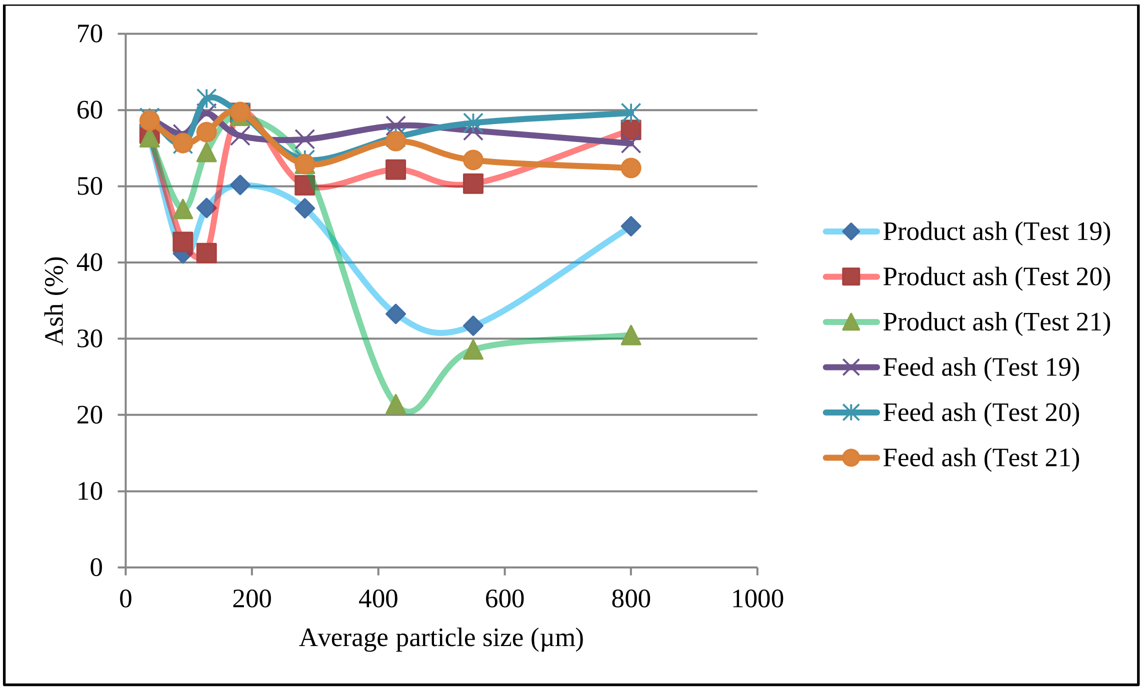

Figure D-2.26: Variation of ash with particle size using 6 channels at 9 l/min (0-15 minutes)

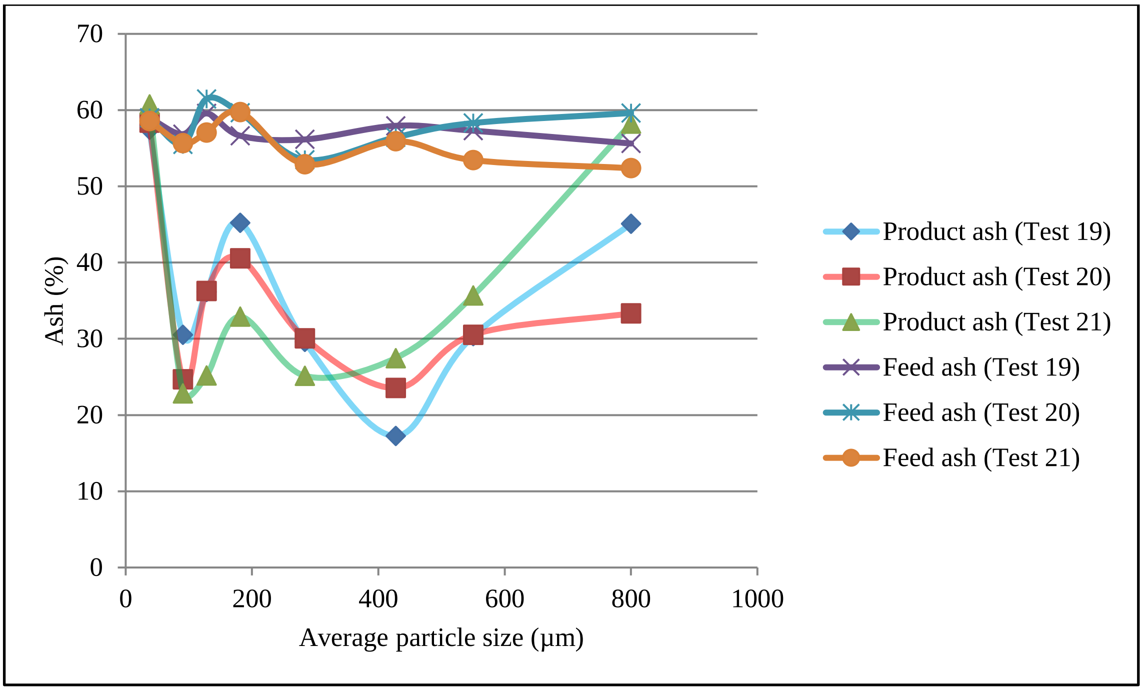

Figure D-2.27: Variation of ash with particle size using 6 channels at 9 l/min (15-30 minutes)

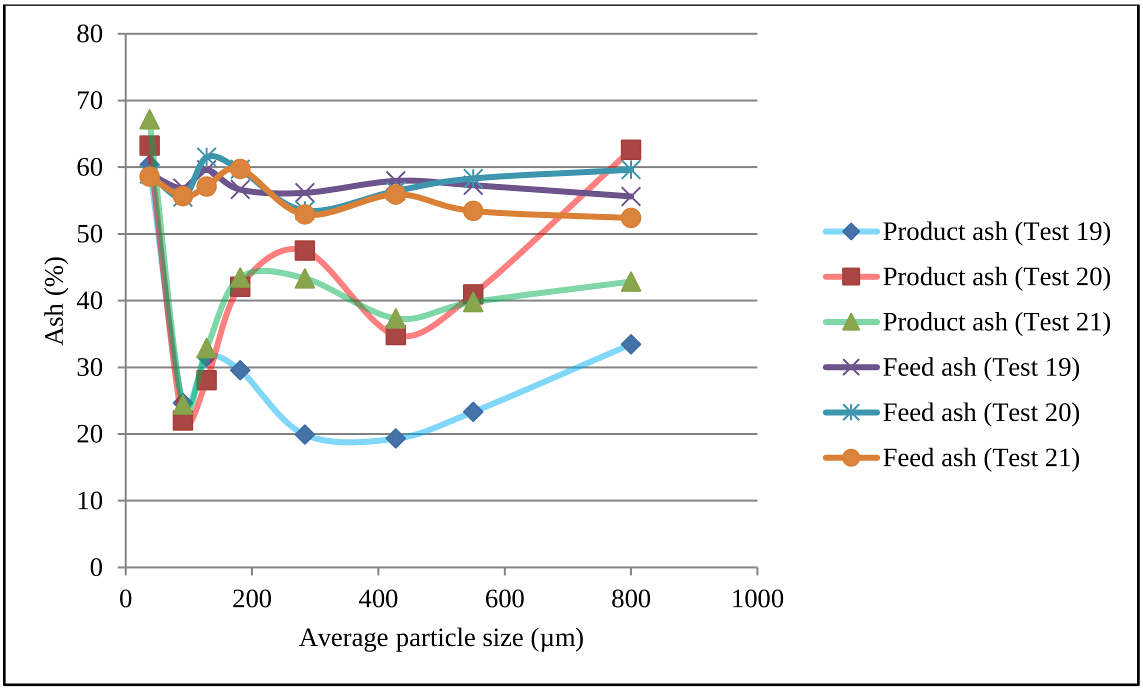

Figure D-2.28: Variation of ash with particle size using 6 channels at 9 l/min (30-45 minutes)

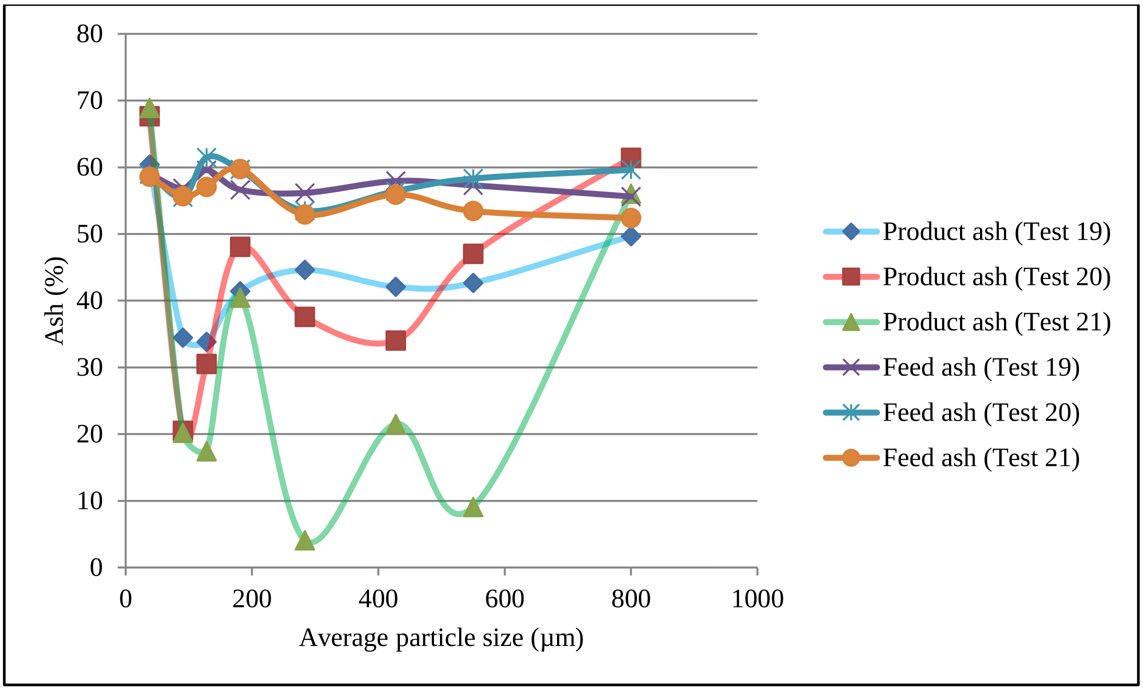

Figure D-2.29: Variation of ash with particle size using 6 channels at 9 l/min (45-60 minutes)

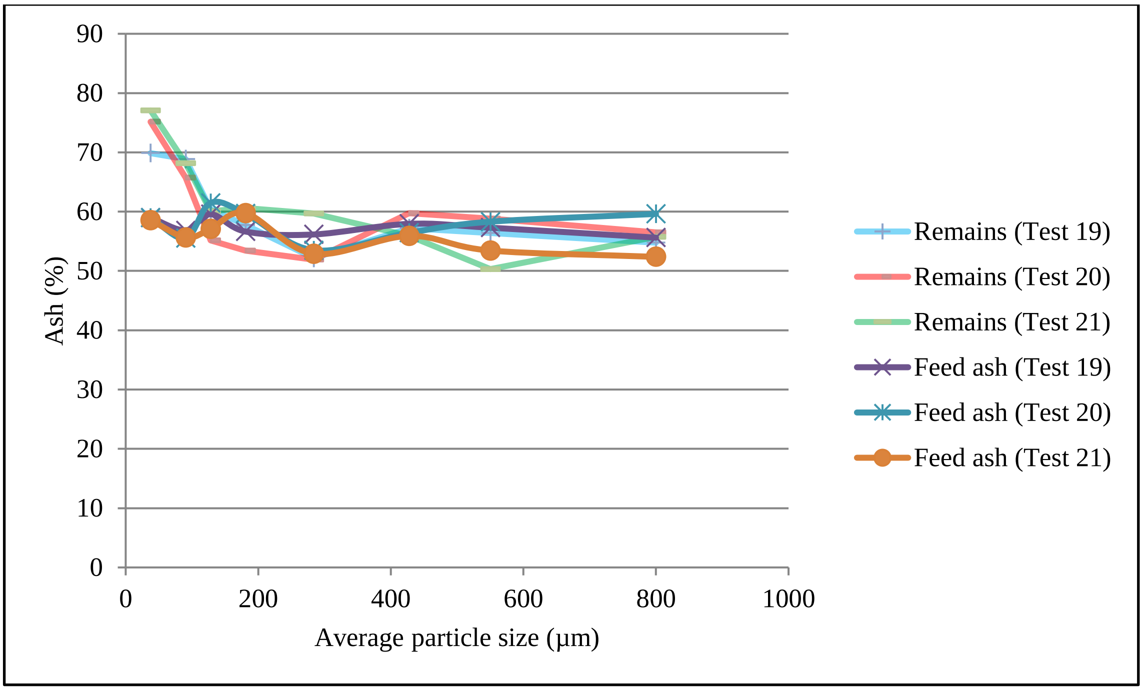

Figure D-2.30: Variation of ash with particle size using 6 channels at 9 l/min (Underflow)

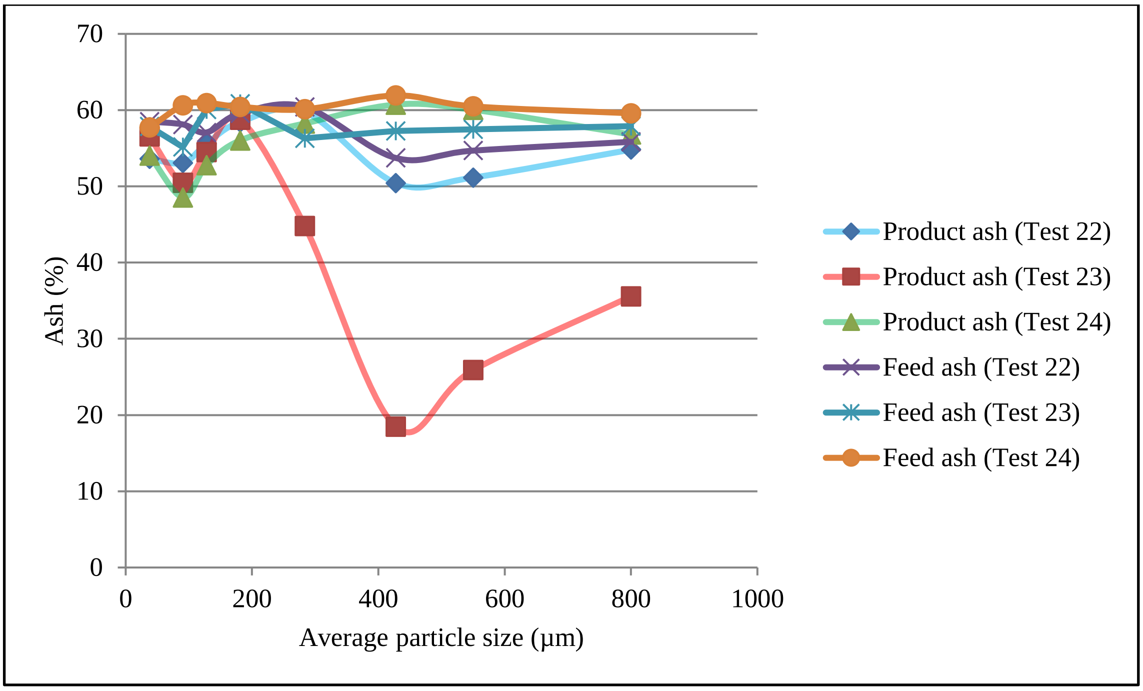

Figure D-2.31: Variation of ash with particle size using 8 channels at 9 l/min (0-15 minutes)

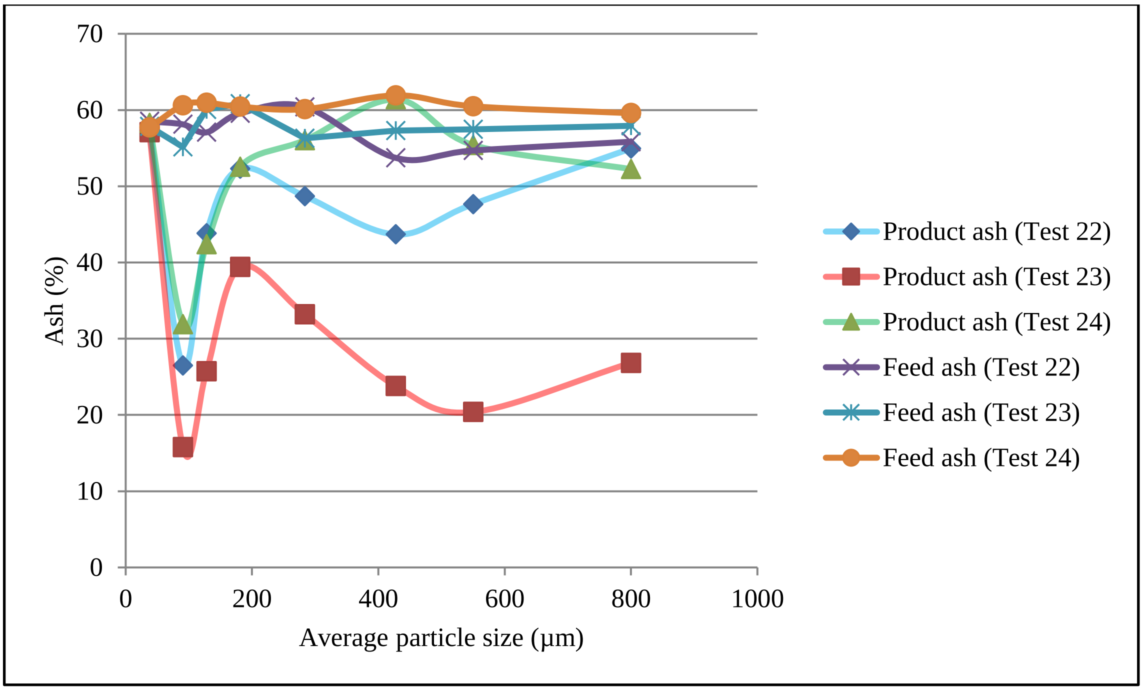

Figure D-2.32: Variation of ash with particle size using 8 channels at 9 l/min (15-30 minutes)

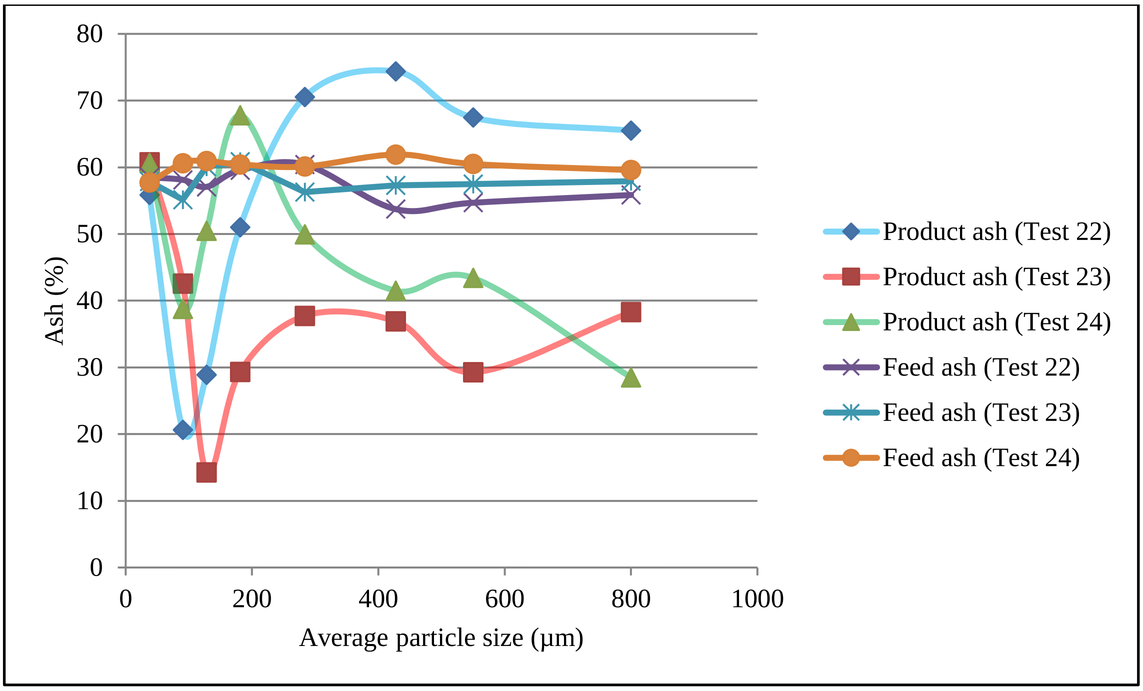

Figure D-2.33: Variation of ash with particle size using 8 channels at 9 l/min (30-45 minutes)

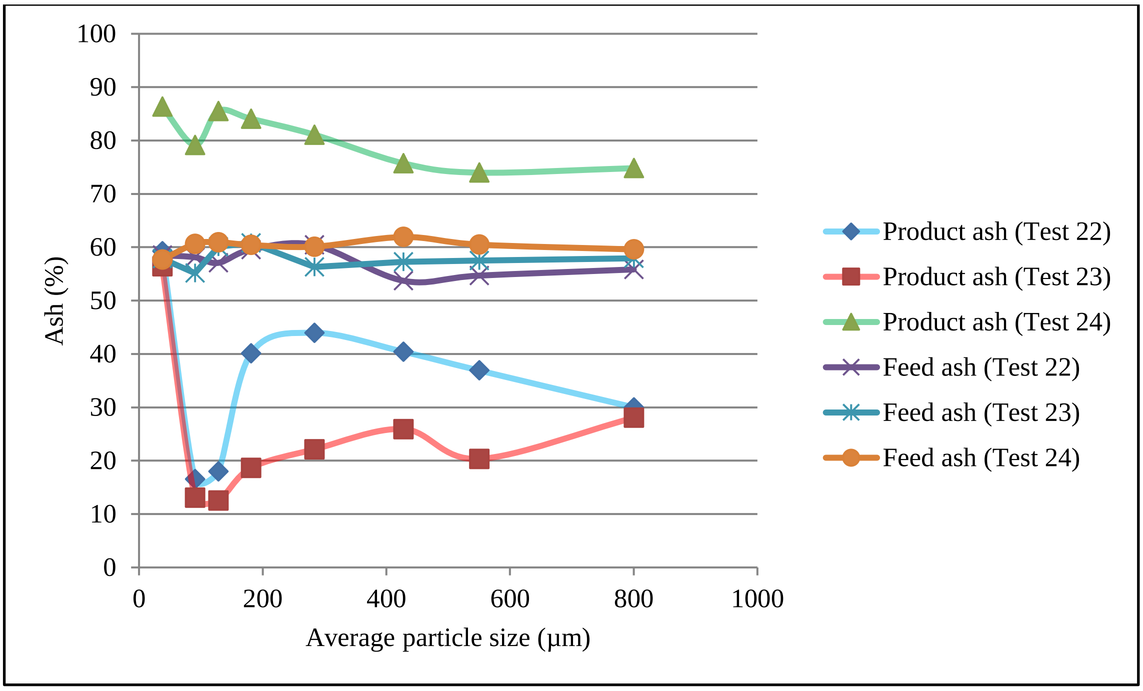

Figure D-2.34: Variation of ash with particle size using 8 channels at 9 l/min (45-60 minutes)

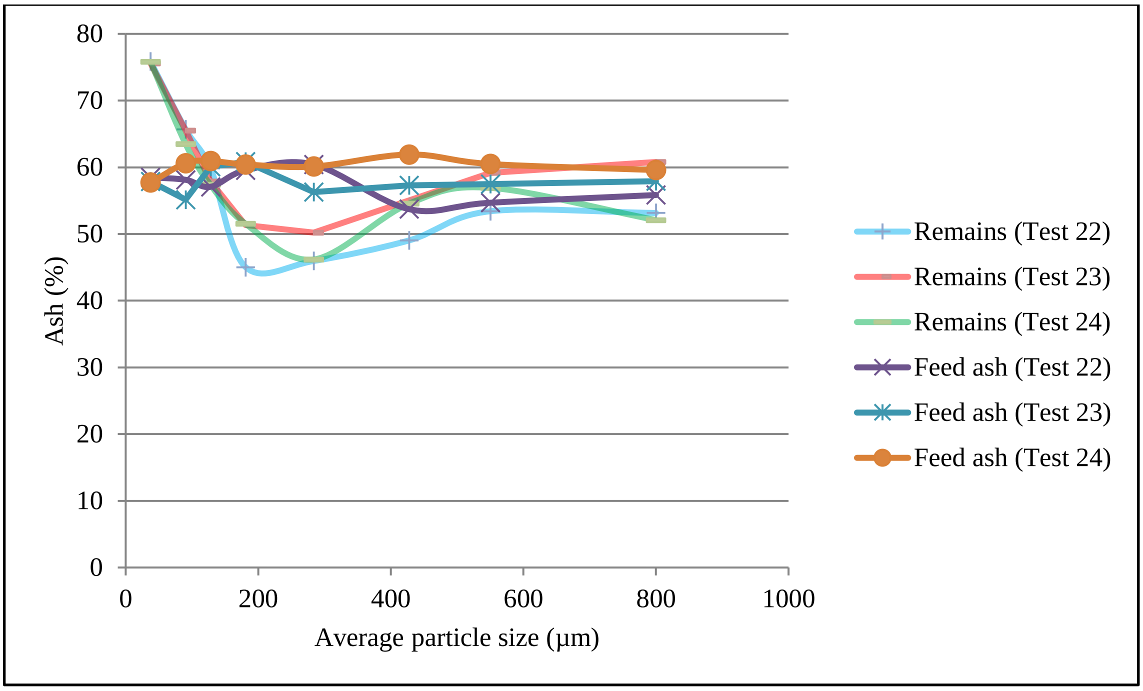

Figure D-2.35: Variation of ash with particle size using 8 channels at 9 l/min (Underflow)

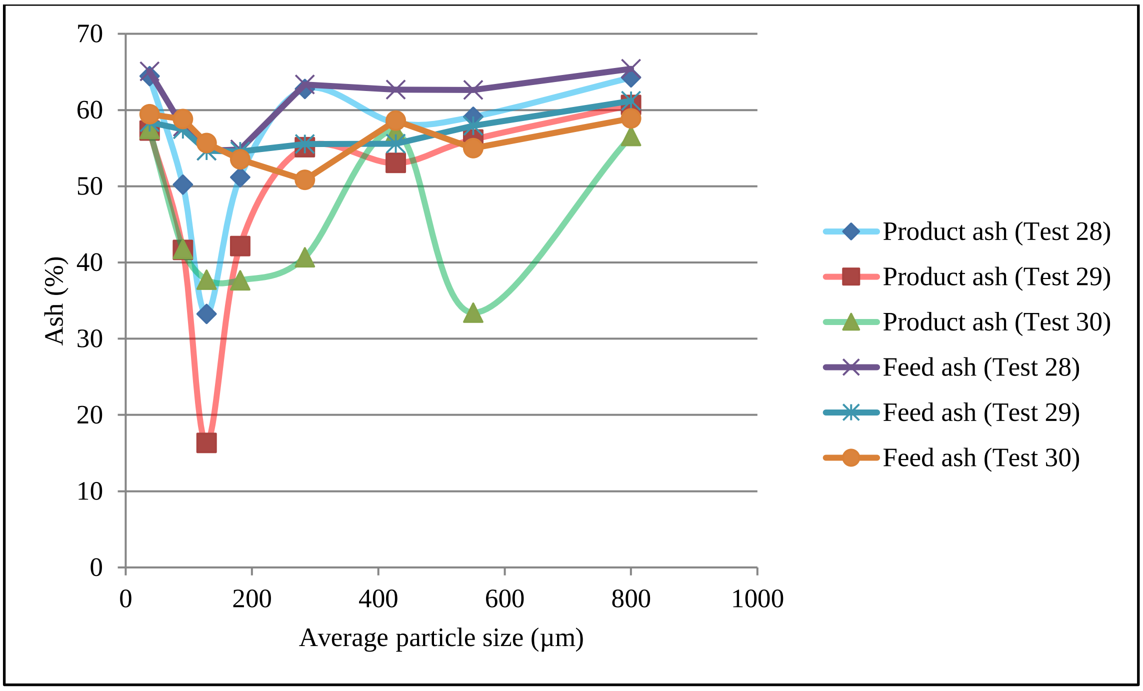

Figure D-2.36: Variation of ash with particle size using 6 channels at 12 l/min (0-15 minutes)

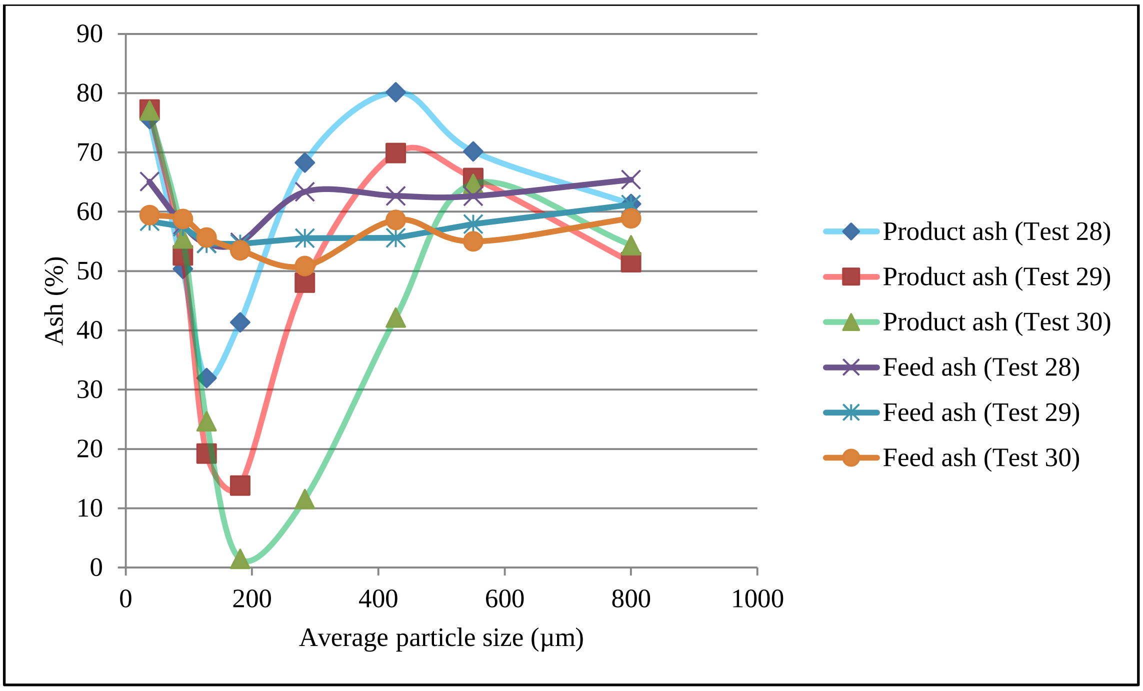

Figure D-2.37: Variation of ash with particle size using 6 channels at 12 l/min (15-30 minutes)

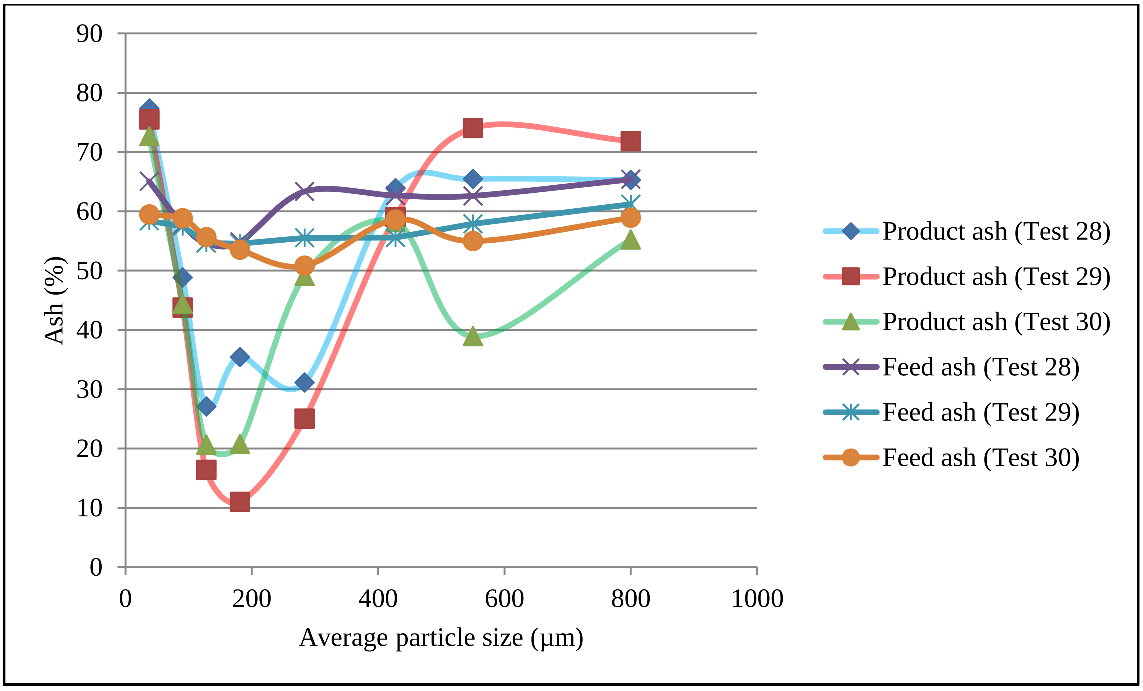

Figure D-2.38: Variation of ash with particle size using 6 channels at 12 l/min (30-45 minutes)

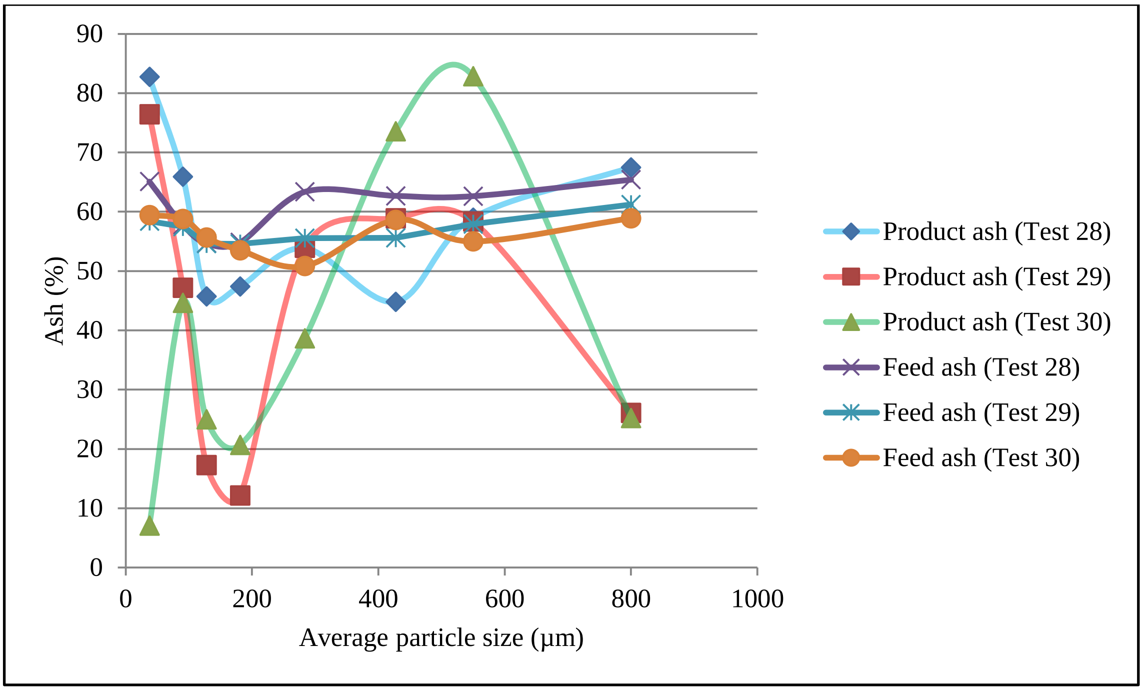

Figure D-2.39: Variation of ash with particle size using 6 channels at 12 l/min (45-60 minutes)

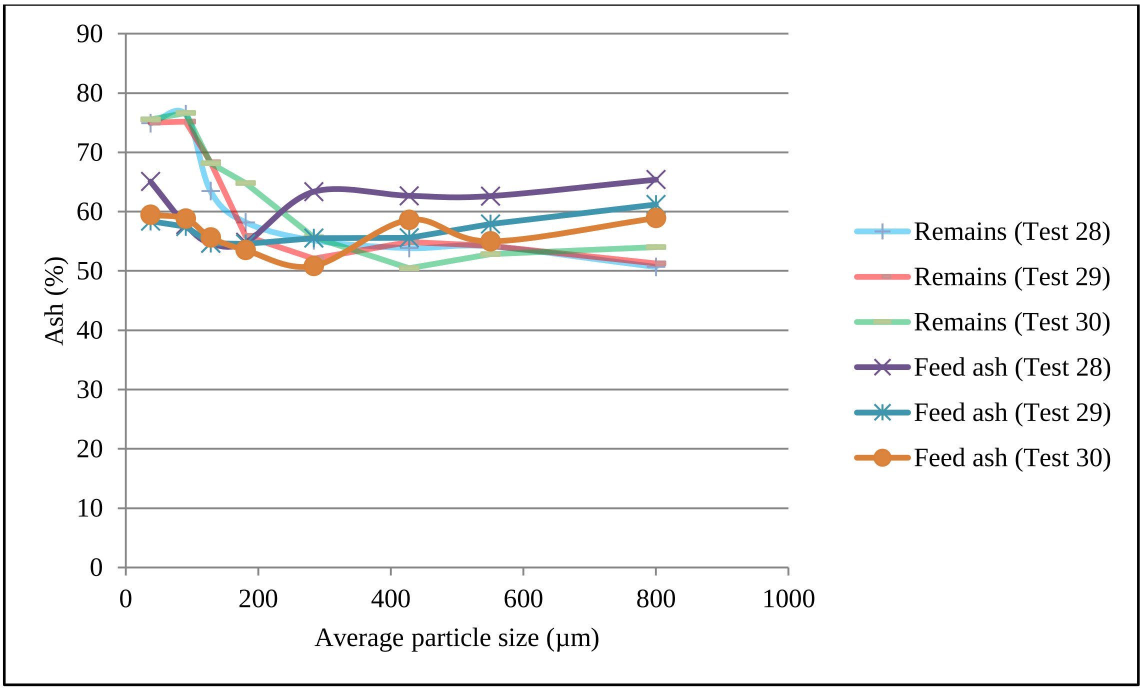

Figure D-2.40: Variation of ash with particle size using 6 channels at 12 l/min (Underflow)

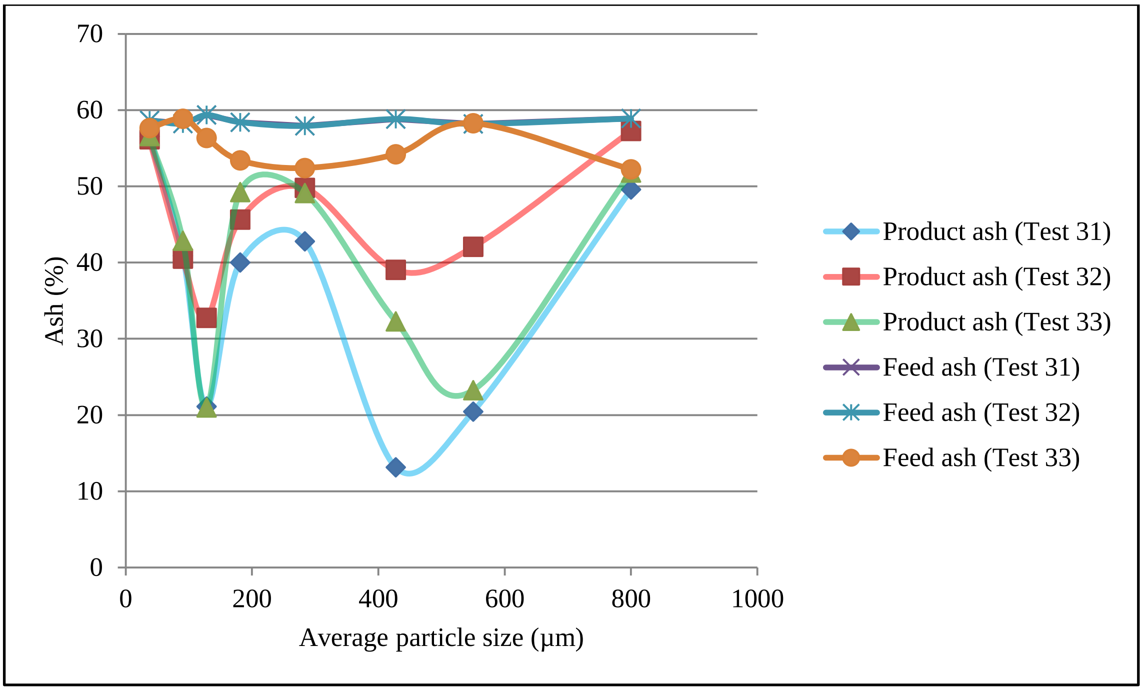

Figure D-2.41: Variation of ash with particle size using 8 channels at 12 l/min (0-15 minutes)

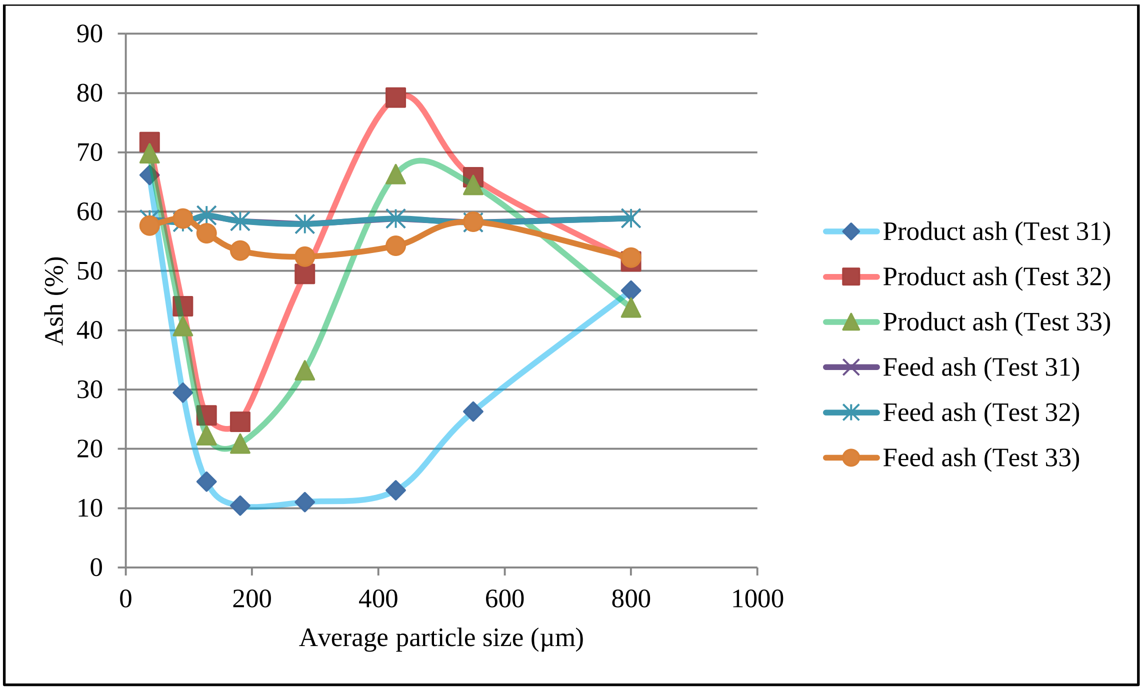

Figure D-2.42: Variation of ash with particle size using 8 channels at 12 l/min (15-30 minutes)

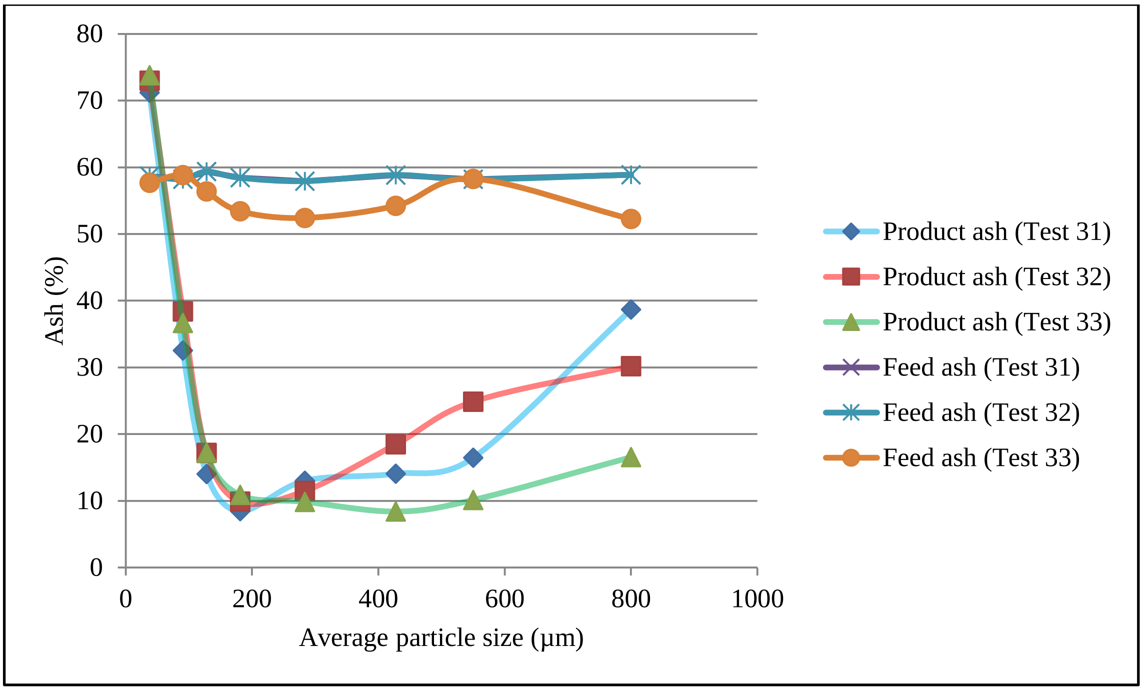

Figure D-2.43: Variation of ash with particle size using 8 channels at 12 l/min (30-45 minutes)

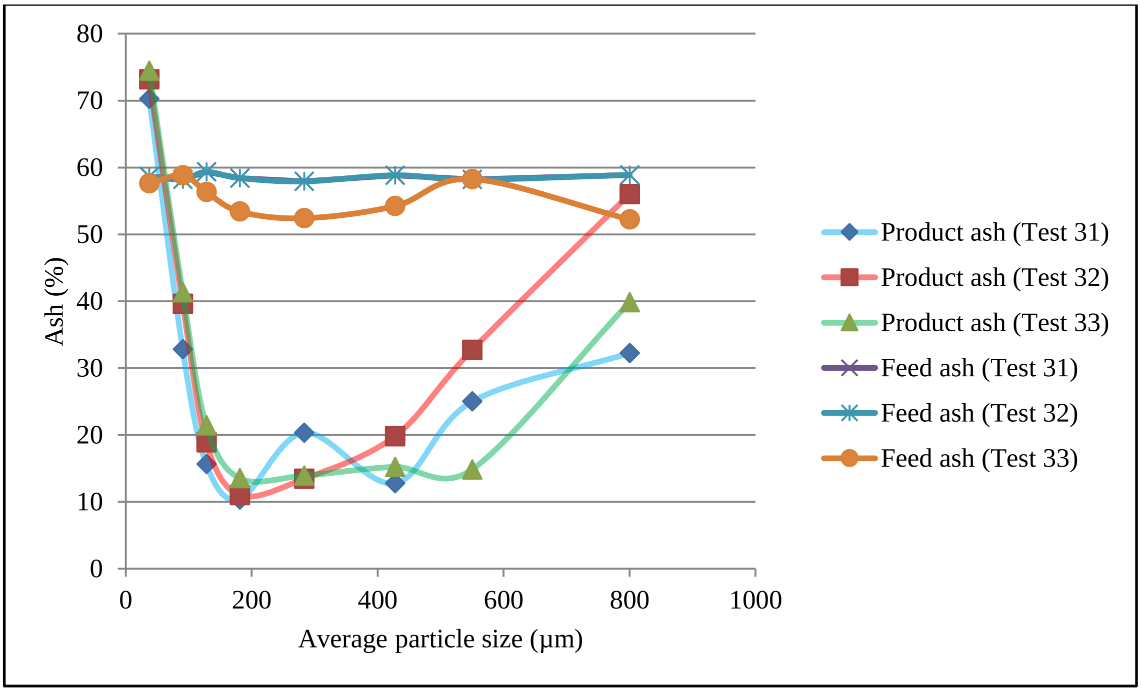

Figure D-2.44: Variation of ash with particle size using 8 channels at 12 l/min (45-60 minutes)

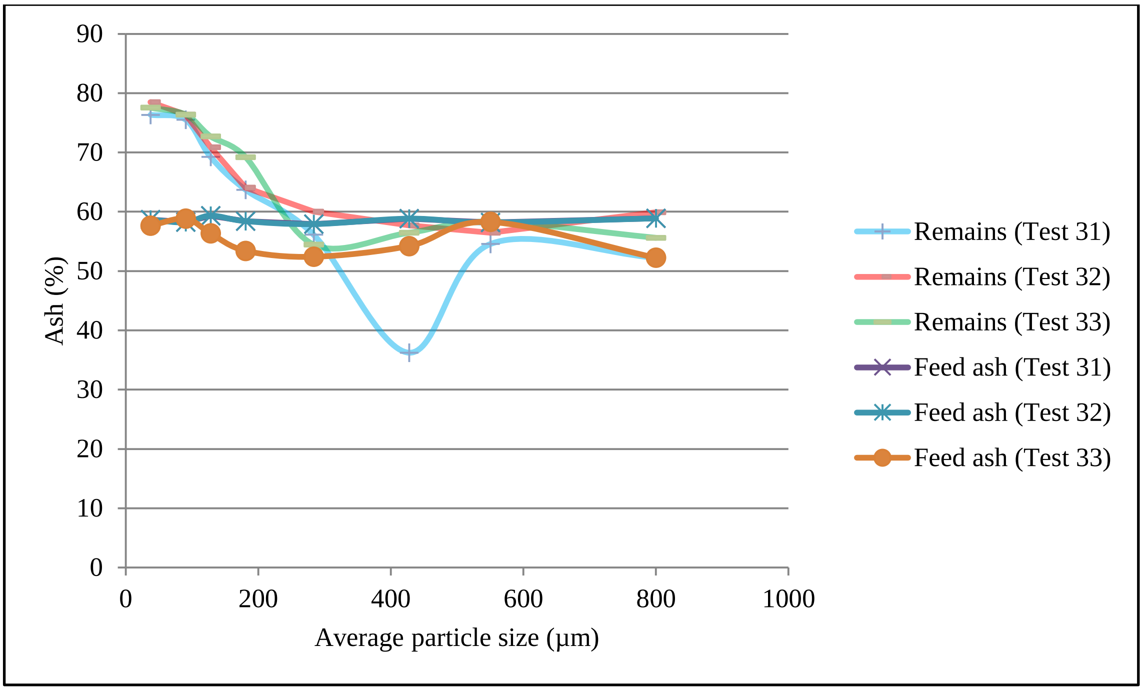

Figure D-2.45: Variation of ash with particle size using 8 channels at 12 l/min (Underflow)

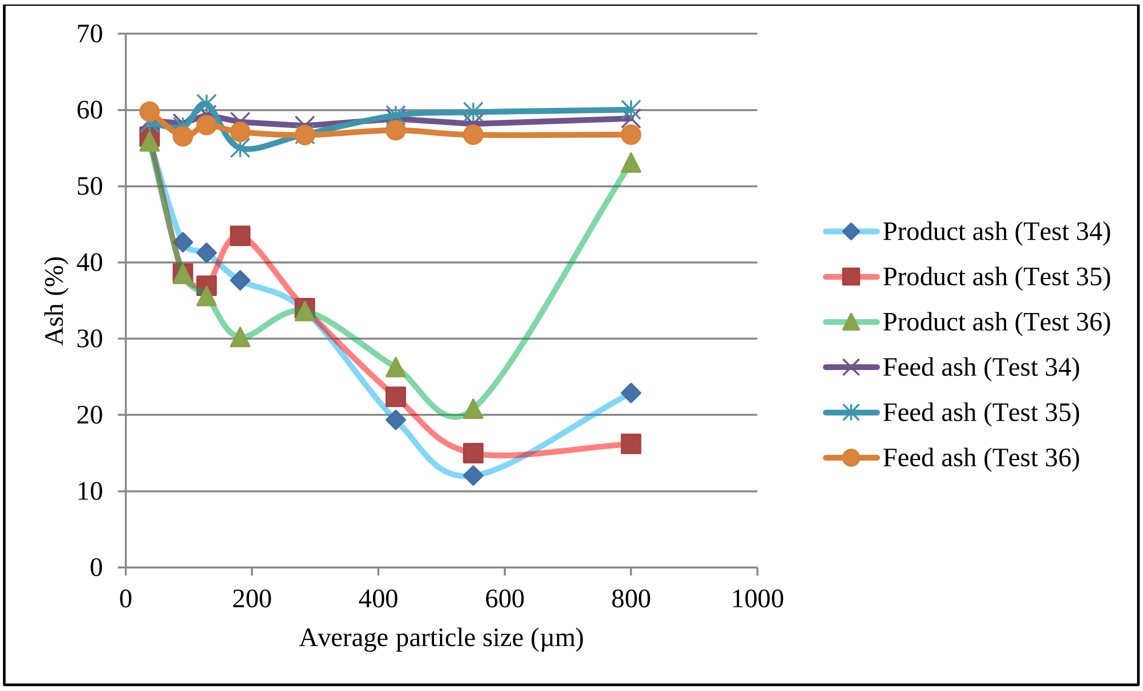

Figure D-2.46: Variation of ash with particle size using 12 channels at 12 l/min (0-15 minutes)

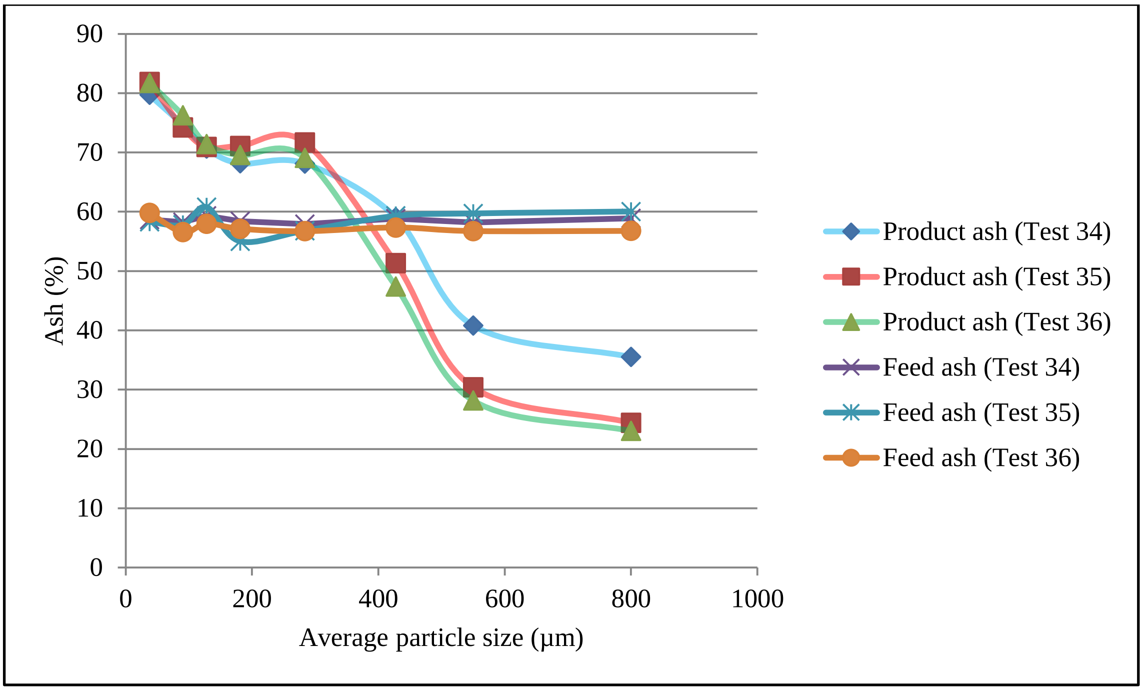

Figure D-2.47: Variation of ash with particle size using 12 channels at 12 l/min (15-30 minutes)

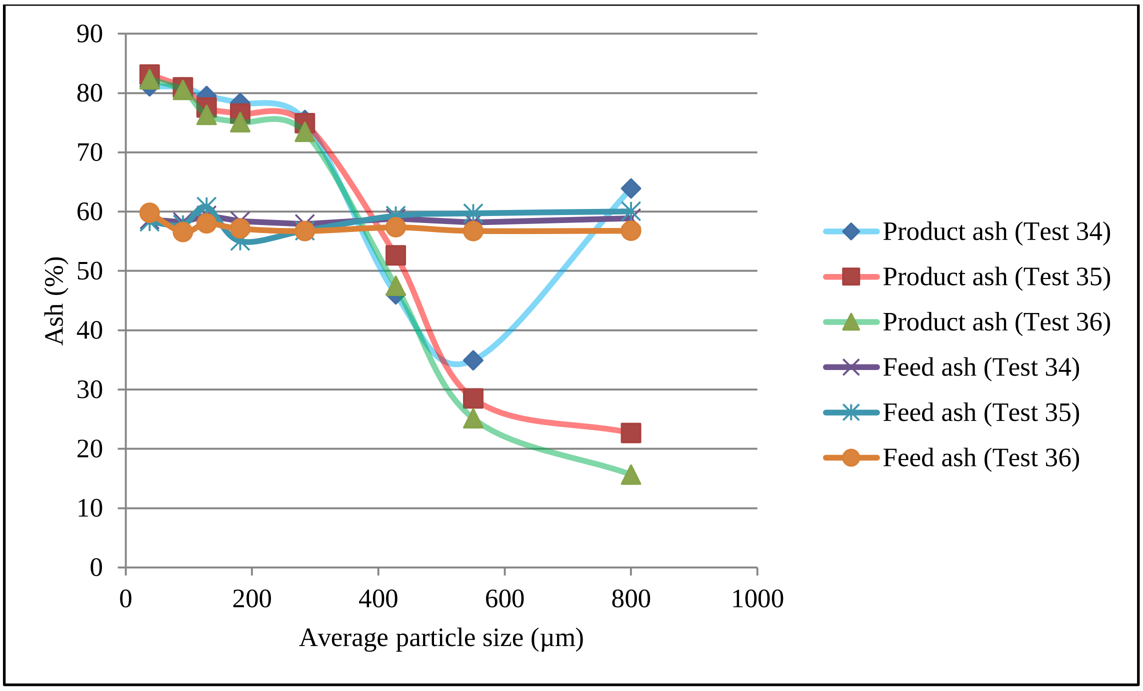

Figure D-2.48: Variation of ash with particle size using 12 channels at 12 l/min (30-45 minutes)

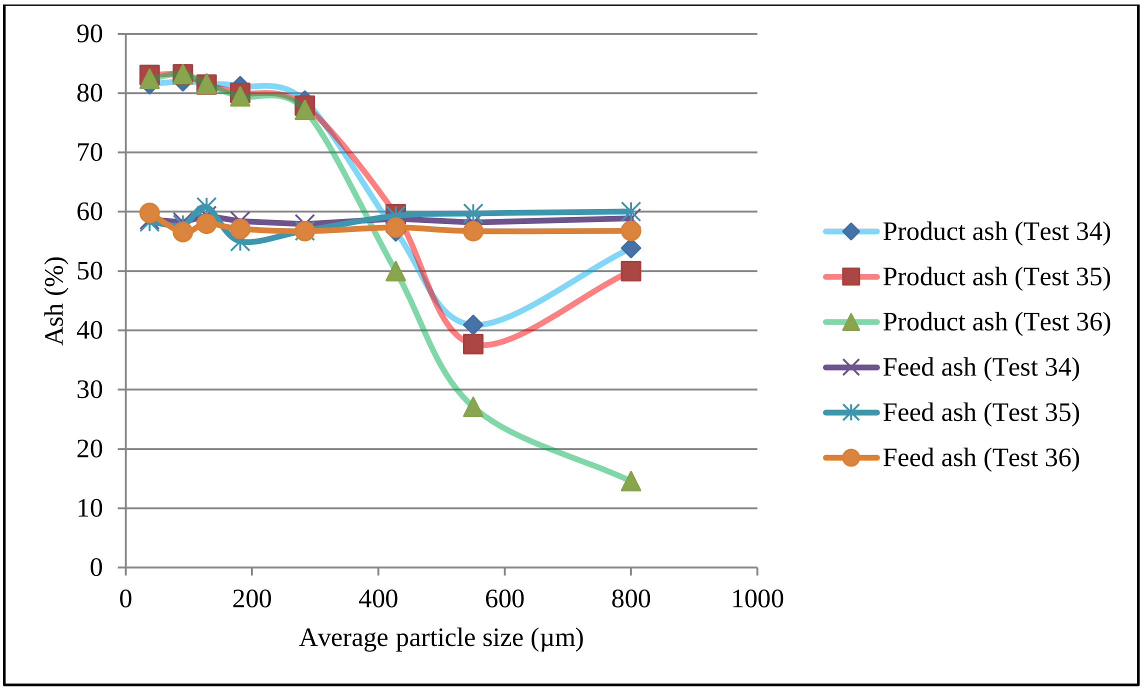

Figure D-2.49: Variation of ash with particle size using 12 channels at 12 l/min (45-60 minutes)

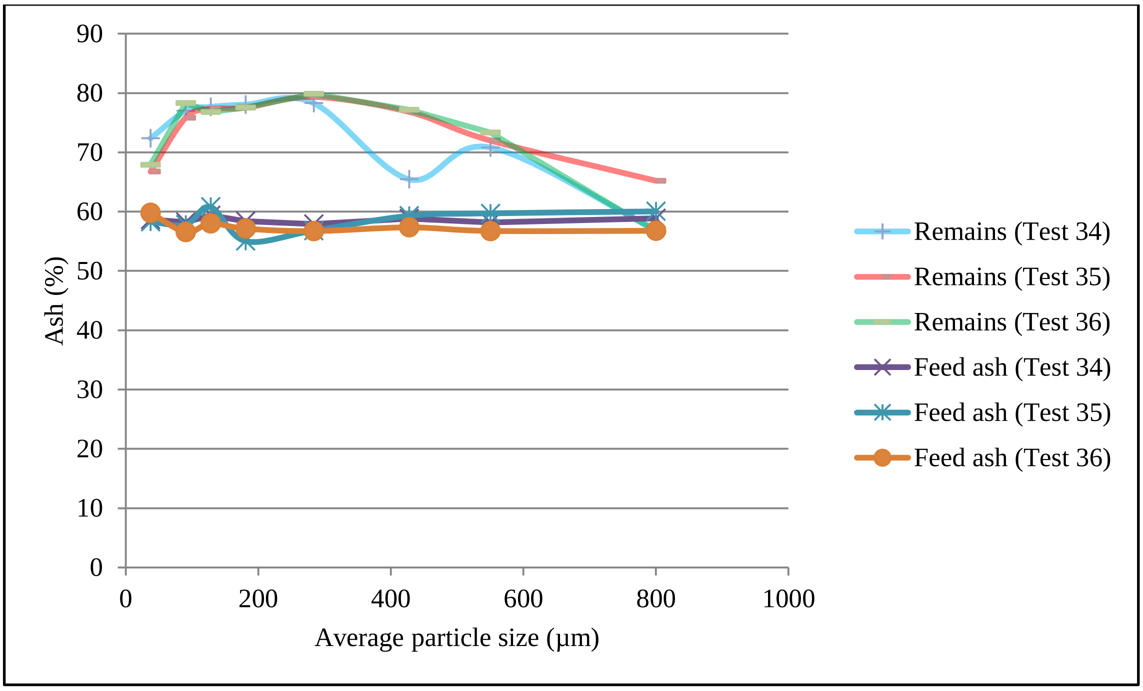

Figure D-2.50: Variation of ash with particle size using 12 channels at 12 l/min (Underflow)