THE CONSTRAINING EFFECT OF FEED BULK ON THE VOLUNTARY FEED INTAKE OF LAYING HENS

MARTINA LOUISE MOORE

BSC. AGRIC. PRETORIA

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN AGRICULTURE

In the

Discipline of Animal Science and Poultry Science

School of Agricultural Sciences and Agribusiness

University of KwaZulu-Natal

Pietermaritzburg

2004

DECLARATION

The experimental work described in this thesis was carried out in the Discipline of Animal Science and Poultry Science, School of Agricultural Sciences and Agribusiness, University of KwaZulu-Natal, Pietermaritzburg, under the supervision of Professor R.M. Gous.

These studies represent original work by the author and have not otherwise been submitted in any form for any degree or diploma to any University. Where use has been made of the work of others, it has been duly acknowledged in the text.

R M Gous
Supervisor

M.L. Moore
Candidate

Do not go where the path may lead,
Go instead where there is no path and leave a trail.

Ralph Waldo Emerson

CONTENTS

ABSTRACT

1. Two experiments were designed to determine a suitable method of measuring and predicting feed bulk, such that this could be used to predict when the feed intake of a laying hen would be constrained by feed bulk.
2. In the first trial the diluents used were cellulose, plasterer's sand, sunflower husks, sawdust and vermiculite. These were included at 100, 250 and 500 g/kg into a commercial layer feed which was used as the basal feed. The trial was divided into three phases of 21 days each. After each phase, either the diluent fed was changed, or the inclusion level of the diluent was changed.
3. It was observed that as the water-holding capacity (WHC) of the feed increased, the feed intake decreased. The scaled feed intake (SFI) of the hens was fitted to the reciprocal of the WHC to give the relationship; SFI (g/kg body weight) = 313.6 (±8.9) × 1/WHC. This regression was the best fit and represents the maximum amount of feed that the laying hen can consume when the constraint measured is the reciprocal of WHC.
4. Trial 2 identifies the physical characteristics of the feed that best describe the bulkiness of the feed, and also determined the extent, and the rate at which, the laying hen can adapt to feeds that are high in bulk. The five diluents that were used were wheat bran, river sand, potter's clay, unexpanded polystyrene and sawdust, and the inclusion rates were 50, 100 and 150 g/kg. The hens were fed the feeds for six weeks. The equation from Trial 1 was fitted to the data from Trial 2 and few treatments were found to be constraining.
5. The constraining feeds from both trials and Williams (1993) were combined to obtain a more accurate assessment of the relationship between the SFI and the reciprocal of WHC. This relationship was represented by the equation; SFI (g/kg body weight) = 301.4 (±8.9) × 1/WHC.
6. The prediction of the effect of feed bulk on the voluntary feed intake of the hen is an important aspect for accurately predicting the feed intakes of the hen and formulating a "perfect" diet. The variation in constrained intakes was not accurately predicted by the WHC of the feed, although this measure of bulkiness was considerably better than any of the other measures applied.

LIST OF FIGURES

Figure 3.4: *The feed intake of hens (g/day) fed feeds varying in diluent inclusion percentage and diluent, given feeds with a series of different wet density levels. The observed mean values for each level of diluent inclusion are shown as points: □=C, ♦=S, ▲=SD, ×=SF, and *=V, where C represents cellulose, S sand, SD sawdust, SF sunflower husks, and V vermiculite. SE = 14.3 and the percentage variation accounted for is 83.3%*

Figure 3.5: *The feed intake of hens (g/day) fed feeds varying in diluent inclusion percentage and diluent, given feeds with a series of different inverse of water-holding capacity (1/WHC) levels. The observed mean values for each level of diluent inclusion are shown as points: □=C, ♦=S, ▲=SD, ×=SF, and *=V, where C represents cellulose, S sand, SD sawdust, SF sunflower husks, and V vermiculite.*

Figure 3.6: *The mean relationship between the scaled feed intake of the laying hen (g feed/kg body weight . d) and 1/ WHC of the feed (g water/g dry feed). Solid line includes a constant term ($y = 46.3\ (\pm\ 12.2) + 83.5\ (\pm\ 60.8)\ x$) and takes account of the two outliers; the dotted line is fitted through the origin and ignores the two outliers ($y = 272.4\ (\pm\ 8.91)x$).*

Figure 3.7: *A graphic representation of the relationship between mean feed intake and the level of inclusion of the diluent in the feed over all three phases. The observed mean values are shown as points: □=C, ♦= S, ▲=SD, ×=SF, and *=V, where C represents cellulose, S sand, SD sawdust, SF sunflower husks, and V vermiculite.*

Figure 3.8: *Mean feed intake (g/bird.d) for each diluent in each of the three phases and at the four rates of dilution of the feed (%)*

Figure 3.9: *The relationship between the egg weight (g) and the level of inclusion of diluent (%) in the feed. The observed values are shown as points: □=C and S, ▲=SD, ×=SF, and *=V.*

LIST OF TABLES

Table 3.1: *The composition and analysis of the basal feed (g/kg), purchased from a local feed company, and offered to Brown and White Hy-line hens in all three phases of the trial.*

Table 3.2: *Details of the dietary treatments offered to Brown and White Hy-line variety hens in Phases 1, 2 and 3, giving the dilution level in g/kg*

Table 3.3: *The composition of the mixed feeds (Basal feed + diluent) offered to the laying hens during the trial, including the measurements of crude protein (CP), lipid, ash and moisture contents (g/kg)*

Table 3.4: *The measured bulk characteristics of the basal feed and the individual diluents used in the trial, including mean water-holding capacity (WHC) (g water/g feed), dry and wet density (g/ml), crude fibre (CF), acid detergent fibre (ADF) and neutral detergent fibre (NDF) (g/kg)*

Table 3.5: *The bulk characteristics of the feeds including the mean water-holding capacity (WHC) (g water/g feed), dry and wet density (g/ml), crude fibre (CF), acid detergent fibre (ADF) and neutral detergent fibre (NDF) (g/kg) of feeds used in the trial*

Table 3.6: *The coefficients of the linear regressions of feed bulk (equations of the form $y = ax + c$) on the feed intake illustrated in Figures 3.2 through 3.5*

Table 3.7: *The calculated mean feed intakes (g/bird.d), over all dilution levels of the mixed feeds, for the diluent×level×period, diluent×level, and diluent×period interactions of the model, with corresponding standard error (SE) values and significance shown by the letter superscripts.*

Table 3.8: *The coefficients of the components of the regression equations of each individual diluent in each period, represented in Figure 3.8*

ACKNOWLEDGEMENTS

I wish to express my sincere appreciation to the following persons and organizations for their contributions to this thesis.

The National Research Foundation and the University of KwaZulu-Natal for their financial support,

The technical staff at the Animal Science department for the analysis of material,

The staff at Ukulinga Research Farm for their patience and assistance,

Doctor Ndlovu, Marion Young and Esayas Berhe for their assistance with analyzing the data,

Everyone who helped with the slaughter and processing of the hens,

Elaine, Tracy, Jean, Rowena, Bianca, Dean and Oscar for their friendship and support,

My mum and dad for the opportunity to reach this goal and their unquestioning belief in my success,

Gav for all your support, patience and calming talks,

And most importantly my supervisor, Professor Gous, for his insight, encouragement, advice and the inspiring way it was given. It has been an honour to work with you, Sir.

You have powers you never dreamed of.
You can do things you never thought you could do.
There are no limitations in what you can do
Except the limitations in your own mind as to what you cannot do.
Don't think you cannot, think you can.
Darwin P. Kingsley

CHAPTER 1

LITERATURE REVIEW

1.1. INTRODUCTION

1.1.1. Why predict feed intake in the laying hen?

To formulate a balanced feed for a laying hen, a prior knowledge of the expected feed intake of the hen is required, as well as the requirements of the hen for essential nutrients. Whereas the nutrient requirements of the laying hen have previously been extensively researched, little progress has been made (to date) in predicting voluntary feed intake, mainly because of the lack of a plausible theory (Gous, in consultation, 2004). Although it is possible to calculate the optimum economic intakes of the essential amino acids, it is not possible to convert these into dietary concentrations without knowing how much food a hen will consume in a day. Therefore, it is not possible to formulate a feed with the optimum economic nutrient density until feed intake can be accurately predicted (Gous, in consultation, 2004).

Presently, the Reading model (Fisher *et al.*, 1973) may be used to predict the amino acid requirements of the laying hen. This model considers the mean egg production and body weight of a flock of laying hens, their inherent variability in the flock, and economic factors such as the marginal cost of the amino acids and the marginal revenue for eggs. The theory that is used by the Reading model is that the requirement of the flock for each amino acid is a single point on a response curve – known as the optimum economic intake of that amino acid. A simple factorial model can explain this response for an individual (Fisher, 1976):

$$\text{AA intake} = a.E + b.W \quad (1)$$

Where AA intake is amino acid intake in mg/day, E is egg output in g/day, W is body weight in kg, and a and b are constants, where a and b are constants specific to each amino acid (Table 1.1).

Two constraints can be applied. When the AA intake is less than b.W then E is equal to zero, and when the E is maximal, then E = E_{max}. The response curve for the flock is then derived from the average of the individuals that differ in W and E_{max}. The constants a and b are assumed to be constant for all hens (Fisher, 1976), for a specific amino acid.

Table 1.1: *The estimated coefficients for egg output and maintenance for the essential amino acids for laying hens (McDonald and Morris, 1985) for the equation y=a.E+b.W, where y gives the amino acid requirements for a specific egg output (E in g/day) and body weight (W in kg).*

Amino acid	a	b
Lysine	9.99	73
Methionine	4.77	31
Tryptophan	2.62	11
Isoleucine	7.97	67
Valine	8.90	76
Methionine and Cystine	8.30	80
Arginine	8.90	53
Histidine	3.30	16
Leucine	12.50	32
Phenylalanine and Tyrosine	13.50	32
Threonine	6.90	32

The most important limitation of the Reading model is that it can only be used for flocks of young laying pullets in which E_{max} is normally distributed. Although the optimum intakes are accurately predicted, the model leads to an overestimation of requirements when the intake is divided by the mean feed intake of the flock. The model also assumes that egg value is directly proportional to egg mass, which may not always hold true (Fisher, 1976). This latter problem has been addressed by Morris and Gous (1988).

A model is required that will accurately predict the requirements of the mature laying hen so that overfeeding is minimized and an economical diet can be formulated easily and accurately. This can only be done when the feed intake of the hen is accurately predicted and the hen's requirements can be accurately converted into dietary concentrations. This will lead to less fat deposition during the laying period and, therefore, more efficient egg production.

1.1.2. Modelling feed intake

Emmans (1981a) proposed that an animal would eat to attain its genetic potential, through satisfying its requirement for maintenance and growth. The genetic potential for laying hens is defined by its egg output, which is the product of the number of eggs weighed and the egg weight. To meet this potential, defined by her genotype, the hen must consume sufficient quantities of the nutrients she requires from the feed provided to her. There are factors that exist that may prevent the hen from consuming sufficient nutrients. These factors are referred to as constraints and include the bulkiness of the feed, environmental temperature, nutrient excesses and toxins, and the health status of the hen (Emmans and Oldham, 1988).

The nutrient requirements for laying hens to sustain egg production and maintenance are defined by nutritional constants (Figure 1.1). The feed and the environment provide the resources to meet these requirements. The hen has a certain capacity to eat sufficient nutrients to meet these requirements. If the requirements can be met the hen will have achieved a desired feed intake (DFI). If the hen's capacities prevent the consumption of sufficient nutrients from the feed provided, feed intake will be constrained (CFI). The actual feed intake (AFI) is the lesser of the DFI and the CFI and will define the performance of the laying hen. This is illustrated in Figure 1.1.

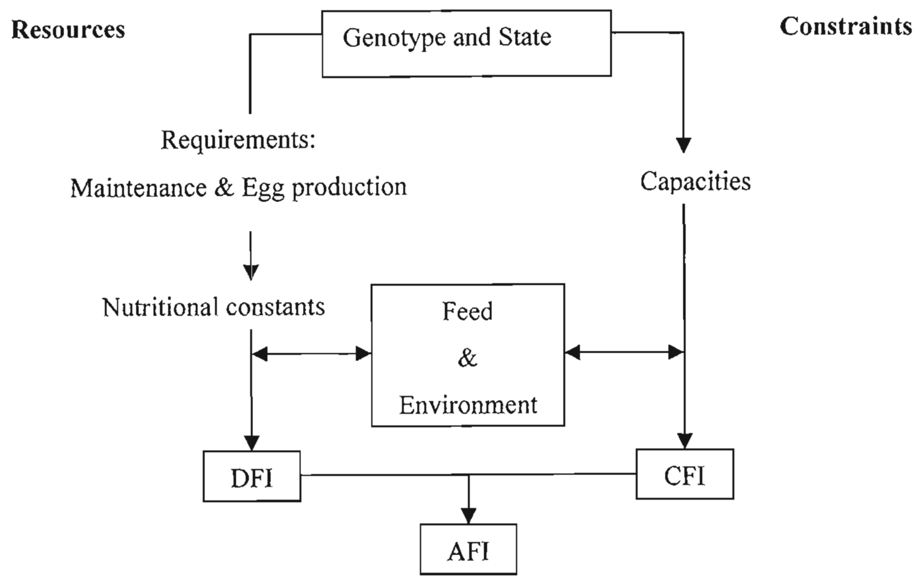

Figure 1.1: *A scheme proposed by Emmans and Oldham (1988) showing the regulation of feed intake in the laying hen, where DFI = desired feed intake, AFI = actual feed inatke, and CFI = constrained feed intake.*

1.2. MAINTENANCE REQUIREMENTS OF THE LAYING HEN

In broiler chickens to market age, maintenance is an almost negligibly small proportion of the total requirement for nutrients and a relatively small proportion of the requirement for energy. Conversely, in laying hens, even those producing at a high rate, maintenance energy is a major part of the total energy requirement and maintenance represents an appreciable proportion of the total requirement for protein and energy (Emmans and Fisher, 1986, and Young, 1998). The importance of quantifying maintenance requirements is thus much more important in laying hens than in commercial broilers. Armsby and Moulton (1925) describe the concept of maintenance as conserving the existing status of the animal, while doing no work and producing no product. There should be an exact balance between the in- and outflow of ash, nitrogen, heat and energy. This means that there is neither a loss nor gain of protein, fat, carbohydrate or mineral matter (Emmans and Fisher, 1986). Production animals are rarely kept in this non-productive state, so it might seem only of academic interest to derive the maintenance requirements of the laying hen. However, summing the requirements calculated separately for maintenance and production arrives at the total requirements of several classes of animals. Consequently knowledge of the maintenance requirements is of practical and theoretical significance (McDonald *et al.*, 1995).

The nutrient requirements of the laying hen will depend on the state of the hen (maintenance) and the potential rate of production. The animal requires resources to maintain its current state. These resources are defined as the animal's maintenance requirements. The maintenance requirements are reflected by the chemical composition of the body and feathers and the weights of these two components of the hen. Armsby and Moulton, 1925, defined the body of an animal as the gut-fill and the empty body. The empty body is calculated as:

$$\text{Empty body (g)} = \text{protein} + \text{ash} + \text{water} + \text{lipid} \tag{2}$$

To predict the composition of an animal in a certain state the values of eight parameters must be known and substituted into Equation 3 to determine the rate of change of the body composition (dEW/dt) (Emmans and Fisher, 1986).

$$dEW/dt = [P_m \,.\, B.\, \ln(1/u)](u + z^1 \,.\, u^c + z^2 \,.\, u^{c2} + z^3 \,.\, u^{c3}) \tag{3}$$

Where z^1, c^1 are for ash, z^2, c^2 are for water, z^3, c^3 are for lipid, P_m is the mature protein weight and B = 1/k, where k is a characteristic of the animal. The value of u is calculated as the ratio of the protein weight against the protein weight at maturity, and is referred to as the degree of maturity. The growth and composition of the hen depend on her genotype and are, therefore, inherited. It can be assumed that the parameters of the equation are then inherited. The values for $c_{ash} = 0$, $z_{ash} = 0.19$, $c_{water} = -0.11$, and $z_{water} = 3$ are constant across all genotypes. The values for c_{lipid} and z_{lipid} are highly correlated across genotypes, but vary widely between genotypes. The gut fill can be predicted from the rate of feed intake and the feed composition (Emmans and Fisher, 1986).

Maintenance energy is mainly obtained by the oxidation of body fat if the animal is given no food (McDonald *et al.*, 1995). This production of energy is transferred to the nutrients in a diet if food is provided. No heat is produced if the efficiency of conversion of the nutrients to energy is the same as when body fat is converted to energy.

For maintenance: PR = LR = 0

Therefore: ER = 0

Where PR is the protein retention, LR is the lipid retention, and ER is the energy retention (Emmans, 1994).

The protein requirements for maintenance can be described as the loss of nitrogen in the faeces and urine once the protein reserves of the animal have been depleted (McDonald *et al.*, 1995). The nitrogen in the faeces arises from the enzyme and cell residues of the digestive tract. The nitrogen in the urine represents nitrogen which has been incorporated into materials, subsequently expended, and which cannot be recovered by the body for re-use. The majority of the nitrogen in the urine is in the form of urea, the by-product of amino acid catabolism. The turnover rate of body proteins varies from one tissue to another. The amino acids released when body proteins are broken down form a pool from which replacement proteins are synthesised. Therefore, the body proteins exchange amino acids amongst themselves. Amino acids liberated from one protein may fail to be incorporated into another and are catabolised. The amino groups yield urea, which is excreted in the urine (McDonald *et al.*, 1995).

Once the protein reserves of an animal have been depleted, the urinary nitrogen excretion reaches a minimal and rather constant level. The nitrogen excreted at this minimal level is known as the endogenous urinary nitrogen. The endogenous urinary nitrogen excretion can therefore be used to estimate the nitrogen, and protein, required by the animal for maintenance (McDonald *et al.*, 1995).

When the animal is eating a maintenance diet, the rates of protein and lipid retention are zero, but the animal is consuming feed and is, therefore, producing heat (HM, kJ/day) (Emmans, 1994). The heat increment of a maintenance diet (HIM) relative to the maintenance heat (MH) can be defined as Equation 4.

$$\text{HIM (kJ/day)} = \text{HM} - \text{MH} \tag{4}$$

The general scaling rule of maintenance (Equation 5) relates the supply of nutrients to the animal's state and genotype so that the lipid and protein retention is zero.

$$MH = M_E \times P_m^{0.73} \times u \qquad (MJ/d) \qquad (5)$$

Where P_m is the mature protein weight in kg and u is the degree of maturity. The degree of maturity is calculated by dividing the body protein weight by the mature protein weight. The value of M_E is constant over all values of P_m and degrees of maturity. The maintenance scaling rule implies that no energy is needed to maintain body lipid. Work done with pigs has shown that body lipid has a zero rate of turnover (Emmans, 1987). Emmans (1987) defines M_E as a constant equal to 1.63 MJ/unit per day in a thermally neutral environment with the maintenance unit of the function equal to $P_m^{0.73} \times u$ per day (Emmans, 1987). The amino acid requirements for maintenance can then be calculated from the maintenance protein requirement and the amino acid composition of body protein (Emmans, 1987).

Emmans (1994) assumes that the heat increment produced over the MH is related to two activities:

- The hen's consumption of organic matter (OM).
- The excretion of nitrogen in the urine (UN).

The maintenance diet of OM (g/d) will lead to the excretion of 0.16 × digestible crude protein (DCP) to give the amount of urinary nitrogen (UN) in grams of nitrogen (g N) in the urine/day. The maintenance diet will also lead to the production of methane (MTHE, kg/d) (Emmans, 1994). It is assumed that the heat increment over the maintenance heat, due to the animal eating a maintenance diet, is related to just three activities: its consumption of organic matter, its excretion of N in the urine, and its production of methane. It is further assumed that the rates of heat production associated with these activities are linearly related to the quantities of OM, UN and MTHE (Emmans, 1994). Therefore, the heat increment (HI), due to the animal consuming a maintenance diet, is given by Equation 6.

$$HIM\ (kJ/d) = (w_d \,.\, OM) + (w_u \,.\, UN) + (w_m \,.\, MTHE) \qquad (6)$$

Where w_d is the heat associated with the digestibility of the OM in the diet, w_u is the heat associated with the excretion of UN, and w_m is the heat associated with the production of methane (Emmans, 1994). For most cases the MTHE value can be considered zero for single stomached animals (Emmans, 1994). Therefore, the HIM can be estimated from the digestible OM, know as the faecal organic matter (FOM), and the UN in Equation 7.

$$\text{HIM (kJ/day)} = (w_d \cdot \text{FOM}) + (w_u \cdot \text{UN}) \qquad (7)$$

Combining Equations 5 and 7 allows the amount of ME required for maintenance (MEM) to be defined in Equation 8 (Emmans, 1994).

$$\text{MEM (kJ/day)} = \text{MH} + \text{HIM} \qquad (8)$$

Equation 8 defines the energy requirements of the laying hen for maintenance which can be converted to nutrient concentrations when the feed intake is predicted.

1.2.1. White layers vs. brown layers

The Hy-line variety Brown hens lay slightly less hen-housed and hen-day eggs than the Silver Brown variety, but on average they lay slightly heavier eggs. The Hy-line variety Brown requires less feed per kg eggs produced than the Silver Brown variety, the difference being 20 g (Hy-line Commercial Management Guide, 2004). Therefore the Brown variety has slightly higher production requirements than the Silver variety, but the maintenance requirements are similar.

1.2.2. Feathering

The feather conditions of the hen will affect her maintenance requirements and her feed efficiency. Leeson and Morrison (1978) found that feed efficiency was significantly correlated with feather weight and could be described by the linear equation:

$$\text{Y (FE (g feed/g egg mass))} = -0.04\ (\text{FW}) + 5.4 \qquad (9)$$

Where y is the feed efficiency ($P < 0.05$) (Leeson and Morrison, 1978). This suggests that feed efficiency deteriorates for every 0.04g (SE ± 0.01) for each gram loss in feather cover. The effect of feather cover in relation to feed efficiency is likely to increase at low ambient temperatures.

1.3. The Requirements for Egg Production

The hen requires nutrients to sustain her egg output. The egg output is defined as the product of the rate of egg production and weight of the eggs being produced. Therefore, by analysing these factors, the requirements of the hen for production can be estimated.

1.3.1. Composition of the hen's egg

The nutrient composition of the egg will depend on the relative proportions of yolk, albumen and shell of which the egg is composed. Table 1.2, Table 1.3 and Table 1.4 describe the average characteristics of these three components from the work of Romanoff and Romanoff (1949), Cunningham *et al.* (1960), Jaffé (1964), and Shenstone (1968). These characteristics may be used to define the composition of an average egg.

Table 1.2: *The yolk, albumen and shell as a percentage of the whole egg, also showing the percentage of water and solids in the three components. Taken from Romanoff and Romanoff (1949), Cunningham et al. (1960), Jaffé (1964), and Shenstone (1968)*

Component	*Percentage of whole egg*	*Water percentage*	*Solids percentage*
Yolk	32	23.6	51.0
Albumen	58	76.2	20.0
Shell	10	0.2	29.0

Table 1.3: *The weight in grams of the components of the egg. Taken from Romanoff and Romanoff (1949), Cunningham et al. (1960), Jaffé (1964), and Shenstone (1968)*

Component	Solid (g)	Water (g)	Total (g)
Yolk	9.9	9.1	19.0
Albumen	3.8	29.4	33.2
Shell	5.7	0.1	5.8
Total	19.4	38.6	58.0

Table 1.4: *The percentage composition of the yolk, albumen and shell. Taken from Romanoff and Romanoff (1949), Cunningham et al. (1960), Jaffé (1964), and Shenstone (1968)*

Chemical class	Yolk	Albumen	Shell
Water	47.5	88.5	1.0
Protein	17.4	10.5	4.0
Lipid	33.0	-	-
Carbohydrate	0.2	0.5	-
Inorganic ions	1.1	0.5	95.0
Other	0.8	-	-

1.3.1.1. Composition of the yolk

The yolk is made up of two parts, namely the white and yellow yolk. These two parts are chemically different to each other. The white yolk makes up 1-2% of the total yolk mass and the rest is made up of the yellow yolk. The white and yellow yolk are laid down in layers, which has lead to the development of the 'alternating-layer' theory (Romanoff and Romanoff, 1949 and Bellairs, 1964). Because the yellow yolk is not homogenous the yolk granules may become layered resulting in the apparent layered effect (Bellairs, 1964). White yolk contains only 10-13% solids and is described by Bellairs (1964) as an oil-water emulsion. White yolk has a higher proportion of protein to lipid than yellow yolk (Bellairs, 1964).

In general, yolk contains just over 50% solids (Romanoff and Romanoff, 1949). These proteins are divisible into three classes depending on their behaviour in the ultra-centrifuge (Gilbert, 1972). The protein classes are low density (LD), water soluble and granular fractions. The LD fraction is the most abundant, making up 34% of the yolk, and containing 90% of the lipids and nearly 20% of the phosphorus as phospholipid. The water-soluble proteins form 10% of the yolk solids and contain 30% of the yolk protein (Gilbert, 1972). The granular fraction is divided into two more fractions, namely the high-density fraction (lipovitellins) and the phosvitin fraction (Gilbert, 1976). The phosvitin fraction contains nearly 70% of the yolk phosphorus as phosphoprotein, but only forms 4% of the yolk solids. The high-density fraction forms 16% of the yolk solids (Connelly and Taborsky, 1961) and is 25% lipid (Gilbert, 1972).

The amino acid composition of the yolk is shown in Table 1.5. This can represent the requirement to produce an egg.

Table 1. 5: *The amino acid composition of the yolk of a hen's egg in mg/g nitrogen (Lunven and Le Clement De St Marcq, 1973)*

Amino Acid	Standard average amino acid composition (mg/g Nitrogen)
Arginine	434
Cysteine	163
Histidine	148
Isoleucine	348
Leucine	548
Lysine	477
Methionine	175
Phenylalanine	273
Threonine	313
Tryptophan	121
Tyrosine	253
Valine	378

Yolk lipids are restricted to the lipovitellins and the low-density fractions of the yolk. In total yolk lipids form 30% of the yolk and 60-70% of the yolk solids (Romanoff and Romanoff, 1949).

The composition of the yolk is summarized by Gilbert (1972) and is shown in Table 1.6.

Table 1.6: *Composition of the yolk of a hen's egg (Gilbert, 1972)*

Protein class	% yolk weight	% yolk solids	% yolk proteins	% yolk lipids
LD fraction	33.7	65.0	22.0	93.0
Livetins	5.3	10.0	30.0	-
Granules:				
Phosvitin	2.1	4.0	12.0	-
Lipovitellins	8.3	16.0	36.0	7.0
Other	2.6	5.0	-	-

1.3.1.2. Composition of the albumen

The albumen weighs just less than two thirds of the egg and consists of one part protein to two parts water. The solid portion makes up 11% of the total, of which 92% is protein. The non-protein solids are made up of carbohydrates and inorganic ions (Gilbert, 1972).

Egg albumen is not homogenous, but consists of two fractions; a thin, watery solution (thin albumen) and a thick gelatinous material (thick albumen) (Gilbert, 1972). The protein content of each layer differs only slightly (Feeney and Allison, 1969). The thick albumen forms 60% of the total albumen and is rich in the albumin protein ovomucin (Shenstone, 1968). This seems to be the only difference between the thick and thin albumen fractions.

There are a vast number of different proteins present in the egg albumen. What is of importance when predicting the requirements of the laying hen is the amino acid composition of these proteins. This is shown in Table 1.7.

The amino acid composition of the hen's egg can be used to predict the amino acid requirements of the hen for egg production. Amino acid requirements are a function of the rate of production, the weight and composition of the egg, and the efficiency with which the hen converts dietary amino acids into egg protein (Fisher, 1976).

Table 1.7: *The amino acid composition of the albumen of a hen's egg in mg/g Nitrogen (Lunven and Le Clement De St Marcq, 1973).*

Amino Acid	Standard average amino acid composition (mg/g Nitrogen)
Arginine	330
Cysteine	178
Histidine	132
Isoleucine	331
Leucine	521
Lysine	378
Methionine	240
Phenylalanine	368
Threonine	272
Tryptophan	116
Tyrosine	257
Valine	429

1.4. Efficiency of Utilization of Nutrients

Dietary amino acids are not converted directly to egg protein: there is some loss in efficiency in the process that must be taken into account when calculating the amino acid requirements for egg production. McDonald and Morris (1985) examined the efficiency of conversion of five dietary amino acids into egg protein. The efficiencies ranged from 0.74 to 0.83 (Table 1.8). Combining these estimates gives an average efficiency of 0.77 (McDonald and Morris, 1985). Differences in efficiency may result from uncertainties in the estimates of *a* or of the amino acid content of egg protein or both. A contributing factor may be differences in the digestibility of amino acids, or in the case of methionine, amino acid being diverted to an alternative output-dependent process (McDonald and Morris, 1985). The calculated efficiencies for the conversion from feed into egg protein are given in Table 1.8.

Table 1.8: *The calculation of efficiency of utilization of amino acids to produce 1g of egg protein*

Amino acid	AA present in egg (mg/g nitrogen) (Lunven and Le Clement De St Marcq, 1973)	mg AA / g egg	AA requirement per 1 g egg output (mg/g egg)	Efficiency of utilization (McDonald and Morris, 1985)
Lysine	378	7.93	10.04	0.79
Methionine	240	3.90	5.27	0.74
Isoleucine	331	6.33	8.33	0.76
Tryptophan	116	2.21	2.99	0.74
Valine	429	7.55	9.10	0.83

Determining what quantity of the limiting amino acid is required per gram of egg output, and then comparing this with the amount of that amino acid deposited in the egg can yield the efficiency of utilization of an amino acid. The amount of amino acid deposited in the egg can be calculated from the constants in Table 1.7. The average protein in the albumen and yolk are calculated separately and then added together to give the total protein in the egg. The weight of the albumen is calculated based on the fact that the albumen constitutes 58% of the total weight of the egg (Romanoff and Romanoff, 1949, Cunningham *et al.* 1960, and Shenstone, 1968). The protein weight of the albumen is then calculated as 10.5% of the total albumen weight (Table 1.4). This is then converted into mg of nitrogen by dividing by the constant 6.25. The yolk protein is then calculated by substituting 17.4% for the 10.5% (Table 1.4). The proportion of the weight that the yolk makes up is 32% (Romanoff and Romanoff, 1949, Cunningham *et al.* 1960, and Shenstone, 1968). These values are then compared with the amount of amino acids that the hen requires to produce 1 g of egg output. By calculating the ratio between the mg of amino acid per gram of egg and the mg amino acid required to form a gram of egg the efficiency of utilization of the amino acid can be calculated. Table 1.8 illustrates the amount of each amino acid required to produce 1 g of egg.

When referring to efficiencies the limiting amino acid is always referred to – there is no value in determining to what extent the non-limiting amino acids are utilized, as this depends on the amount of feed consumed relative to the first limiting amino acid. It is only really important to know to what extent the first limiting amino acid is utilized by the bird, as this is then applied to all amino acids, assuming that each will be first limiting – which is the case in a perfectly balanced feed (Fisher *et al.* 1973). Knowing the requirements of the laying hen and her rates of maintenance and production, her total requirements related to these two factors can be calculated for the individual.

1.4.1. Energy requirements of egg production

A diet that leads to positive retentions of protein and lipid, at the rates of PR and LR (g/d), will be associated with the production of faecal organic matter (FOM) and UN (Emmans, 1994). It is assumed that there are heat increments (HI), in addition to the HI associated with maintenance, with the positive retention of protein and lipid. These HI are assumed directly proportional to PR and LR. Therefore, a diet that leads to positive protein and lipid retention has a heat increment of the feed (HIF) relative to the maintenance heat (MH) given as shown in Equation 10.

$$\text{HIF (kJ/d)} = (w_d \,.\, \text{FOM}) + (w_u \,.\, \text{UN}) + (w_p \,.\, \text{PR}) + (w_l \,.\, \text{LR}) \qquad (10)$$

Where w_p is the heat associated with the rate of PR and w_l is the heat associated with the rate of LR.

The laying hen also has heat production associated with egg production. This is related to the rate of heat produced per egg, or the heat of combustion of the egg, and the average energy content of the egg produced (Emmans, 1994). Hoffman *et al.* (1973), as cited by Young (1998), stated the heat of combustion of eggs (w_e) as 0.48 kJ/kJ where the average energy content of eggs is 251 kJ/g egg (Emmans, 1994). Therefore the heat increment (HI) of egg production can be defined as:

$$\text{HI (egg production)} = 0.48 \times 251 = 120.48 \text{ kJ/ g egg} \qquad (11)$$

This can be included into the classical metabolisable energy (ME) equation so that:

$$ME\ (kJ/day) = FHP + h_p.PR + h_l.LR + w_e.(EW.ROL) + H \quad (12)$$

Where FHP is the fasting heat production, PR and LR are the rates of retention of protein and lipid in g/d and h_p and h_l are their heats of of combustion in kJ/g, EW is the egg weight, w_e is the heat of combustion of an egg, ROL is the rate of lay, and H is the rate of heat production/loss (Emmans, 1994).

There is an obvious increase in the heat production (HP) when the hen is fed above maintenance requirements. This increase in heat production is due to the deposition of protein and lipid, the excretion of UN and FOM, and the formation of eggs. Therefore;

HP (kJ/day) = MH + HI (excretion) + HI (defæcation) + HI (fattening) + HI (egg prod.)

1.4.1.1. The effective energy (EE) scale for the laying hen

The heat increment of feeding (HIF) can be broken down as the heat increment of maintenance (HIM) and the heat increment of the feed. These are defined as (Emmans, 1994):

$$HIM\ (kJ/day) = (w_u.UN) + (w_d.FOM) \quad (13)$$

$$HIF\ (kJ/day) = (w_p.PR) + (w_l.LR) \quad (14)$$

But, UN = 0.16 (DCP – PR), therefore;

$$HIM\ (kJ/day) = (w_u\ .\ 0.16(DCP\text{-}PR)) + (w_d\ .\ FOM) \quad (15)$$

By subtracting the HIM from ME in the diet leaves the energy supply scale:

$$EE\ (kJ/day) = ME - [(w_u\ .0.16.DCP) + (w_d\ .\ FOM)] \quad (16)$$

Where FOM is the faecal organic matter and DCP is the digestible crude protein. The term relating to the excretion of methane is assumed zero for single stomached animals and not included for the laying hen. The requirement for effective energy (EERQ) is the sum of the maintenance heat (MH) and the heat increment (HI) of the positive protein and lipid retentions:

$$EERQ\ (kJ/day) = MH + PR\ [(h_p - a) + (w_p - 0.16w_u)] + LR\ (h_l + w_l) \quad (17)$$

By substituting in the constants w_U = 29.2 kJ/g, w_d = 3.8 kJ/g, w_p = 36.5 kJ/g, and w_l=16.4 kJ/g the effective energy scale is defined as:

$$\text{EERQ (kJ/day)} = \text{MH} + 50\text{PR} + 56\text{LR} \tag{18}$$

The EERQ defines the effective enegy requirement of the animal. In the laying hen, growth is not a major consideration once point of lay has been reached. It is for this reason that Emmans (1994) developed another equation for laying hens.

$$\text{EERQ (kJ/day) HENS} = \text{MH} + 8.8\ \text{EO} \tag{19}$$

Where EO is the egg output in g/day and 8.8kJ/g is the effective energy required per gram of egg. The effective energy required per gram of egg was calculated by Emmans (1994), using the information of Hoffman *et al.* (1973), as cited by Young (1998). The average energy of the eggs recorded by Hoffman *et al.* was 6.71 kJ/g and 0.1117g protein per g egg, compared to the 0.12 g protein per g of egg calculated from Tables 1.3 and 1.4. The heat increment was calculated as 0.48 × 6.71 = 3.22 kJ/g egg (Young, 1998).

On the effective energy scale, the energy retained in eggs needs to be reduced by 5.63 kJ/g protein and the heat increment by 4.67 kJ/g protein (Emmans, 1987). This means that the effective energy requirement per egg becomes:

$$\text{EERQ} = (6.71 + 3.22) - 0.1117(5.63 + 4.67) = 8.8\ \text{kJ/g egg.} \tag{20}$$

1.4.2. Predicting the production requirements of the laying hen

The protein and energy requirements for egg production can be predicted considering the characteristics of the egg being formed (Emmans and Fisher, 1986). Analysing the egg produced and including an efficiency factor to account for the efficiency with which feed nutrients are converted to egg protein can predict the quantity of nutrients required to form the egg. However, the composition of every egg is not identical and factors like the age of the hen and the size of the egg will affect the requirements. The degree to which these factors affect the egg composition is important when predicting the requirements for producing an egg (Emmans and Fisher, 1986).

Egg production is more difficult to describe than growth because a longer period is involved and the hen passes through many periods in her productive life. The laying hen's productive life can be divided into three periods (Gilbert, 1969). The first period represents the onset of reproductive activity. The laying pattern of the hen during this period is often erratic and irregularities are common. These irregularities include laying more than one egg a day, production of soft-shelled eggs, the production of double yolked eggs, and irregular laying intervals. Egg weight is often low during this period, but increases exponentially to sexual maturity (Gilbert, 1969). The second period represents the main period of lay after sexual maturity has been reached and should be the longest period in the productive life of the hen. Egg weight and egg output should be constant during this period (Gilbert, 1969). The third period represents the end of lay for the hen. Egg production declines rapidly as the production of ova ceases. The ideal choice of inputs would involve the simultaneous consideration of all stages, even though the main laying period is considered the most economically important period (Gilbert, 1969).

Egg is a mixture of yolk, albumen and shell, of which each can be regarded as having a constant composition. If we can predict the production requirements of producing the yolk component, then the production requirements of producing the albumen and shell components can be calculated by difference. Emmans and Fisher (1986) have done this in three steps.

1. Predicting the rate of production of yolk material

If y is taken as the rate of yolk production, t the time from first egg and G_0 the initial state the prediction of yolk production is as follows,

$$Y = ae^{-c.t} \exp - [\exp(G_0 - b.t)] \qquad (21)$$

Where, a is a decay parameter, c is the initial state parameter at $t = 0$ and a growth parameter, b (Emmans and Fisher, 1986).

2. Predicting the partition of yolk material into individual yolks

If the function in Equation 21 predicts the potential rate of yolk deposition in the ovary, then the mean yolk weight (MYW) is,

$$\text{MYW} = y/\text{R} \qquad (22)$$

Where R is the rate of ovulation and lay (Emmans and Fisher, 1986). Here it is important to remember that not all ovulated yolks will become eggs (Gilbert, 1972). At a given time a hen has an internal cycle length of ICL hours. The environment also has a cycle defined by the light length and is referred to as a length of EXCL hours. Therefore, when ICL = EXCL then the hen is expected to ovulate once in each environmental cycle (Emmans and Fisher, 1986). In this case the rate of lay, R, per 24 hours is given by:

$$\text{R} = 24/\text{EXCL} \qquad (\text{when ICL} = \text{EXCL}) \qquad (23)$$

The two other cases to consider are when EXCL > ICL and where EXCL < ICL. In the first of these cases the hen becomes entrained to the external cycle and the rule is that it cannot lay more than one egg per external cycle. In the second case, where EXCL < ICL, at each ovulation the hen will incur a 'lag' of ICL – EXCL hours. This lag is accumulated and when this value attains a value of L hours, the bird does not ovulate, and misses a day. This develops a clutch pattern and the rate of lay (R) is defined as (Emmans and Fisher, 1986):

$$\text{R} = \text{L} / [(\text{ICL} - \text{EXCL})\,(1 + [\text{L} / (\text{ICL} - \text{EXCL})])] \qquad (24)$$

3. Predicting the albumin and shell weights from yolk weight

In non-limiting conditions it is reasonable to think that mean albumen output per yolk, MAW, is related to mean yolk weight (MYW) and that mean shell weight (MSW) is related to mean egg contents weight, MECW = (MYW + MAW). From this assumption we can then calculate the mean egg weight (MEW) as MYW + MAW + MSW and mean egg output is given by MEW.R (Emmans and Fisher, 1986).

The proportions of the albumen, yolk and shell in the egg are given in Table 1.2 as 58%, 32% and 10% respectively. If the average weight of the egg is known then the amino acid requirements for each component of the egg can be calculated. These are then added together to give the total requirement for the egg produced (Emmans and Fisher, 1986).

If the albumen proportion of the egg is 58% and the weight of the egg is 60 g then the weight of the albumen in the egg is:

$$60 \text{ g} \times 0.58 = 34.8 \text{ g}$$

The protein content of the albumen is given as 10.5%. The total weight of protein in the albumen of a 60 g egg is given as:

$$34.8 \text{ g} \times 0.105 = 3.654 \text{ g}$$

The nitrogen content of this albumen protein can then be calculated by dividing the protein weight by 6.25.

$$3.654 \text{ g}/6.25 = 0.585 \text{ g N}$$

The average amino acid composition of the albumen of a hen's egg is in Table 1.7. If these figures are multiplied by the weight of nitrogen in the albumen then the average for each amino acid in the albumen is given. If these are then added up for each component the total amino acid requirement for egg production is given.

1.4.3. Factors affecting production requirements

1.4.3.1. Rate of lay

The rate of lay and the timing of albumen and shell formation will be influenced by the hen's individual ovulatory cycle. A hen produces a sequence of ovulations on successive days, occurring slightly later each day, until the total lag exceeds eight to ten hours. This is when no ovulation occurs and a pause day occurs (Emmans and Fisher, 1986). This will not affect the deposition of yolk, which is a continuous process (Gilbert, 1972, Emmans and Fisher, 1986). The mean rate of lay in a flock of hens at a specific age is determined by the individual laying patterns of sequential laying at that time. The slopes of the initial rise in egg production and peak rate of lay are influenced by the distribution of the ages at sexual maturity and by the lengths of the individual sequences (Johnston and Gous, 2003).

1.4.3.2. Egg weight

Morris (1985) suggested that egg weight is related to the age of the hen and her genotype. This suggestion corresponds with the fact that, at the commencement of lay, egg weight is low (Morris, 1985). The environment has more of an indirect effect on egg weight. The direct effect is the feed intake. In warmer climates, feed intake may be lower, which may lead to lighter eggs (Morris, 1985).

Nutritional means may be used to alter the egg weight slightly. Early in the egg production cycle, this may prove essential to increase the egg weight. In a study done by Leeson and Summers (1983), the weight of eggs from pullets was not affected by increases in dietary levels of methionine, linoleic acid or protein above the established requirement (Morris, 1985). Another study showed that by increasing the linoleic acid content of the diet from 0.6% to 4.3% the egg weight during the first 14 weeks of production increased. This did not affect the average daily egg yield.

Morris and Blackburn (1982) showed that as the dietary protein content is increased the increase in the egg weight response gradually decreases and approaches an asymptotic value. This resulting response curve is consistent with the Reading Model, which assumes that the shape of the curve is a function of individual variation in body weight and potential egg output (Morris and Blackburn, 1982).

Sell and Johnson (1974) showed in a different study that by adding 3 to 6% fat to diets, fed to laying hens during early egg production, increased the egg weight by increasing the yolk weight whether the diets were isocaloric or not. When egg weight is increased by fat supplementation of diets, it is not known if the response is due to the fat in general, or if it is a specific response to linoleic acid. Increasing the percentage of fat or oil in isoenergetic diets caused hens to lay heavier eggs (Sell and Johnson, 1974). Decreasing the dietary energy level may decrease the egg weight. Diet costs may increase when supplemental fats are used to obtain higher dietary fat and energy concentrations (Sell and Johnson, 1984).

Decreasing the dietary levels of the most limiting amino acid can affect egg weight (Morris and Gous, 1988). A review of 12 scientific papers indicated that; as the most limiting amino acid level decreased below the required level, egg weight and the rate of egg production decreased proportionately. This reduction occurred until the egg weight decreased to about 90% of the maximum. Decreases beyond this level only caused a decrease in the rate of egg production. An exception to the general effects of an amino acid inadequacy occurs with tryptophan, as a deficiency fails to decrease the egg weight (Morris and Gous, 1988).

1.4.3.3. Moulting

Moulting is induced in commercial laying hens by imposing a period of fasting on the hens. The length of this period can vary, although the most common periods are between 4 and 10 days. During this period the hen receives no food, and sometimes no water. The lighting is often decreased to that of a normal day length or less. The period of moulting in wild birds coincides with the incubation of eggs and brooding of offspring (Summers and Leeson, 1977).

Feather loss and regrowth will cause the maintenance requirements of the hen to increase and, therefore, her feed intake will increase (Emmans and Charles, 1977, as cited by Hughes, 1980). Hughes found the maintenance requirements to increase by an increment of 7%.

The requirements of the laying hen have been defined in this chapter, but it is important to remember that the requirements are only met through the feed intake of the hen, which can be constrained by either the feed or the environment. This subject will be dealt with next.

CHAPTER 2

CONSTRAINTS ON FEED INTAKE

In an ideal environment, if the hen were provided with an ideal feed, she would be able to eat to meet her requirements and, therefore, achieve the potential defined by her genotype. This is rarely the case in practice, as the feed is not always perfect, and constraints occur in most environments. The actual feed intake consumed will define her performance. This actual intake must be predicted to maximize the hen's performance in a specific environment. In order to do this, the requirements of the hen must be known, and the feed must be formulated to account for these requirements as well as the constraints that may exist. Figure 2.1 represents the effect that constraints are proposed to have on the feed intake of a laying hen.

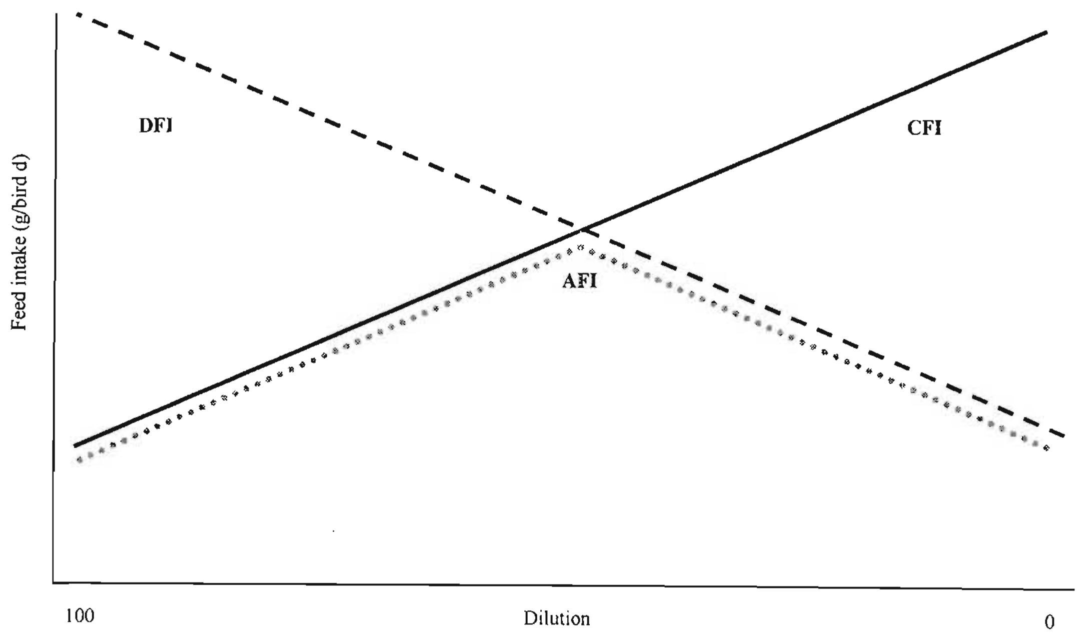

Figure 2.1: *Graph showing the proposed relationship between the desired feed intake (DFI, broken line), constrained feed intake (CFI, solid line) and actual intake (AFI, dotted line) as feed is diluted with an inert filler (Gous, in consultation, 2004).*

Three kinds of constraints can operate to limit feed intake (Emmans, 1981(a)). The environmental temperature can limit the heat loss of the animal, thereby constraining feed intake; the gut capacity of the hen may not allow sufficient food to be consumed due to the quantity required or the bulkiness of the feed; and the presence of toxins or imbalances in the feed may limit the feed intake by the hen.

CFI can be calculated as (Emmans, 1987):

$$CFI = CAP / FCON \quad \text{(kg/day)} \tag{25}$$

Where CAP = Capacity for the first limiting constraint (units/day).

FCON = Feed's yield of the first limiting constraint (units/day).

Each constraint will be dealt with briefly in turn. However, the bulk constraint of the feed will be dealt with in more detail, being the subject of this thesis.

2.1. Environmental Heat Demand

Hens are classed as homeotherms and a homeotherm is defined by Mount (1979) as an animal that usually maintains a stable deep body temperature within narrow limits, even though the environmental temperature fluctuates and the animal's activity fluctuates. The thermal physiological features of birds are that they usually have a core temperature above 40 °C, they have an insulating layer of feathers that lower their capacity for a high rate of heat loss, and under hot conditions their body temperature is controlled mainly by evaporative heat loss from the respiratory tract (Marsden and Morris, 1987). Several components of the physical environment affect the heat loss of the animal. In order of importance these are:

- Dry bulb temperature
- Radiant temperature
- Air speed
- Wet bulb temperature (Marsden and Morris, 1987).

A heat balance exists in the animal between the animal's heat production and heat loss. The result of this balance is that the core temperature of the animal is maintained. Feeding increases the heat produced. Therefore, when feed intake is high the level of heat production in the zone of thermal neutrality is higher than when feed intake is low (Marsden and Morris, 1987).

The feed supplied to the animal is that animal's sole source of energy and substrate for the formation of energy reserves. The chemical energy in the feed is oxidized by the animal and utilized. The heat of combustion produced by the feed measures the amount oxidized. However, some of this chemical energy can escape unutilised in two ways (Emmans, 1994):

1. Energy in the excreta and gases.
2. Energy through heat production.

The energy in the excreta and gases can be predicted by the calculation of the metabolisable energy (ME) in the feed available to the animal. The energy in the heat of production can be calculated through the prediction of the heat increment produced through feeding (Emmans, 1994), explained in Section 1.4.1.

The ME is the potential energy supplied to the animal by the feed it receives. The ME of the diet is predicted through the heat of combustion of the feed. The organic matter (OM) component of the feed yields the heat produced by combustion; therefore, the potential energy of the diet depends on the rate of OM intake multiplied by the heat of combustion. Some of this potential energy is lost as OM in the excreta (Emmans, 1994). The useful amount of ME in the diet can be defined by Equation 26.

$$\text{ME (kJ/day)} = \text{GE} - (\text{FE} + \text{UE} + \text{MTHE}) \qquad (26)$$

Where ME is the rate of supply of metabolisable energy and FE, UE and MTHE are the rates of loss of energy in the faeces, urine and combustible gases respectively (Armsby (1903) as cited by Emmans, 1994). The laying hen is classed as a monogastric, meaning that the MTHE value can be considered zero.

The ME in Equation 26 is known as the classical ME (ME_c). It can be useful to correct this ME value to reflect the ME if the rate of nitrogen retention is zero (Emmans, 1994). This is termed the nitrogen-corrected ME (ME_N) and can be estimated as:

$$ME_N = ME_c - a\ (6.25\ NR) \tag{27}$$

Where NR is the nitrogen retention in g/day and the value of a is constant and equal to 5.63 kJ/g (Emmans, 1994).

It has been defined previously that at maintenance the rate of protein retention is zero. If this is the case then ME_N is the ME measured at maintenance (Emmans, 1994). The ME in the diet is either retained by the animal or lost as heat. The ME retained is in the form of either protein or lipid (Emmans, 1994). This means that the ME_c can be defined as:

$$ME_c\ (kJ/day) = h_p\ .\ PR + h_l\ .LR + H \tag{28}$$

Where H is the rate of heat production, PR and LR are the rates of protein and lipid retention (g/day), respectively, and h_p and h_l are their respective rates of combustion (Emmans, 1994). The values of h_p and h_l are constant and estimated as 23.8 and 39.6 kJ/day respectively (Emmans, 1994). If ME_c is corrected for zero nitrogen retention the Equation 28 becomes:

$$ME_c\ (kJ/day) = (h_p - a)\ .\ PR + h_l\ .\ LR + H \tag{29}$$

The problem now lies in predicting the heat production. The heat production can be divided into two components (Emmans, 1994):

1. FHP = the fasting heat production which is the rate at which the animal produces heat when given no food.
2. HIF = the heat increment resulting from feeding.

Fasting heat production is only produced from the catabolism of protein and lipid within the body. The heat produced by lipid catabolism is equal to its heat of combustion. However, protein catabolism occurs with the loss of some energy in the form of nitrogen-containing compounds in the urine. This means that the heat produced by protein catabolism is less than its heat of combustion. This reduction in the potential energy supplied to the hen can be calculated by multiplying the protein retention in the hen by the energy value of the nitrogen-containing compounds in the urine (34.4 kJ/g) multiplied by the amount of nitrogen in protein (0.16). [PR × (34.4 × 0.16)] (Emmans, 1994). The FHP is given as:

$$\text{FHP (kJ/day)} = (h_p - a) .\text{PR} + h_l .\text{LR} \qquad (30)$$

Where PR and LR are the rates of loss of reserves during the fast, considered here as positive quantities (Emmans, 1994).

The synthesis and excretion of the nitrogen-containing compounds, produced during protein catabolism, produces a specific 'heat of excretion' (HEX, kJ/day) (Emmans, 1994). This is produced at a rate of w_U in the urine and is defined as:

$$\text{HEX (kJ/day)} = w_U \,.\, \text{FUN} \qquad (31)$$

Where FUN (g/day) is the rate of nitrogen excretion during fasting (Emmans, 1994).

Animal behaviour is also important when calculating heat production. It can change heat loss in the short-term. Animals fed at less than *ad libitum* show a lower heat loss at low temperatures than those fed *ad libitum* (Emmans, 1981(a)). This appears to be due to behavioural rather than biochemical adaptation (Emmans, 1981(a)). With *ad libitum* feeding, it is assumed that the environmental heat demand (EHD), can be represented by the equation:

$$\text{EHD} = \text{MBW} (a - bT) \qquad (32)$$

Where MBW is the metabolic body weight and T is the effective temperature. The values of a and b are regarded as being independent of the environment and feed composition. As they reflect the insulation value of the animal's coat, they can be considered as functions of the degree of maturity.

A feed that allows production of either protein and lipid, or eggs, will also produce heat increments which are referred to as the HIF. The HIF is assumed to be directly proportional to the rate of production, and the amount of energy needed to digest the feed. This will affect the rate of production of a hen on a specific feed. The equation that represents the HIF is Equation 10, and Equation 11 represents the specific HIF equation for egg production.

Marsden and Morris (1987) showed that egg production could be maintained up to an environmental temperature of 30°C by adjusting the composition of the diet. Higher dietary protein concentrations were needed to maintain egg output at higher temperatures. At 30°C the reduction in egg output was not attributable to inadequate protein intake. Increasing the dietary energy concentration was attempted to counteract the decline in egg production at 30°C. The increase in dietary energy resulted in some increase in egg output at all experimental temperatures, but it did not prevent the reductions in egg output at 30°C.

Marsden and Morris (1987) found that the relationship between temperature and ME intake is curvilinear. Feed intake decreased more rapidly as the environmental temperature approached body temperature. The adapted heat production of the bird was also found to be a curvilinear function of temperature and tended toward a value of zero as the environmental temperature approached the body temperature. Energy intake and heat output can be expressed linearly between 15 and 30°C when they are expressed as functions of metabolic size ($kg^{0.73}$). It was estimated that the energy available for egg production was at a maximum at 23°C for brown Leghorns and at 24°C for white Leghorns. Gross energetic efficiency is at a maximum at 30°C, but egg output is greatly reduced at this temperature (Marsden and Morris, 1987).

2.2. BULK CONSTRAINT

2.2.1. Relationship between feed bulk and feed intake

When a highly digestible feed is diluted with a "bulkier" feed it can be assumed that the hen will increase her feed intake so that her intake of required nutrients remains relatively constant and, therefore, her performance remains unaffected. Emmans (1981(b)), states that an animal has a potential rate of performance at a given time and it seeks to eat an amount that will allow this potential rate of performance to be achieved. If the dilution of the feed continues, a critical point will be reached when the hen's feed intake will decrease and performance will be reduced. This critical point needs to be defined so that feed intake can be accurately predicted as it reflects the capacity of the hen for 'bulk'. It is this equilibrium value that will be used in prediction equations (Whittemore *et al.,* 2003). The time taken to adapt to a new feed also needs to be known. This time can be affected by the previous diet that the hen was consuming (Tsaras *et al.*, 1998, and Whittemore *et al.*, 2003).

The digestive tract of the hen is responsible for the digestion and absorption of the feed and nutrients. The most obvious constraint that the feed bulk can impose here is the physical limitation to the quantity of food that the digestive tract can contain. The factors that affect the gut capacity, extent of stretch of the organ and the rate of emptying are important in providing an accurate measurement of this constraint. Feed intake is regulated through the hypothalamus, through the ventromedial hypothalamic satiety centre and the lateral hypothalamic feeding centre, and is therefore a homeostatic function (Sykes, 1986). It is thought that the distention of the gut plays a large role in regulating feed intake. Polin and Wolford (1973) showed that the continuous distention of the crop inhibited feed intake. Richardson (1972) found that feed intake was reduced with the physical restriction of the duodenum of cockerels. This may be due to the fact that physical factors within the duodenum appear to inhibit gastric motility and, therefore decrease the feed intake of the bird.

The amount of a 'bulky' feed that a hen can consume depends on her capacity for bulk and the bulk content of the feed. Tsaras *et al.* (1998) found that in pigs the maximum capacity for food bulk was directly proportional to the live weight of the animals.

Savory (1980) found that the density of the feed affects the amount of time that the birds spend eating. He found that by altering the density of the feed, the amount of time that the birds spend eating and, therefore, feed intake is altered. The results showed that birds fed a diluted feed consumed more than the birds on a non-diluted feed. The feeding patterns also varied according to the nutrient density of the feed. Birds on non-diluted feeds increase their intake of feed throughout the day, while birds fed a diluted feed have a consistent high feed intake throughout the day. If the values making up the feed intake are limited by bulk, the actual feed intake is fixed by the volume intake and *ad libitum* feeding is no longer in operation (Emmans, 1981(a)).

2.2.2. The digestive system

The components of the digestive system that are important to the hen in the digestion of the feed are the crop, the proventriculus, the gizzard, the small intestine and the colon. The feed is ingested and swallowed without mastication and is stored in the crop until it can be ground and mixed with digestive juices (Morris, 2004).

In the crop, the feed is moistened with ingested water and liquid secretions. Feed moves from the crop, small quantities at a time, into the proventriculus. Here the digestive juices are added to the feed. The feed then passes into the gizzard, which grinds the feed before it enters the small intestine. More gastric juices are added to the feed in the small intestine and the absorption of nutrients occurs here (Morris, 2004).

Jorgensen *et al.* (1996) found that broiler chickens can adapt to high fibre diets by increasing the size of the digestive tract and increasing the length of the small intestine. The partitioning of retained energy between body protein and body fat also changes in favour of body protein. The changes in the size of the digestive tract will have an effect on the maintenance requirements of the animals because of the relationship between the maintenance requirements of an animal and the animal's metabolic weight.

2.2.3. Measurement of feed bulk

Feeds and feed ingredients are often analysed to obtain detailed information about their nutritional composition. This information should not only allow the nutritionist to check that the nutrient requirements of the hen are satisfied, but also that she is able to consume sufficient of the feed to meet these requirements.

It is important to find a suitable method to determine the bulk density of a specific feed. The method applied should be an accurate measurement of the *in vivo* environment and it should be quick and easy to perform or calculate. The best method would, of course, be a calculation. This could be possible by determining if a correlation exists between the chemical components of the feed and the density of the feed.

2.2.4. Methods of expressing feed bulk

2.2.4.1. Water-displacement method

This method was described by Moughan *et al.* (1999). A 50 g sample is taken as fed, i.e. no further grinding, and analysed using a 250 ml volumetric flask and a 37°C water bath. The 50 g sample is placed in the 250 ml volumetric flask and 100 ml of 37°C distilled water is added. The sample is then mixed and 50 ml distilled water is added. It is then allowed to equilibrate for 15 minutes. Finally an additional 50 ml of distilled water is added and again the sample is allowed to equilibrate for 15 minutes. The flask is then filled to volume by adding the distilled water via a pipette. The density is calculated by dividing the weight of the sample added at the beginning by the total amount of distilled water added to the volumetric flask. The wet-density is expressed in g/ml.

2.2.4.2. Dry-density determination

Cherry *et al.* (1983) described this rather inaccurate, but quick, method of feed density determination. A 10 g sample is placed into a graduated cylinder and the cylinder is then tapped 10 to 12 times to remove any air pockets. The sample volume is then recorded and the dry-density is calculated and expressed as g/ml.

2.2.4.3. Water-holding capacity

The bulk characteristics of the feed may change when the feed enters the digestive tract. The main effect of this change will be the water-holding capacity of the feed. Kyriazakis and Emmans (1994), and Whittemore *et al.* (2003) have used the water-holding capacity (WHC) of the feed as a measurement of the bulk of the feed. The WHC of the feed has been determined by two different methods in the past, the filtration method and the centrifugation method.

The filtration method was described by Kyriazakis and Emmans (1994). A 1 g sample of the feed, as fed, is soaked in 500 ml of distilled water for 24 hours. The samples are then filtered through filter paper (Whatman #2 filter paper, Whatman International Ltd., Maidstone, Kent) and the wet sample weight is determined. The samples are then freeze-dried and the dry sample weight is recorded. The WHC of the feed is calculated and expressed as g water/g dry feed.

The centrifugation method involves placing a 0.5 g sample of oven-dried feed into a 25 ml centrifugation tube. The sample is then soaked for 24 hours in distilled water before being centrifuged at 6000*G* for 15 minutes. The supernatant fraction is decanted and the fresh weight of the feed is determined. The samples are then freeze dried and the WHC is expressed as g water/g dry feed (Robertson and Eastwood, 1981).

2.2.4.4. Crude fibre, NDF and ADF

The bulk volume of the feed can be measured by the fibre content of the feed, or the indigestible portion of the feed. Lehmann (1941), as cited by Whittemore *et al.* (2003), proposed that a suitable scale for bulk would be to measure the undigested dry matter. Voluntary feed intake models that have previously been developed have used dry matter as a measure of bulk (Whittemore *et al.* 2003), or undigested organic matter as a measure of bulk (Lehmann (1941), as cited by Whittemore *et al.* (2003)).

The determination of dry matter as a measure of bulk is inadequate across the complete range of feeds that exist (Kyriazakis and Emmans, 1994). Mraz *et al.* (1957) determined that the dry matter from different feeds has different filling effects in chickens. It has also been suggested that undigested dry matter may also have different bulk equivalents. This was suggested after Brouns *et. al.* (1991) discovered that the voluntary feed intake of sows is depressed far more by feeds based on sugar-beet pulp than by other, more indigestible materials, like straw and rice bran. Brouns *et al.* concluded from this that there must be another property of feeds that could be responsible for the reduction of feed intake.

This leads to the question of which method describes the bulk density of the feed best? This will be dealt with in Chapter 3.

2.3. Toxins and Nutrient Excesses or Imbalances

At some level in a feed, all chemicals, including nutrients, are toxic because feed is a mixture and, therefore, must obey the geometry of mixtures (Emmans, 1981(a)). Simply this means that as the amount of a single ingredient in the feed increases, so one or more of the others must decrease. Nutrient excesses can be seen as an example of how an animal reacts to toxins (Emmans, 1981(a)). Faced with the intake of some material an animal has several options:

- It can refrain from absorbing it.
- It can excrete it.
- It can alter it to a less harmful form.
- It can store it (Emmans, 1989).

The process of altering the ingredient to a less harmful form will increase as the exposure to the ingredient increases. The excretion and storage of the ingredient will eventually reach an upper limit. If the way in which the animal deals with the toxin is understood and can be quantified it should be possible to predict the level at which feed intake will be depressed (Emmans, 1981(a)).

2.4. Other feed intake control mechanisms

Neural control, both peripheral and central, serve as important regulators of feed intake. Peripheral receptors in the upper digestive tract are important regulators of feed intake. These receptors are presumed to be interrelated and in contact with the hypothalamus via neurons (Polin and Wolford, 1973). Five theories exist that have been based on a variable monitored by the central nervous system. Each of these theories will be discussed briefly. The theories that exist are those of the glucostatic theory, thermostatic theory, lipostatic theory, aminostatic theory and the ionostatic theory.

The glucostatic theory has been reported to exist in mammals, but it is not readily detectable by normal protocols in birds (National Research Council, 1987). Feeding has not been altered after the manipulation of blood glucose levels. (National Research Council, 1987).

The thermostatic theory is based on the exchange of heat between the animal and its environment. Several peripheral detectors exist that sense temperature changes and stimulate the central controller in the brain to increase or decrease feed intake (National Research Council, 1987).

The lipostatic theory is based on a feed-back system from fat depots to the brain and results in long-term control of feed intake. Polin and Wolford (1973) have shown this mechanism to exist in poultry and influence feed intake, but these effects are not consistent with the normal functioning of a lipostatic mechanism in mammals, and it is therefore questionable whether or not a negative feed-back exists from adipose tissue in poultry (National Research Council, 1987).

The balance of amino acids markedly influences feed intake and this is the basis of the aminostatic theory. Imbalanced diets cause rapid decreases in feed intake and a reduction of the first limiting amino acid in the blood. This may be the signal that causes the reduction in feed intake (National Research Council, 1987).

The role of Na^+ and Ca^{++} within the brain, specifically the hypothalamus, has effects on the body temperature of the hen and feed intake and is the basis of the ionostatic theory. It is this effect on body temperature, caused by an imbalance of ions, which affects the feed intake (National Research Council, 1987).

The factors that affect the feed intake of the laying hen have been summarized in the above chapters. The effect of the feed bulk on feed intake will be investigated to determine a suitable measure of feed bulk and to quantify the upper limit of feed bulk that the hen can consume before intake is constrained.

CHAPTER 3

THE EFFECT OF FEED BULK ON FEED INTAKE IN THE LAYING HEN

3.1. INTRODUCTION

For a hen to attain her genetic potential, she must eat sufficient of the food offered to her to meet her requirements for all essential nutrients. She may be constrained from doing so if the feed is too bulky, if the environmental temperature is too high that she is incapable of losing sufficient heat to the environment in which she is placed, or if there are toxins in the feed that she can detect (Williams, 1993). The research reported in this thesis deals with the first of these constraints, namely, feed bulk. The objectives of the research are to define the physical characteristics of the feed that best describe the bulkiness of the feed, and to define the maximum capacity of the hen to consume feed bulk.

As a means of finding a suitable method of describing feed bulk, diluents used in such a study should vary in physical properties such that the most suitable measure(s) can be found for predicting when feed intake by the hen would be constrained by bulk. Characteristics such as wet and dry density, water-holding capacity, crude fibre, acid-detergent fibre, neutral-detergent fibre, and even dry matter and undigested organic matter have been used for this purpose, with different degrees of success (Williams, 1993).

The most obvious constraint that feed bulk can impose is the physical limitation to the quantity of feed the hen can consume. However, although birds are capable of increasing crop capacity, as a means of storing food prior to its being processed (Williams, 1993), this is not an adequate measure of gut capacity, as it does not account for the rate at which the food is processed (Williams, 1993). Because food is not stored in the true stomach (proventriculus) of birds, as it is in simple stomached animals, the extent of stretch of the stomach is also unlikely to be the factor that constrains intake (Williams, 1993). The rate of flow of digesta is clearly important in providing an accurate measure of this constraint (Williams, 1993). Whatever the mechanism for constraining feed intake, the effect is an intake lower than would be predicted, given the extent to which the food has been diluted.

For example, a hen would be thought to attempt to consume twice her characteristic intake if the food were diluted 1:1 with an inert filler, in order to satisfy her requirement of nutrients to attain her genetic potential.

The physico-chemical properties of the feed, such as fibre content and water-holding capacity, are likely to relate the feed composition to the feed intake. A good measure of feed bulk would be a measure of one of these physico-chemical properties that would allow an accurate prediction of feed intake for both bulky and dense feeds. The measure needs to predict the effect of the digestive tract and juices on the feed and the change that these factors will cause on the feed. For example, a feed that is dense may have a high water-holding capacity when wet, which will increase the bulk and viscosity of the digesta (Williams, 1993).

Apart from the constraint on feed intake, it is likely that changes in reproductive performance of the hen may be attributed to the constraint that the feed imposes on the hen. The equilibrium value of feed intake, as defined by Whittemore (2003), is defined as the point when increased dilution of the feed will cause a reduction in performance, and it is this point that needs to be predicted from knowledge of the bulkiness of the food and the gut capacity of the hen. Hence there is an advantage in measuring the reproductive traits in addition to feed intake in such trials.

The objectives of this trial were to define the physical characteristics of the feed that best describe the bulkiness of the feed, and to define the maximum capacity of the hen to consume feed bulk. This should lead to the definition of the capacity of the laying hen for feed bulk such that it would be possible to predict, by means of a feed intake model, when the hen will be constrained by food bulk; and therefore no longer be capable of consuming sufficient of the food to attain her potential reproductive performance.

3.2. Materials and Methods

3.2.1. Animal description

One hundred and sixty laying hens were randomly allocated to the individual laying cages. The hens selected were Hy-line Variety Silver. They were hatched on the 19th of September 2002 and were transferred to group pens in an adjacent laying house on the 27th of February 2003 at the start of their 24th week. At the commencement of the trial the hens were 49 weeks old. The hens were kept on a commercial layer feed, to which they had become accustomed, for one week after being moved to the individual cages, before the test treatments were offered. The commercial layer feed was used as the basal feed and an adaptation period of 1 week was allowed between treatments, when the hens were fed the basal feed.

3.2.2. Facilities

The birds were housed individually in wire floored laying cages, arranged in two tiers, in an open-sided laying house with adequate ventilation. Each cage was equipped with a nipple drinker located at the rear of the cage and an individual feed trough at the front.

3.2.3. Basal feed and diluents used

A commercial layer feed (Table 3.1), known to sustain good egg production, was used as the basal feed in the trial. This was sourced from a local feed company. This basal feed was diluted with one of five diluents, each being included at four levels, resulting in 20 dietary treatments in total. The diluents used were cellulose, sand, sawdust, sunflower husks and vermiculite, and the rates of dilution were 0, 100, 250 and 500g/kg. The diluents were included into the feed as a percentage of the final weight required, for example, to mix 50kg of a sand diluted feed at 100 g/kg, 5 kg of sand were added to 45 kg of the commercial feed. The addition of the diluent into the basal feed would not alter the balance of nutrients within the feed, but would increase the bulkiness and dilute the nutrient density of the feed. The physical properties and the daily consumption of the diluted feed will provide information on the gut capacity of the laying hen.

Table 3.1: *The composition and analysis of the basal feed[1] (g/kg), purchased from a local feed company, and offered to Brown and White Hy-line hens in all three Phases of the trial.*

Ingredient	*Inclusion (g/kg)*
Yellow maize	512.0
Bran	150.0
Hominy chop	53.0
Molasses	20.0
Soya oilcake (47.0 g/kg protein)	70.5
Sunflower oilcake (38.0 g/kg protein)	100.0
Limestone	81.5
Monocalcium phosphate	5.9
Salt	4.0
DL methionine	0.6
Lysine HCl	1.3
Layer premix and Phytase	1.6
Analysis of basal feed	*Determined (g/kg)*
Protein (g N x 6.25 kg)	145.0
ME (MJ/kg)	11.3
Lysine (g/kg)	6.9
Ca (g/kg)	34.0
P (g/kg)	5.0

The diluents sourced for this trial were chosen so that they would have contrasting physiochemical properties. Diluents with high fibre contents, e.g. cellulose, were contrasted with a diluent with little or no fibre content, e.g. sand. Diluents with differing densities were chosen, but all diluents were chosen so that they would combine well with the basal feed and not be unattractive to the hens.

[1] Basal feed supplied by Nutrex (KZN) (Pty) LTD. P.O. Box 179, Umlaas Road, 3730.

3.2.4. Design

Three phases were used in each trial, Phase 1, Phase 2, and Phase 3, each lasting three weeks. In the Phase 1, 20 dietary treatments were randomly allocated, using the random function in Microsoft Excel Software, between one hundred and sixty laying hens, each treatment, therefore, being offered to eight hens. In the Phase 2, the hens whose feed was diluted at the rate of 100 g/kg in Phase 1 were switched to a dilution rate of 500 g/kg, and the hens that received a feed diluted at the rate of 500 g/kg in Phase 1 were switched to a dilution rate of 100 g/kg. Those hens receiving feed diluted at a rate of 250 g/kg remained on that feed. This was designed to confirm the effect that different dilutions of the same diluent had on the feed intake of the laying hen.

In the Phase 3, four of the diluents were switched: hens on the cellulose and sand treatments were swapped, as were the hens on the sawdust and sunflower husk treatments, all hens received the same dilution as was used in Phase 2. This design would confirm that different diluents had a different effect on the feed intake. Hens initially on the vermiculite treatment were kept on vermiculite for the entire nine weeks; hence those hens fed vermiculite-diluted at a rate of 250 g/kg received the same feed for the entire nine weeks. The details of the dietary treatments are presented in Table 3.2. The design's purpose was to give sufficient information of the effects of the different bulk densities on feed intake. All data was analysed using the Genstat release 6.1.

Feed was available to the hens *ad libitum.* The feed was weighed into the self-feeding trough at the start of the week, and the amount remaining at the end of the week was weighed in order to calculate feed intake, by difference, for the week. The feed was weighed into buckets for each individual hen, from which that hen was fed throughout the week. Feed was weighed in on a Monday and the orts were weighed out the following Monday.

Table 3.2: *Details of the dietary treatments offered to Silver Hy-line variety hens in Phases 1, 2 and 3, giving the dilution level in g/kg*

Diluent	Symbol	Dilution level			
		Phase 1	*Phase 2*	*Phase 3*	
				Diluent	*Level*
Cellulose	C	0	0	S	0
Cellulose	C	100	500	S	500
Cellulose	C	250	250	S	250
Cellulose	C	500	100	S	100
Plasterer's sand	S	0	0	C	0
Plasterer's sand	S	100	500	C	500
Plasterer's sand	S	250	250	C	250
Plasterer's sand	S	500	100	C	100
Sawdust	SD	0	0	SF	0
Sawdust	SD	100	500	SF	500
Sawdust	SD	250	250	SF	250
Sawdust	SD	500	100	SF	100
Sunflower husks	SF	0	0	SD	0
Sunflower husks	SF	100	500	SD	500
Sunflower husks	SF	250	250	SD	250
Sunflower husks	SF	500	100	SD	100
Vermiculite	V	0	0	V	0
Vermiculite	V	100	500	V	500
Vermiculite	V	250	250	V	250
Vermiculite	V	500	100	V	100

Due to the biological nature of the theory being investigated a dose-response analysis of the data was adopted. The output is expected to increase with increasing inputs, leading to an asymptotic response (Morris, 1999). This response may initially be linear, but becomes curvilinear as the ceiling is reached. Eventually, a plateau is reached where there is no response to further increases in input (Figure 3.1). At the high end of the scale there may, or may not, be a reduction in output when the input is supplied in excess (Morris, 1999).

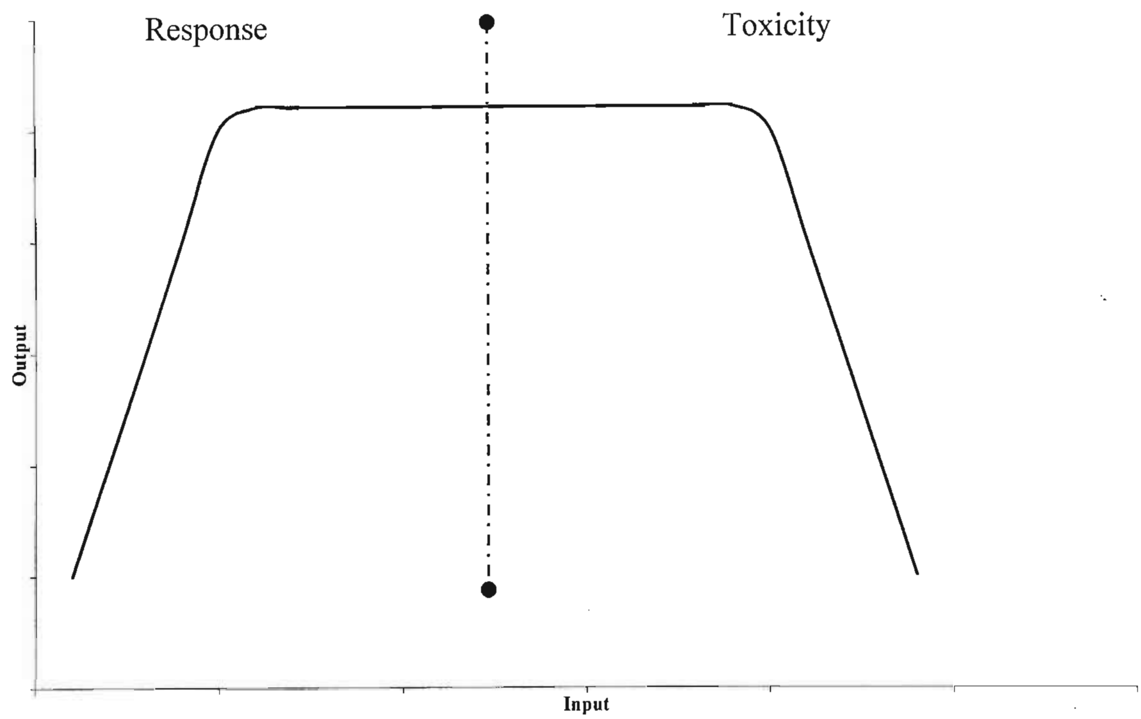

Figure 3.1: *A general model of response to increasing inputs, applicable to many animal experiments. The model implies that some positive input is required before any output can be obtained, although it may be difficult to investigate the responses to very small inputs. Some inputs may lead to 'toxicity'; others may not (Morris, 1999).*

For a single animal two straight lines can be fitted to data in the form of a bent-stick model (Morris, 1999). The two components of this model represent the maintenance and production requirements of the animal. The maintenance requirement is fitted to a horizontal line and the production requirement is fitted by linear regression. The production requirement is the subject of focus in this trial and, therefore, only linear regressions will be fitted to the data. For the bent-stick model, the residual sum of squares is then calculated about the pair of fitted lines and the interception is moved one place both sides and the residual sum of squares is calculated as well. The lowest residual sum of squares value represents the best pair of fitting lines (Morris, 1999). The regression model adopted to determine the response of the interactions between the period, diluent and level of diluent inclusion was:

Response = μ + Group effect + [Period effect + Diluent effect + Level effect]

3.2.5. Feed and diluent analyses

The methods used to analyse the feeds are described below, and all analyses were done in duplicate. All feeds and ingredients were analysed using the following methods.

3.2.5.1. Water-displacement method

This method was described by Moughan *et al.* (1999). A 50 g sample is taken as fed, i.e. no further grinding, and analyzed using a 250 ml volumetric flask and a 37°C water bath. The 50 g sample is placed in the 250 ml volumetric flask and 100 ml of 37°C distilled water is added. The sample is then mixed and 50 ml distilled water is added. It is then allowed to equilibrate for 15 minutes. Finally an additional 50 ml of distilled water is added and again the sample is allowed to equilibrate for 15 minutes. The flask is then filled to volume by adding the distilled water via a pipette. The density is calculated by dividing the weight of the sample added at the beginning by the total amount of distilled water added to the volumetric flask. The wet-density is expressed in g/ml.

3.2.5.2. Dry-density determination

Cherry *et al.* (1983) described this rather inaccurate, but rapid method of feed density determination. A 10 g sample is placed into a graduated cylinder and the cylinder is then tapped 10 to 12 times to remove any air pockets. The sample volume is then recorded and the dry-density is calculated and expressed as g/ml.

3.2.5.3. Water-holding capacity

The bulk characteristics of the feed may change when the feed enters the digestive tract. The main effect of this change will be that water will combine with the feed thereby increasing its density, so it is useful to know the water-holding capacity (WHC) of the feed. Kyriazakis and Emmans (1994) and Whittemore *et al.* (2003) have both used this characteristic as a measurement of the bulk of a feed. The water-holding capacity of the feed represents the property of the non-starch polysaccharides of the feed to trap water within its matrix and swell to form gels of high water content. This is relevant to the specific type of polysaccharide and it can also be influenced by the preparation of the feed before measuring the WHC (Kyriazakis and Emmans, 1994). The formation of a gel within the gastrointestinal tract will increase the viscosity of the feed, as well as increase the bulk. The WHC of the feed has been determined by two different methods in the past: the filtration method and the centrifugation method.

The *filtration* method was described by Kyriazakis and Emmans (1994). A 1 g sample of the feed, as fed, is soaked in 500 ml of distilled water for 24 hours. The samples are then filtered through filter paper (Whatman #4 filter paper, Whatman International Ltd., Maidstone, Kent) and the wet sample weight is determined. The samples are then freeze-dried and the dry sample weight is recorded. The WHC of the feed is calculated and expressed as g water/g dry feed.

The *centrifugation* method involves placing a 0.5 g sample of oven-dried feed into a 25 ml centrifugation tube. The sample is then soaked for 24 hours in distilled water before being centrifuged at 6000*g* for 15 minutes. The supernatant fraction is decanted and the fresh weight of the feed is determined. The samples are then freeze-dried and the WHC is expressed as g water/g dry feed (Robertson and Eastwood, 1981).

Only the centrifugation method was used since previous authors have found the two methods to be highly correlated and the filtration method posed the problem of separating the sediment from the filter paper (Robertson and Eastwood, 1981).

3.2.5.4. Crude fibre, NDF and ADF

The fibre content of the feed or its indigestible portion may be used as a measure of the bulkiness or volume of the feed. Lehmann (1941), as cited by Whittemore *et al.* (2003), proposed that a suitable scale for bulk would be to measure the undigested dry matter (Kyriazakis and Emmans, 1994).

All the fibre analysis was done by the Nutrient Analysis Laboratory, Discipline of Animal and Poultry Science, University of KwaZulu-Natal. Crude fibre (CF) and acid detergent fibre (ADF) were analysed on a Dosi-Fibre machine using the AOAC Official Method 920.39 and AOAC Official Method 973.18, respectively. Neutral netergent fibre (NDF) was analyzed on a Dosi-Fibre machine according to the method described by Van Soest *et al.* (1991).

3.2.6. Measurements

Rate of lay was measured daily for each hen and egg weight was recorded three times a week. Feed intake was recorded weekly. The body weights of the hen at the start, and after each three-week period, were recorded, and the change in body weight of the hen was calculated by difference. The body weight of the hens was recorded to check the feed intake and the welfare of the birds. Those hens whose body weight had dropped below 1000g were removed from the trial and returned to the basal feed. One mortality was recorded and this was due to the hen having a split beak and being unable to eat the feed in a mash form.

3.3. RESULTS AND DISCUSSION

3.3.1. Bulk content analysis

The calculated analysis of all the feeds offered in the trial is given in Table 3.3. Measurements were done for protein, ash, fat, moisture, crude fibre (CF), neutral detergent fibre (NDF) and acid detergent fibre (ADF) in the Feed Analyses Laboratory at the University of KwaZulu-Natal.

Table 3.3: *The composition of the mixed feeds (Basal feed + diluent) offered to the laying hens during the trial, including the measurements of crude protein (CP), lipid, ash and moisture contents (g/kg)*

Diluent	Diluent inclusion level (g/kg)	CP	Fat	Ash	Moisture
Cellulose	0	144.1	31.8	129.6	112.0
	100	138.4	22.4	146.6	108.0
	250	104.8	13.0	164.4	100.0
	500	67.8	5.3	237.8	94.0
Sand	0	144.1	31.8	129.6	112.0
	100	129.3	24.5	242.9	92.0
	250	108.2	17.0	320.1	98.0
	500	75.0	10.0	616.8	54.0
Sawdust	0	144.1	31.8	129.6	112.0
	100	135.3	27.5	97.0	116.0
	250	114.2	25.7	90.3	114.0
	500	77.0	22.4	64.2	119.0
Sunflower husk	0	144.1	31.8	129.6	112.0
	100	125.1	34.9	111.1	107.0
	250	123.9	33.9	91.3	111.0
	500	99.1	32.9	65.2	109.0
Vermiculite	0	144.1	31.8	129.6	112.0
	100	128.7	24.0	202.5	105.0
	250	108.2	17.0	320.1	98.0
	500	73.5	15.3	483.1	79.0

The bulk characteristics for each of the feeds used in the trial, as well as each diluent, were measured, as described above. Values for each of the feeds used are presented in Table 3.5, and for the diluents in Table 3.4.

Table 3.4: *The measured bulk characteristics of the basal feed and the individual diluents used in the trial, including mean water-holding capacity (WHC) (g water/g feed), dry and wet density (g/ml), crude fibre (CF), acid detergent fibre (ADF) and neutral detergent fibre (NDF) (g/kg)*

Diluent	WHC (g water/g Feed)	Dry density (g/ml)	Wet density (g/ml)	CF (g/kg)	ADF (g/kg)	NDF (g/kg)
Basal feed	4.55	0.66	1.34	43.2	67.0	145.9
Cellulose	25.00	0.37	0.67	158.6	336.0	437.4
Sand	1.49	1.43	1.99	-	-	-
Sawdust	7.14	0.23	0.93	689.0	768.7	874.5
Sunflower husk	6.25	0.25	0.54	519.9	648.8	751.6
Vermiculite	6.67	0.16	0.55	-	-	-

Table 3.5: *The bulk characteristics of the feeds including the mean water-holding capacity (WHC) (g water/g feed), dry and wet density (g/ml), crude fibre (CF), acid detergent fibre (ADF) and neutral detergent fibre (NDF) (g/kg) of feeds used in the trial*

Diluent	Level (g/kg)	WHC (g water/g Feed)	Dry density (g/ml)	Wet density (g/ml)	CF (g/kg)	ADF (g/kg)	NDF (g/kg)
Cellulose	100	5.00	0.57	1.31	*	91.0	201.2
	250	5.88	0.55	0.98	*	126.4	257.1
	500	7.69	0.50	0.60	*	192.3	264.7
Sand	100	4.55	0.70	1.43	34.6	396.7	132.4
	250	3.03	0.78	1.53	25.3	341.9	111.9
	500	2.27	0.92	1.81	20.4	560.8	79.8
Sawdust	100	4.76	0.56	1.32	105.1	137.9	224.6
	250	5.00	0.48	1.29	165.9	228.6	342.3
	500	5.56	0.32	1.14	305.3	386.6	513.3
Sunflower husk	100	4.76	0.48	1.20	145.6	187.5	297.0
	250	5.00	0.47	1.15	134.4	190.0	294.4
	500	5.26	0.39	0.95	288.2	330.9	443.6
Vermiculite	100	4.76	0.51	1.13	40.8	83.3	145.7
	250	5.00	0.41	1.04	38.1	100.0	126.2
	500	5.26	0.37	0.86	28.4	112.6	97.4

*Sample was impossible to filter to obtain results for crude fibre, due to the nature of the substance.

Each measure of bulk will be discussed in turn.

3.3.1.1. Crude fibre

The values used for crude fibre were determined from researched values (Williams, 1993). Crude fibre content was negatively related to the feed intake, but different diluents expressed different slopes (Figure 3.2), making a standard measurement difficult to calculate and the relationship could not be represented by one equation. The relationship between crude fibre content in the feed and feed intake was linear but this relationship was significantly different ($p<0.05$) for each diluent.

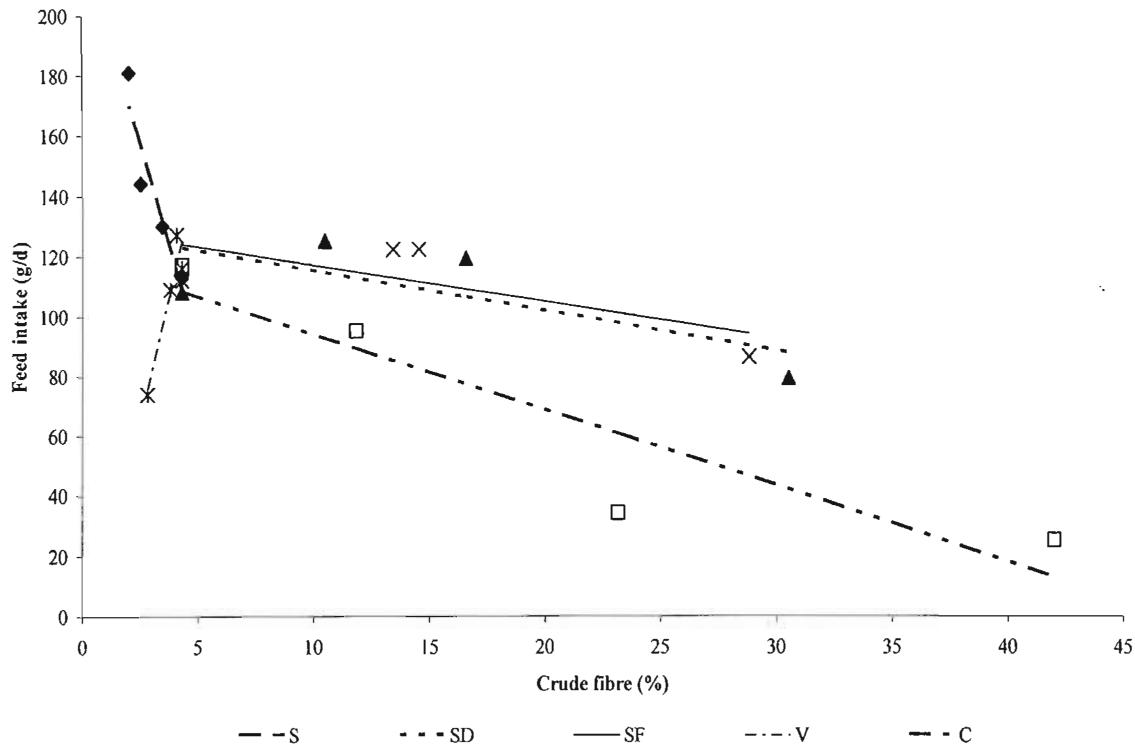

Figure 3.2: *The feed intake of hens (g/day) fed feeds varying in diluent inclusion percentage and diluent, giving feeds with a series of different crude fibre levels. The observed mean values for each level of diluent inclusion are shown as points: □=C, ♦=S, ▲=SD, ×=SF, and *=V, where C represents cellulose, S sand, SD sawdust, SF sunflower husks, and V vermiculite. SE = 15.6 and the percentage variation accounted for is 80.4% obtained over the data set.*

As the crude fibre content of the feed increased, so feed intake decreased. The rate of decrease in feed intake was not the same between diluents, suggesting that a factor other than crude fibre was directly responsible for altering the feed intake of the hen, i.e. palatability of the feed or environmental temperature. The rate of decrease in feed intake was significantly greater for the sand-diluted feeds than for the sawdust-, vermiculite- and sunflower husk-diluted feeds.

The determination of dry matter as a measure of bulk is inadequate across the complete range of feeds that exist (Kyriazakis and Emmans, 1994). Mraz *et al.* (1957) determined that the dry matter from different feeds had different filling effects in chickens. It has also been suggested that undigested dry matter may have different bulk equivalents. This was suggested after Brouns *et al.* (1991) discovered that the voluntary feed intake of sows was depressed far more by feeds based on sugar-beet pulp than by other, more indigestible materials like straw and rice bran. Brouns *et al.* (1991) concluded from this that there must be another property of feeds that could be responsible for the reduction of feed intake.

The coefficients of the regression equation are recorded in Table 3.6.

Table 3.6: *The coefficients of the linear regressions equations (of the form y = ax + c) of feed bulk on the feed intake illustrated in Figure 3.2 through 3.5*

Diluent		CF		Dry Density		Wet Density		1/WHC	
	% variance	71.7%		71%		83.3%		59.8%	
	SE	13.5		18.9		14.3		26.6	
	Coefficient	*a*[1]	*c*[1]	*a*[1]	*c*[1]	*a*[1]	*c*[1]	*a*[1]	*c*[1]
Cellulose		*	*	604	-276.8	115.6	-54.4	72.8	46.04
Sand		-26.8	224.8	604	-276.8	115.6	-54.4	72.8	41.73
Sawdust		-1.3	128.7	97	58.2	115.6	-54.4	72.8	49.52
Sunflower husk		-1.2	129.3	60	80.2	115.6	-23.4	72.8	50.16
Vermiculite		33.1	-18.1	114	51.2	115.6	-23.4	72.8	49.98

[1] Equation of the form y = ax + c

3.3.1.2. Dry density

Feed intake was directly proportional to the dry density of the feed. As the dry density of the feed increased, feed intake increased. However, the slopes of the responses differed between diluents. As with crude fibre, this again suggests that the dry density of the food is not a good measure for predicting the constraining effects of the food on feed intake, and that another measure must be acting to restrain the feed intake of the hens.

No significant difference ($p<0.05$) was found between the sand- and cellulose-diluted feeds when a simple linear regression was fitted to the data (Figure 3.3). There was a significant difference observed between the sand- and cellulose-diluted feeds and all the other treatments.

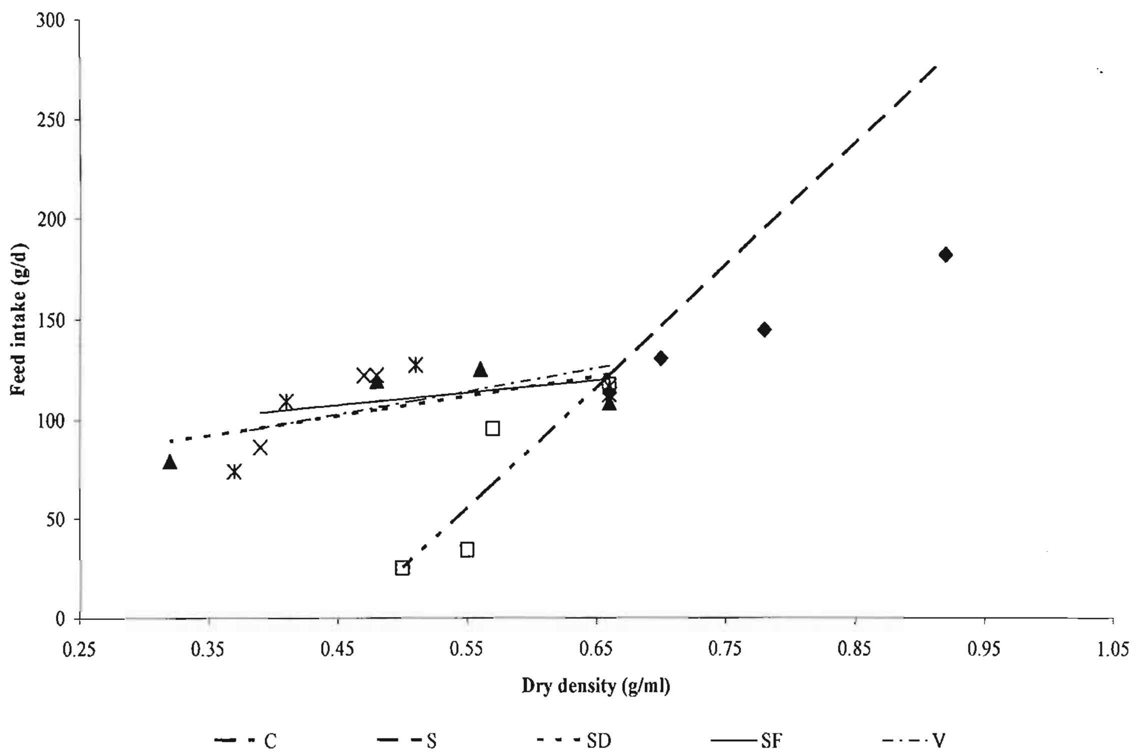

Figure 3.3: *The feed intake of hens (g/day) fed feeds varying in diluent inclusion percentage. and diluent, giving feeds with a series of different dry density levels. The observed mean values for each level of diluent inclusion are shown as points: □=C, ♦=S, ▲=SD, ×=SF, and *=V, where C represents cellulose, S sand, SD sawdust, SF sunflower husks, and V vermiculite. SE = 18.9 and the percentage variation accounted for is 71%.*

The coefficients of the regression equation are recorded in Table 3.6.

3.3.1.3. Wet density

Figure 3.4 shows the slopes of all diluents to be the same when feed intake is plotted against the wet density of the feed. The cellulose-, sand- and sawdust-diluted feeds lay on one line, while the sunflower husk- and vermiculite-diluted feeds lay on another line. There was no significant difference ($p<0.05$) in feed intake between the cellulose-, sand- or sawdust-diluted feeds. A significant difference ($p<0.05$) existed between the feeds that lay on the same line and the sunflower- and vermiculite-diluted feeds. The feed intake of the hen is directly positively related to the wet density of the feed. Feed intake was highest on the feed with the highest wet density.

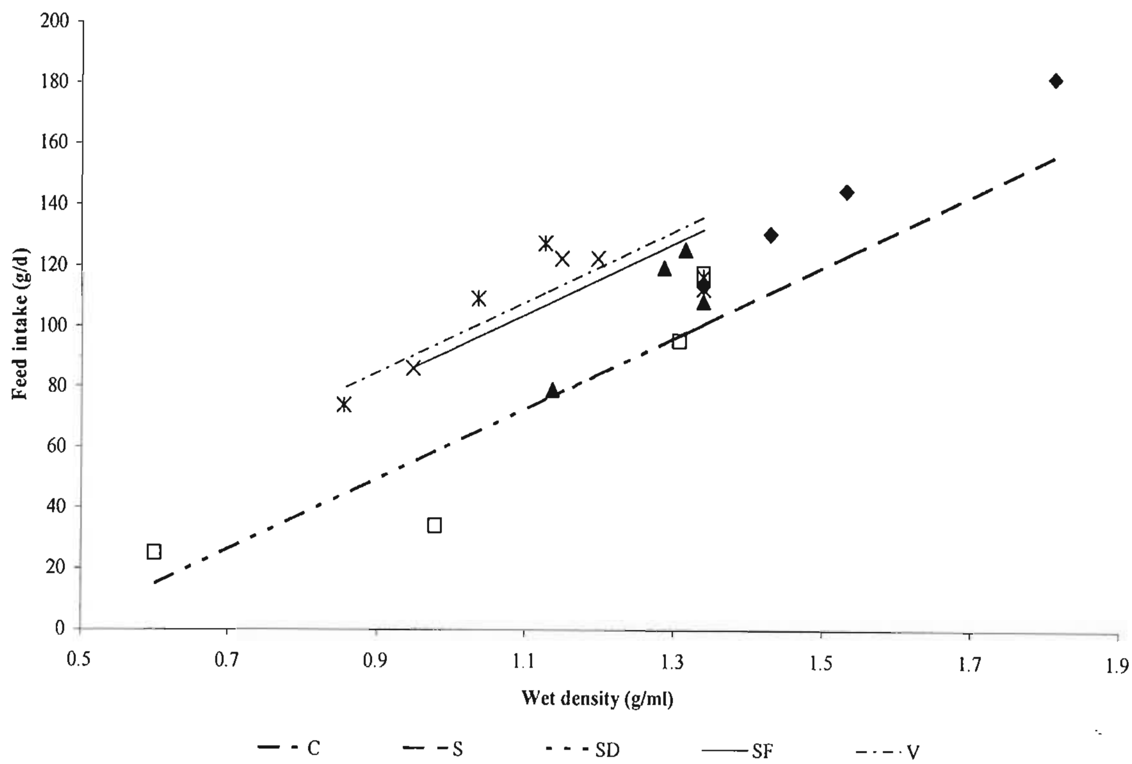

Figure 3.4: *The feed intake of hens (g/day) fed feeds varying in diluent inclusion percentage and diluent, giving feeds with a series of different wet density levels. The observed mean values for each level of diluent inclusion are shown as points: □=C, ♦=S, ▲=SD, ×=SF, and *=V, where C represents cellulose, S sand, SD sawdust, SF sunflower husks, and V vermiculite. SE = 14.3 and the percentage variation accounted for is 83.3%*

The coefficients of the regression equation are recorded in Table 3.6.

3.3.1.4. Water-holding capacity

The feed intake of the hen is positively related to the inverse of the measured water-holding capacity (WHC). Kyriazakis and Emmans (1994) found the relationship between the scaled feed intake (SFI) and the reciprocal of water-holding capacity to be linear in pigs and Figure 3.5 shows this to be true in laying hens. The feed intake was converted to scaled feed intake, by calculating the feed intake per kilogram of body weight (BW). However, the y-intercept differs between all treatments; therefore, there is a significant difference in feed intake between feeds that differ in WHC.

The separation between the lines has been illustrated in Figure 3.5, although there was no significant difference ($p<0.05$) between the scaled feed intakes of the different feeds. The separation between lines may exist because of the difference in the intakes of the basal feed, which can be attributed to the differences in the average weight of the hens in each treatment. A common line was fitted to the data (Figure 3.6) in order to predict the SFI for the entire group. The coefficients of the regression equation are recorded in Table 3.6.

The relationship between SFI and 1/WHC was linear and is shown as:

$$\text{SFI (g feed/kg BW.d)} = 46.3\ (\pm\ 12.2) + 83.5\ (\pm\ 60.8)\ x \qquad (33)$$

Equation 33 was adjusted to pass through the origin (represented in Figure 3.6 as the broken line) and gives the equation:

$$\text{SFI (g feed/kg BW.d)} = 272.4\ (\pm\ 8.91)\ x \qquad (34)$$

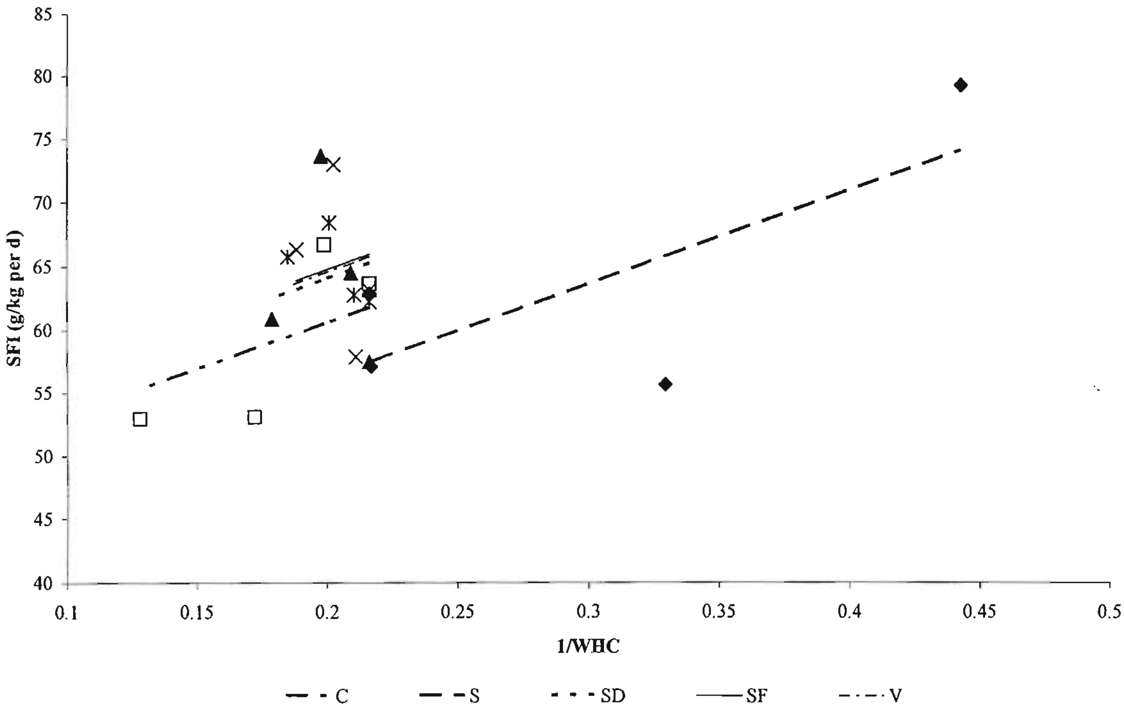

Figure 3.5: *The feed intake of hens (g/day) fed feeds varying in diluent inclusion percentage and diluent, giving feeds with a series of different inverse water-holding capacity (1/WHC) levels. The observed mean values for each level of diluent inclusion are shown as points: □=C, ♦=S, ▲=SD, ×=SF, and *=V, where C represents cellulose, S sand, SD sawdust, SF sunflower husks, and V vermiculite.*

The constant term was suppressed because, although it is the best fit, it is not significantly different from zero. This is equivalent to saying that (SFI × WHC) is constant at the value of 272 g/kg per d which can be assumed to be the limit of laying hens for WHC (Figure 3.6).

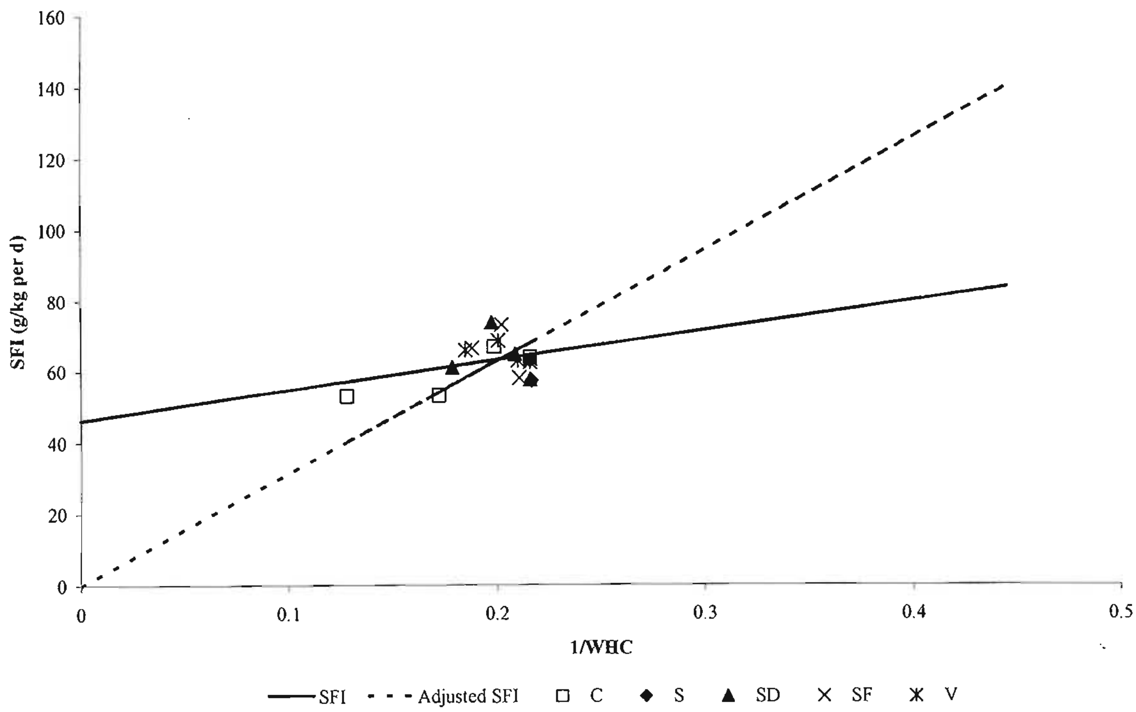

Figure 3.6: *The mean relationship between the scaled feed intake of the laying hen in g feed/kg body weight . d and 1/ WHC of the feed (g water/g dry feed), where C represents cellulose, S sand, SD sawdust, SF sunflower husks, and V vermiculite. Solid line includes a constant term (y = 46.3 (± 12.2) + 83.5 (± 60.8) x) and take account of the two outliers; the dotted line is fitted through the origin and ignores the two outliers (y = 272.4 (± 8.91)x).*

3.3.2. Feed intake

The mean feed intakes for each diluent and period are presented in Table 3.7. Feed intake was analysed according to the main effects of the Phase, diluent and level of diluent inclusion. Each of these were analysed separately and then the interactions between the Phase and diluent, diluent and level of inclusion, and then the phase and diluent and level of inclusion were analysed. Over all diluents, feed intake was significantly higher ($p<0.05$) in Phases 2 and 3 than in Phase 1. The highest mean feed intake was recorded in Phase 2.

The feed intake was highest in the sand-diluted treatments, this being significantly higher ($p<0.05$) than on the sawdust, sunflower husk and vermiculite treatments. Feed intake was lowest on the cellulose treatments. On the cellulose treatments feed intake declined rapidly from the zero to 25% inclusion rates, but then the rate of decline decreased between the 25% and the 50% cellulose inclusion rates.

Table 3.7: *The calculated mean feed intakes (g/bird.d), over all dilution levels of the mixed feeds, for the diluent×level×period, diluent×level, and diluent×period interactions of the model, with corresponding standard error (SE) values and significance shown by the letter superscripts.*

Diluent	Period	Dilution rate (g/kg)				*Period x Diluent*
		0	*100*	*250*	*500*	*(SE = 5.66)*
Cellulose	1	107.8^{c}	79.3^{b}	27.5^{c}	21.1^{c}	58.9^{b}
(SE=2.83)	2	128.3^{a}	107.9^{a}	44.5^{b}	31.3^{b}	78.0^{a}
	3	114.9^{a}	98.5^{a}	29.9^{b}	23.3^{b}	66.7^{b}
Diluent x Level (SE = 4.90)		117.0^{a}	95.2^{b}	34.0^{c}	25.2^{c}	
Sand	1	102.4^{ab}	117.0^{a}	113.7^{ab}	137.6^{a}	117.7^{c}
(SE=2.83)	2	116.5^{bc}	135.7^{b}	152.9^{b}	187.7^{a}	148.2^{b}
	3	119.8^{c}	136.9^{c}	166.7^{b}	217.2^{a}	160.1^{a}
Diluent x Level (SE = 4.90)		112.9^{d}	129.9^{c}	144.4^{b}	180.8^{a}	
Sawdust	1	96.1^{a}	107.1^{a}	104.2^{a}	78.2^{ab}	96.4^{b}
(SE=2.83)	2	108.9^{ab}	131.9^{a}	125.5^{a}	80.7^{b}	111.8^{a}
	3	119.0^{a}	135.6^{a}	126.9^{a}	79.1^{b}	115.1^{a}
Diluent x Level (SE = 4.90)		108.0^{ab}	124.9^{a}	118.9a	79.3^{b}	
Sunflower husk	1	105.9^{a}	104.2^{a}	112.6^{a}	63.4^{b}	96.5^{b}
(SE=2.83)	2	121.9^{a}	136.5^{a}	129.0^{a}	97.9^{b}	121.3^{a}
	3	108.1^{a}	124.8^{a}	122.8^{a}	95.1^{ab}	112.7^{a}
Diluent x Level (SE = 4.90)		112.0^{a}	121.8^{a}	121.5^{a}	85.5^{b}	
Vermiculite	1	113.8^{a}	110.7^{a}	91.2^{ab}	67.0^{c}	95.7^{b}
(SE=2.83)	2	115.2^{a}	134.7^{a}	116.0^{a}	74.3^{b}	110.0^{a}
	3	120.3^{a}	134.9^{a}	119.6^{a}	81.0^{b}	113.9^{a}
Diluent x Level (SE = 4.90)		116.4^{a}	126.8^{a}	108.9^{ab}	74.1^{c}	

In Figure 3.7 the trend lines showing feed intake for each diluent over the entire 9-week period are illustrated by lines of best fit. Mean feed intake was significantly higher ($p<0.05$) at the 100 g/kg inclusion levels than on the undiluted feed, except for cellulose, where intake was lower at a higher dilution. As the inclusion level increased to 250 g/kg, feed intake decreased significantly ($p<0.05$), except for sand and sunflower husks where intake continued to increase, and remained the same, respectively. The lowest mean feed intake was recorded at the 500 g/kg inclusion level for all diluents, other than sand, which had the highest intake at that rate of dilution.

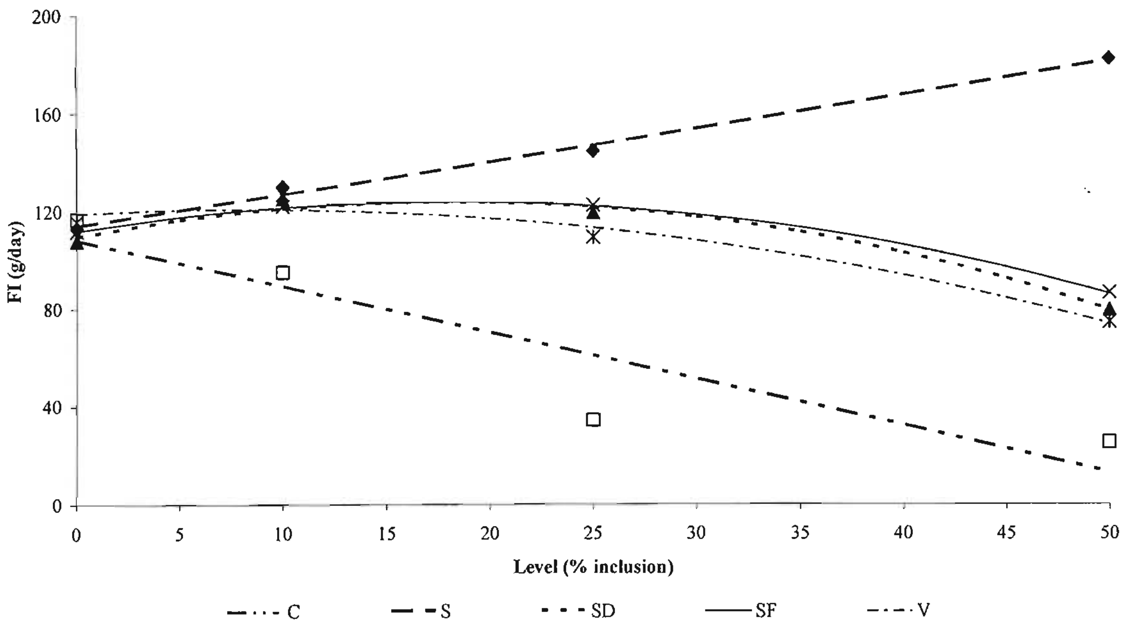

Figure 3.7: *The relationship between mean feed intake and the level of inclusion of the diluent in the feed over all three phases. The observed mean values are shown as points: □=C, ♦= S, ▲=SD, ×=SF, and *=V, where C represents cellulose, S sand, SD sawdust, SF sunflower husks, and V vermiculite.*

In Figure 3.8 the cellulose graph shows that hens increased their feed intake between Phases 1 and 2, but in Phase 3 the feed intake decreased. Hens receiving cellulose-diluted feeds in this period were previously fed sand-diluted feeds, so their gut capacity would not have increased to the same extent as those hens previously on cellulose-diluted feeds, and this is likely to be the reason for the lower intake of food by these birds. This statement is supported by the fact that the feed intake of hens fed the sand-diluted feeds increased over all three phases.

The feed intake of the hens on the sawdust-diluted feeds increased between Phases 1 and 2. In Phase 3 the hens were switched to sunflower husk-diluted feeds and intake increased during this phase. The opposite occurred for the hens fed sunflower husk-diluted feeds, where feed intake increased between Phases 1 and 2, but then feed intake decreased when they were switched onto sawdust-diluted feeds.

Feed intake on the vermiculite-diluted feeds increased over all phases, but the increase in feed intake was greater between Phases 1 and 2 than between 2 and 3. This can be attributed to the fact that between Phases 1 and 2 the hens were swapped between 100 g/kg and 500 g/kg diluted feeds. The hens that moved onto the 100 g/kg diluted feeds from the 500 g/kg diluted feeds were able to consume more of the feed than the hens previously on the 500 g/kg diluted feeds, due to a small amount of bulk capacity adaptation, and may have compensated better than the previous group for the lower nutrient density of the previous feed.

The general trend of feed intake of the cellulose, sawdust, sunflower and vermiculite diluted feeds was a decrease in the voluntary feed intake of the hen as the dilution level increased from the 25% inclusion level. This could indicate that the feed intake of the hens was restricted by these feeds from this level of dilution. The sawdust, sunflower and vermiculite treatments showed an initial increase in the feed intake of the hens between the basal feed and the 10% diluted feed, perhaps indicating that the hen was increasing feed consumption to sustain nutrient intake, however the feed intake then decreased over the 25% and 50% dilution levels.

When statistically analysed the intake of the sand- and vermiculite-diluted feeds was linearly related to the level of the diluent in the feed while, with the other diluents, feed intake was quadratically related to the feed intake and the level of dilution of the feed (Table 3.8 and Figure 3.8). This could indicate that the other diluents did not restrict feed intake, or completely restricted the feed intake leading to a linear or quadratic increase or decrease in feed intake over all levels of inclusion.

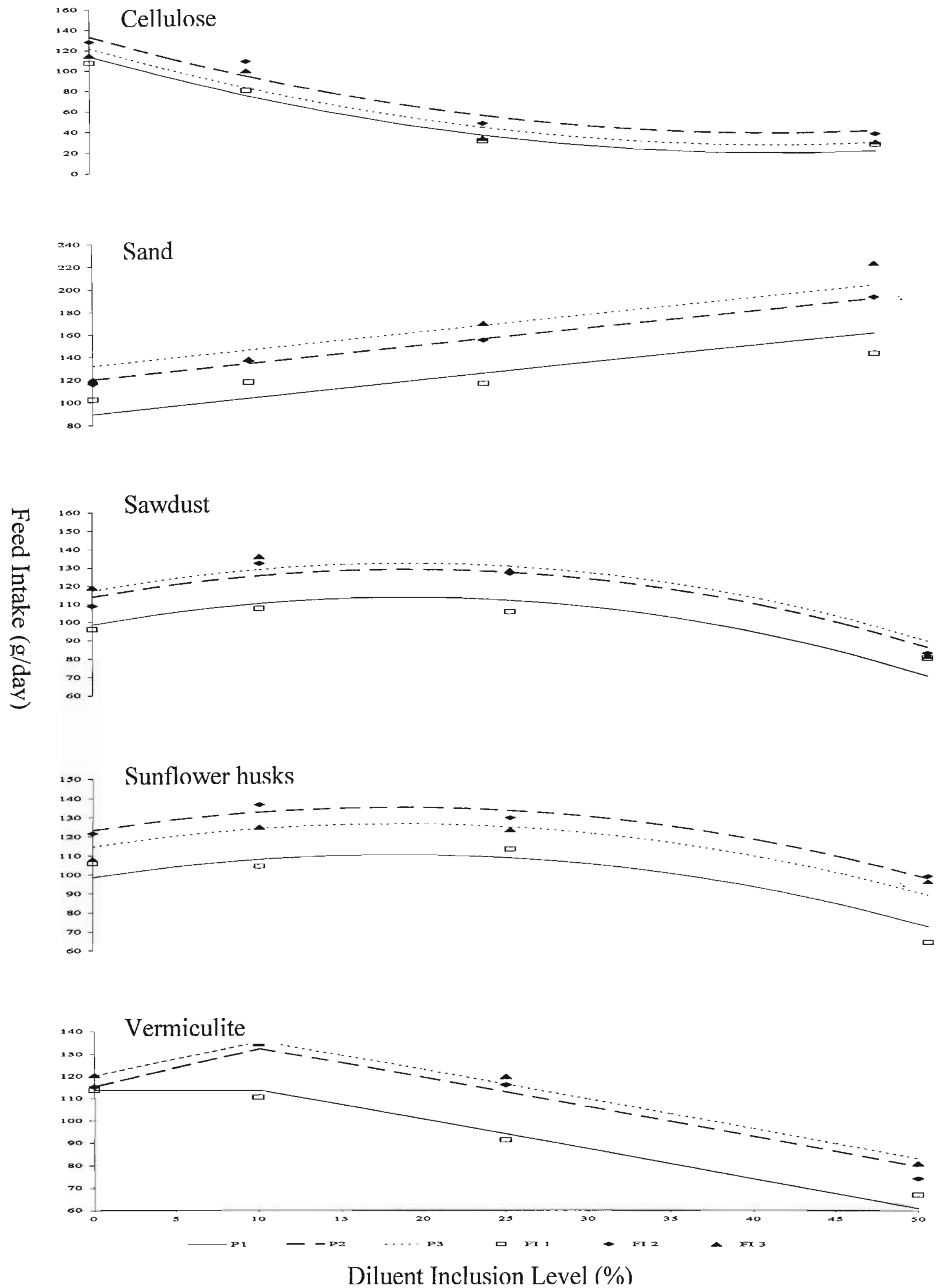

Figure 3.8: *Mean feed intake for each diluent in each of the three phases and at the four rates of dilution of the feed (%) for each individual diluent. P1 represents Phase 1, P2 Phase2, P3 Phase 3, FI1 feed intake in Phase 1, FI2 feed intake in Phase 2, and FI3 feed intake in Phase 3.*

Table 3.8 shows the coefficients for the regression equations for the graphs in Figure 3.8. The form of the regression equation is $y = ax + bx^2 + c$. Where, y is the feed intake and x is the level of diluent included in the feed.

Table 3.8: *The coefficients of the components of the regression equations represented in Figure 3.8*

Diluent	Period	SE	a	b	c
Cellulose	1	3.58	-4.5	0.05	113.92
	2	3.79	-4.5	0.05	133.10
	3	3.76	-4.5	0.05	121.52
Sand	1	6.62	1.326	0	89.52
	2	7.85	1.326	0	120.03
	3	7.85	1.326	0	131.95
Sawdust	1	4.83	1.56	-0.04	98.51
	2	5.07	1.56	-0.04	113.90
	3	5.07	1.56	-0.04	117.26
Sunflower husk	1	5.02	1.30	-0.04	98.46
	2	5.27	1.30	-0.04	123.30
	3	5.27	1.30	-0.04	114.65
Vermiculite	1	4.63	-1.32	0	127.13
	2	5.48	-1.32	0	145.85
	3	5.48	-1.32	0	149.35

3.3.3. Egg weight

The mean egg weights recorded for Trial 1 are represented in Table 3.9. Mean egg weight was significantly higher ($p<0.05$) in Phases 1 and 2 than in Phase 3, which had the lowest mean egg weight.

The highest mean egg weights were recorded on the sunflower husk treatments. Significantly lower ($p<0.05$) mean egg weights compared to all other diluents were recorded on the cellulose treatments.

Table 3.9: *The mean egg weights (g/bird.d), over all dilution levels of the mixed feeds, for the diluent×level×period, diluent×level, and diluent×period interactions of the model, with corresponding standard error (SE) values and significance shown by the letter superscripts.*

Diluent	Period	Dilution Rate (g/kg)				*Period x Diluent*
		0	*100*	*250*	*500*	*(SE=3.36)*
Cellulose	1	60.87^{a}	43.67^{b}	19.72^{c}	15.40^{c}	34.91^{b}
(SE = 1.68)	2	53.81a	27.01^{b}	34.37b	30.68^{b}	36.47^{b}
	3	47.73^{a}	43.67^{a}	51.33^{a}	44.80^{a}	46.88^{a}
Diluent x Level (SE=2.92)		54.14^{a}	38.12^{b}	35.14^{b}	30.29^{bc}	
Sand	1	59.97^{a}	56.76^{a}	22.45^{b}	19.56^{b}	39.68^{b}
(SE = 1.68)	2	59.13^{a}	54.00^{a}	61.66^{a}	58.55^{a}	58.33^{a}
	3	58.10^{a}	13.62^{c}	11.72^{c}	36.77^{b}	30.05^{c}
Diluent x Level (SE=2.92)		59.06^{a}	41.46^{b}	31.94^{bc}	38.29^{b}	
Sawdust	1	57.83^{a}	55.92^{a}	58.60^{a}	23.26^{b}	48.90^{a}
(SE = 1.68)	2	46.02^{a}	45.71^{a}	46.02^{a}	28.33^{b}	41.52^{ab}
	3	54.11^{a}	46.51^{a}	51.16^{a}	33.40^{b}	46.30^{a}
Diluent x Level (SE=2.92)		52.66^{a}	49.38^{a}	51.93^{a}	28.33^{b}	
Sunflower husk	1	55.50^{a}	50.86^{a}	59.81^{a}	26.53^{b}	48.17^{a}
(SE = 1.68)	2	59.19^{a}	28.49^{b}	55.04^{a}	55.02^{a}	49.44^{a}
	3	54.97^{a}	21.96^{b}	57.91^{a}	27.25^{b}	40.52^{b}
Diluent x Level (SE=2.92)		56.55^{a}	33.77^{b}	57.58^{a}	36.27^{b}	
Vermiculite	1	58.71^{a}	59.05^{a}	55.55^{a}	21.01^{b}	48.58a
(SE = 1.68)	2	44.90^{a}	35.04^{ab}	48.34^{a}	27.08^{ab}	38.84^{b}
	3	60.35^{a}	31.19^{b}	47.92^{a}	26.84^{b}	41.57^{b}
Diluent x Level (SE=2.92)		54.65^{a}	41.76^{b}	50.60^{a}	24.98^{c}	

The highest mean egg weight was recorded for the 0 g/kg treatments. The lowest mean egg weight was recorded for the 500 g/kg treatments. The 100 g/kg treatments had a significantly lower ($p<0.05$) mean egg weight than the 250 g/kg treatments. This is presented in Figure 3.9. Production relates to feed intake, and feed intake was higher with the hens consuming the 100g/kg treatment, therefore some other factor is influencing the fact that the egg weight was higher in the 250g/kg treatment, perhaps environmental factors or fat deposits.

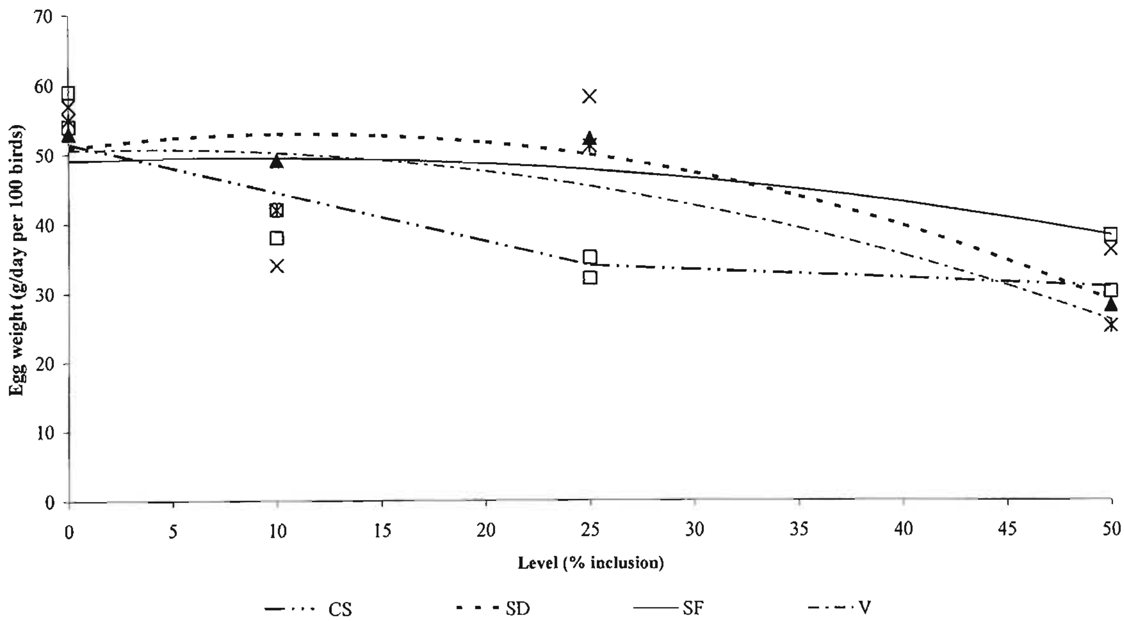

Figure 3.9: *The relationship between egg weight and the level of inclusion of diluent in the feed. The observed values are shown as points: □=CS, ▲=SD, ×=SF, and *=V, where CS represents cellulose and sand, SD sawdust, SF sunflower husks, and V vermiculite.*

3.3.4. Rate of lay

The mean rate of lay recorded for Trial 1 is represented in Table 3.10. The rate of lay was significantly higher ($p<0.05$) in Phase 3 than in Phases 1 and 2, which had the same mean rate of lay.

The sawdust treatments had the highest rate of lay, followed by the sand, sunflower husk, vermiculite and cellulose treatments respectively. The sawdust and sand treatments produced a significantly higher ($p<0.05$) rate of lay when compared to the sunflower husk and vermiculite treatments. The cellulose treatments rates of lay were significantly lower than the sunflower husk and vermiculite treatments ($p<0.05$).

Table 3.10: *The calculated mean rate of lay per 100 birds per day, over all dilution levels of the mixed feeds, for the diluent×level×period, diluent×level, and diluent×period interactions of the model, with corresponding standard error (SE) values and significance shown by the letter superscripts.*

Diluent	Period	Dilution Rate (g/kg)				Period x Diluent
		0	*100*	*250*	*500*	*(SE=3.98)*
Cellulose *(SE=1.99)*	1	75.60^{a}	55.95^{b}	17.26^{c}	14.88^{c}	40.92^{b}
	2	86.31^{a}	8.93^{b}	1.19^{b}	8.93^{b}	26.34^{c}
	3	84.52^{a}	87.50^{a}	85.71^{a}	76.79^{a}	83.63^{a}
Diluent x Level (SE=3.45)		82.14^{a}	50.79^{b}	34.72^{c}	33.53^{c}	
Sand *(SE=1.99)*	1	85.71^{a}	67.86^{b}	20.84^{c}	20.84^{c}	48.81^{b}
	2	80.95^{a}	66.67^{ab}	77.38^{a}	84.52^{a}	77.38^{a}
	3	79.76^{a}	25.00^{c}	17.26^{c}	49.41^{b}	42.86^{c}
Diluent x Level (SE=3.45)		82.14^{a}	53.17^{b}	38.49^{c}	51.59^{b}	
Sawdust *(SE=1.99)*	1	68.45^{a}	77.38^{a}	67.26^{a}	22.03^{b}	58.78^{a}
	2	72.02^{a}	48.81^{b}	65.48^{a}	22.62c	52.23^{ab}
	3	89.88^{a}	37.50^{c}	84.52^{a}	52.98^{b}	66.22^{a}
Diluent x Level (SE=3.45)		76.79^{a}	54.56^{b}	72.42^{a}	32.54^{c}	
Sunflower husk *(SE=1.99)*	1	75.00^{a}	60.12^{a}	69.05^{a}	20.24^{b}	56.10^{a}
	2	81.55^{a}	26.79^{c}	68.45^{b}	72.03^{a}	62.20^{a}
	3	70.83^{a}	30.95^{b}	61.31^{a}	21.43^{b}	46.13^{b}
Diluent x Level (SE=3.45)		75.79^{a}	39.29^{c}	66.27^{b}	37.90^{c}	
Vermiculite *(SE=1.99)*	1	80.95^{a}	79.17^{a}	65.48^{ab}	21.43^{b}	61.76^{a}
	2	75.00^{a}	38.10^{c}	58.33^{b}	21.43^{d}	48.21^{b}
	3	82.14^{a}	37.50^{b}	49.40^{b}	20.83^{c}	47.47^{b}
Diluent x Level (SE=3.45)		79.36a	51.59^{b}	57.74^{b}	21.23^{c}	

The highest rate of lay was recorded at the 0 g/kg level of diluent inclusion. The 250 g/kg level of inclusion had a significantly higher ($p<0.05$) rate of lay than the 100 g/kg inclusion level. Again, as with egg weight, production relates to feed intake, but here another factor must be influencing the rate of lay, other than feed intake. The lowest rate of lay was recorded for the 500 g/kg inclusion level. This is presented in Figure 3.10.

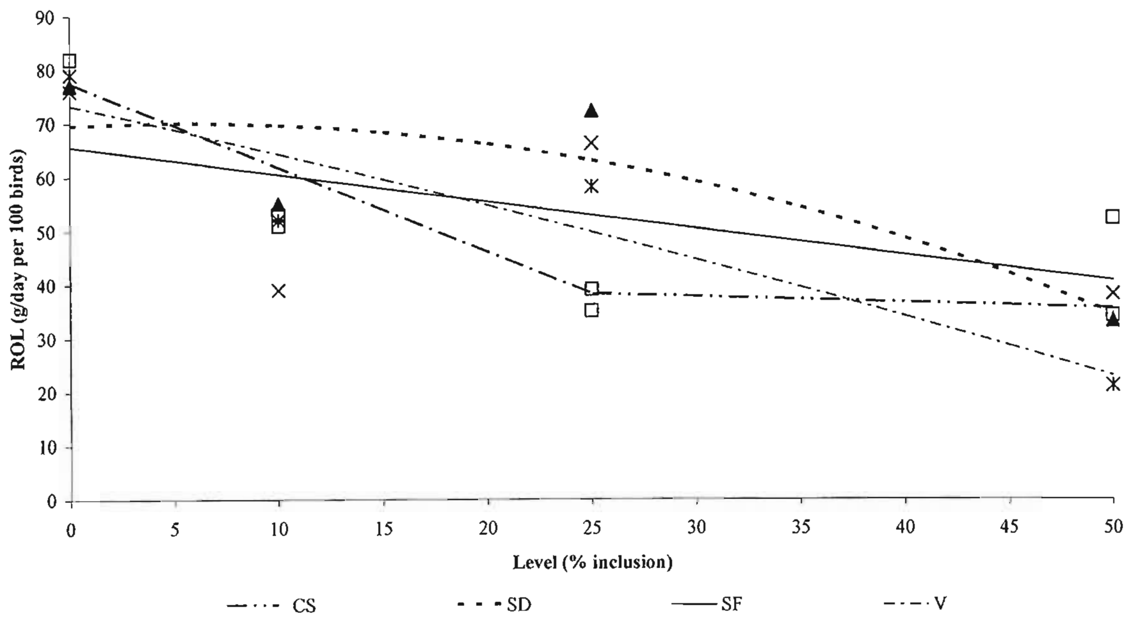

Figure 3.10: *A graphic representation of the effect of the level of inclusion of the diluent on mean rate of lay of the hen. The observed values are shown as points: □=C and S, ▲=SD, ×=SF, and *=V, where C represents cellulose, S sand, SD sawdust, SF sunflower husks, and V vermiculite.*

3.4. CONCLUSION

The objective of this trial was to determine the effect of feed bulk on the voluntary feed intake of the laying hen, so as to determine a suitable measure of feed bulk that would assist in determining the constraining effect of the feed on voluntary intake. Of the bulk characteristics measured on each of the feeds neither the fibre content (CF) nor did the density (dry and wet) expressed a suitable relationship for the prediction of the upper limit of voluntary feed intake and the formation of a single equation. However, the water-holding capacity of the feeds appeared to describe the effect of bulkiness on the voluntary feed intake (Section 3.3.1.4), as scaled feed intake declined linearly as the WHC of the feed increased (Figure 3.11) across dilution levels and diluents.

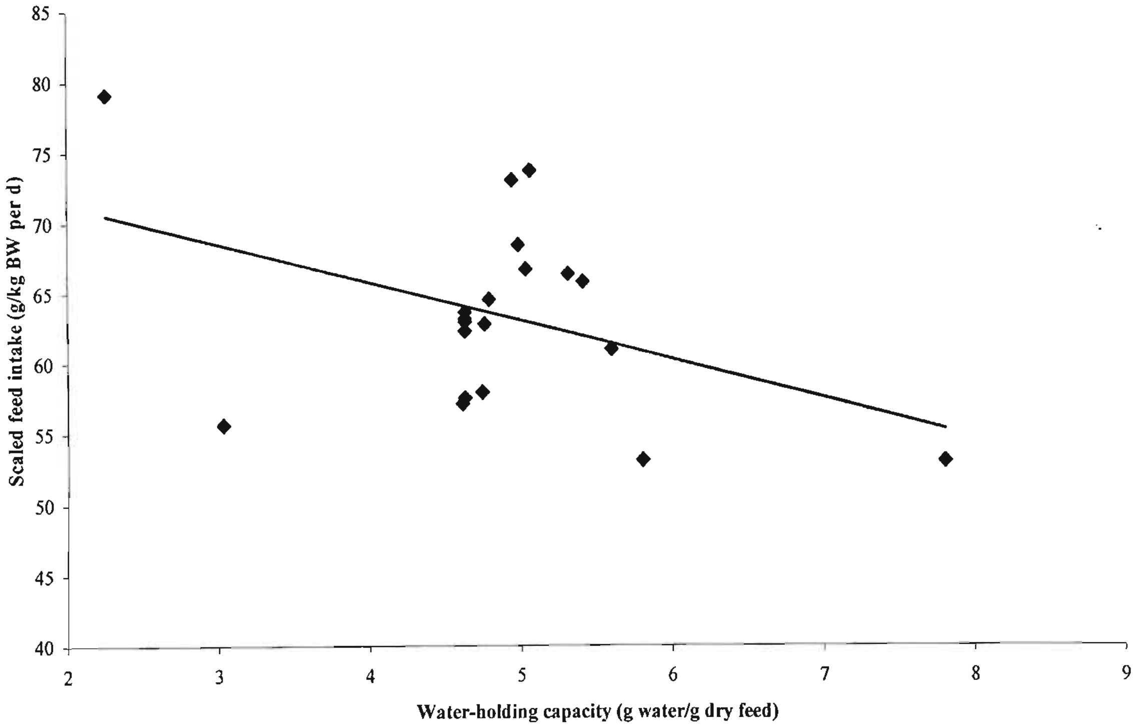

Figure 3.11: *The scaled feed intake (SFI; g/kg live weight per d) on each of the experimental feeds vs. their water-holding capacity determined by centrifugation (WHC; g water/g dry feed). The line shown is that for SFI (g/kg per d) = 272.4 x*

The effect of the WHC of the feed on the feed intake of the hen can be seen when the hens were switched between diluents between Phases 2 and 3. The most noticeable change was that observed in Table 3.7, when the hens on the cellulose-diluted feeds were switched onto sand-diluted feeds and the feed intake of the hens increased significantly (*P<0.05*). This is shown in the change in the feed intake between Phase 2 and 3. The opposite was true for the hens that were changed from a sand-diluted feed to a cellulose-diluted feed. In this case, the hens that had a mean feed intake of 114 g/bird d of hens on the 250 g/kg sand feed in Phase 1 dropped to 45 g/bird d on 250 g/kg cellulose feed in Phase 3. The failing of the design were that there was no allowance for the possibility for carry-over effects that may have occurred when the hens were switched between diets. Whether a carry-over effect has occurred can be deduced by looking at individual hens SFI for each week of a phase and comparing that to her intake in the other phases. Comparing week for week for each individual hen will determine if there were some effects of the previous treatment on the present intake. The other method of increasing the accuracy of the analysis of the collected FI data would be to use the mean FI, for each diluent, of the previous phase as a covariate in the analysis of the data from the next phase. This would also decrease the effect of the carry-over effects.

The body weight data was collected essentially to monitor the welfare of the hens, but could be used to determine a more accurate measure of SFI by using the lean body mass to scale the feed intake, thereby removing the variable of energy deposits and their use for egg production. If this was done the use of the egg data could be used more effectively to show where the FI constrained egg production.

The effect of WHC could also be seen with the change from the sunflower husk- to sawdust-diluted feeds. Sawdust has a higher WHC than sunflower husk, which explains the significant decrease ($P<0.05$) in voluntary feed intake when hens were changed onto sawdust-diluted feeds from sunflower husk-diluted feeds. The opposite reaction was observed when hens were changed onto sunflower husk-diluted feeds from sawdust-diluted feeds and the voluntary feed intake increased significantly ($P<0.05$).

If no constraints existed, the desired feed intake of the hens could be calculated the following way. The basal feed was formulated according to a daily feed intake of 110 g. If this feed were diluted at a rate of 100 g/kg the hen would have to increase her feed intake by 10% to sustain her required level of production. The calculated feed intakes are represented in Table 3.11.

Table 3.11: *The desired feed intake of the basal feed used and scaled feed intakes of hens weighing 1.8kg when offered feeds diluted to the levels used in the trial*

	Dilution rate (g/kg)			
	0	100	250	500
Desired feed intake (g/bird d)	110	121	138	165
Scaled feed intake (g/kg BW per d for a 1.8kg hen)	59	64	73	88

Hens on the cellulose treatments (Table 3.7) did not consume the desired amount of feed (Table 3.11) at any of the dilution levels; i.e. their intake was constrained even by the lowest dilution of cellulose.

Feed intakes by hens on the sand-diluted treatments increased sufficiently to achieve the desired feed intake at each dilution, although production decreased, as illustrated in Figure 3.9 and Figure 3.10. This decrease in egg production could be due to the decreased intakes in Phase 1 and the changing of the feeds every three weeks. The interval between changing the treatments may have been too short, one week, to allow complete adaptation to the feed which would explain the decrease in egg production even though the nutrient intake was sufficient to maintain the original level of production.

Hens managed to compensate and consume sufficient feed on the sawdust-diluted feeds up to the 100 g/kg level of inclusion in Phases 2 and 3. Feed intakes in Phase 1 were below the desired levels. Feed intakes of hens on feeds diluted at the levels of 250 and 500 g/kg were below the desired intakes and were not sufficient to consume sufficient nutrients to maintain the desired level of production. The same pattern occurred for the sunflower husks and vermiculite treatments.

The feed intakes by hens on all treatments in Phase 1 were lower than the predicted feed intake of 110g/bird.d. This hampered the hens from the beginning of the trial and may be the reason why the egg production decreased, even though some hens managed to compensate for the shortfall in nutrients in the diluted feeds in later phases. The hens would have had to use their body reserves in Phase 1 to maintain production which is evident in the decrease in body weights after the first three weeks. This reflects the importance of an adaptation period when changing feeds. The hens used in the trial did receive a week adaptation period to the basal feed before the start of the trial and intakes during this week were satisfactory and did not decrease.

The measurement of the WHC of feed fulfils the experimental objective of identifying an accurate measure of the bulkiness to predict the voluntary feed intake in the laying hen. The actual feed intake is the lower of the constrained and desired feed intakes. The desired feed intake may be calculated from knowledge of the nutrient requirements of the hen and the nutrient content of the feed offered; the first-limiting nutrient in the feed dictating the constraining effect of the feed on intake appears to be 1/WHC. However, it was felt that insufficient data were available from this trial to derive an equation that could be relied upon to describe this constraining effect. A second trial was, therefore, conducted using different diluents, in an attempt to gather further information that might be used when predicting the constraining effect of a feed on voluntary feed intake.

The effect that the feed bulk had on the laying hens may be more accurately and more convincingly proved if the statistical design of the trial is revisited. More adaptation periods are required to completely eliminate the possibility of carry-over effects between phases, and perhaps it would be easier and better to look at each phase of this trial separately. If done correctly this method would be a more accurate assessment of the effect of bulk on the feed intake of laying hens, and this would be supported by two other phases of experimentation. By running each phase for an experimental period of 4 weeks, followed with a period of 2 weeks between the end and the start of the next experimental phase when the hen is fed the basal feed. The hen would then start the next phase, which could be referred to as a completely different trial. The first week of feeding the experimental feed would be the adaptation period, and measurements would be taken from the following 3 weeks. Trial 1 was originally designed as it was because of time and space constraints. The hen's that were supplied were already past their peak and egg production was starting to decline so it was important that the trial happened in a time space that minimised the effect of this decrease on the collected data.

CHAPTER 4

THE EXTENT TO WHICH LAYING HENS ADAPT TO HIGH BULK FEEDS

4.1. INTRODUCTION

A change to a feed of higher bulk content will initially cause a hen to increase her feed intake to compensate for the nutrient shortfall in a diluted feed. Intake may then gradually increase if the hen adapts to the bulkiness of the diet or, if the feed is too 'bulky', the hen may not have the capacity to increase her intake sufficiently and therefore her intake will decrease. This adaptation will continue until an equilibrium intake, appropriate to the feed, is reached. The adaptation may be as a result of dealing better with the direct effect of the bulk, or by an increasing ability of the hen to process the nutrients in the bulky feed (Whittemore *et al.,* 2003). On a constraining feed the equilibrium level of intake will be less than the desired level of feed intake, which is that required for the genetic potential to be achieved (Kyriazakis and Emmans, 1999). In the first trial the inclusion of the diluents was at too high a level, causing most of the diets to be constraining on feed intake. Trial 2 was designed with lower inclusion rate and different diluents to determine the effect on the FI of the hens, and increase the investigation of the effect of WHC on FI.

Jorgenson *et al.* (1996) undertook a study to determine if the development of the digestive tract of broilers, from 12 days of age, was affected by the amount of fibre in the diet. The effect of the higher dietary crude fibre levels was evident through the increases in size of the digestive tract, particularly the length and weight of the small intestine and caecum. These findings supported those of Kondra *et al.* (1974). Summers and Leeson (1986) found that Leghorn's gut size increased when higher levels of crude fibre were fed, particularly the length of the intestine and the weight of the gizzard.

The objectives of this trial were to collect additional data that would assist in defining the physical characteristics of the feed that best describe the bulkiness of the feed, and to determine the extent to which, and the rate at which the laying hen can adapt to feeds that have a high bulk and/or low density. This should lead to a more accurate definition of the capacity of the laying hen for feed bulk such that it would be possible to predict, by means of a feed intake model, at what stage the hen would no longer be capable of adapting to a high bulk feed and, therefore, no longer be able to consume sufficient of the feed to meet her requirements for her potential performance. This required different levels of inclusion of diluents to be examined, as well as diluents that provided different bulk properties, so that the results from the two trials can be combined to give a final conclusion.

4.2. MATERIALS AND METHODS

4.2.1. Facilities

The birds were housed individually in wire floored laying cages, arranged in two tiers, in an open-sided laying house with adequate ventilation. Each cage was equipped with a nipple drinker located at the rear of the cage and an individual feed trough at the front. The lighting program consisted of 16 hours of light and 8 hours of dark.

4.2.2. Animal description

Two hundred laying hens were randomly allocated to the laying cages. The hens selected were the Hy-line Variety Silver. They were hatched on the 4th of September 2003 and were transferred to group pens in the adjacent laying house on the 8th of January 2004. At the commencement of the trial, the hens were 32 weeks old. The hens were offered the formulated basal feed for one week after being moved into the individual cages, before the test treatments were offered.

4.2.3. Basal feed and diluents used

A basal feed was formulated using the WinFeed feed formulation programme (© EFG Software). The raw material composition of the basal feed is given in Table 4.1. The nutrient specifications used in formulating the basal feed were based on an expected feed intake of 100 g/d, thereby ensuring a nutrient-dense feed. The ME of the feed was 11.5

MJ/kg and the amino acid composition was based on the optimum amino acid intakes for a 1.9 kg hen with a mean egg output of 56 g per bird day.

Table 4.1: *The formulated composition of the basal feed used throughout Trial 2, and fed to Hy-line Variety Silver birds.*

Ingredient	*Inclusion (g/kg)*
Maize	530.0
Wheat bran	57.9
Soybean (Full-fat)	248.0
Sunflower (37.0g/kg protein)	50.0
L-lysine HCl	0.10
DL methionine	1.70
Vitamin premix	1.50
Limestone	95.4
Salt	3.30
Monocalcium phosphate	9.50
Sodium bicarbonate	2.50
Analysis of basal feed	*Calculated (g/kg)*
Protein (g N × 6.25 kg)	170.1
ME (MJ/kg)	11.50
Lysine	8.30
Calcium	35.00
Phosphorus	3.50

The basal feed was diluted with one of five diluents. The diluents were included at four levels, resulting in twenty dietary treatments in total. The diluents used were river sand, potter's clay, sawdust, unexpanded polystyrene[2] and wheat bran. The diluents were changed from that of Trial 1 to use a range of different diluents with different bulk properties. The treatments were supplemented with synthetic amino acids and minerals to maintain similar calculated ratios as in the basal food. The inclusion rates of the diluents into the basal feed were 0, 50, 100 and 150 g/kg.

[2] Polystyrene supplier: Isolite Polystyrene Manufacturers, Pinetown, KwaZulu-Natal

4.2.4. Design

The trial ran for a total of seven weeks. During the first week, the hens were fed the basal feed to adapt to the change in feed. The twenty treatments were then randomly assigned to individual hens, using a random number generator, for the remaining six weeks of the trial.

Feed was available to the hens *ad libitum.* The feed was weighed into the self-feeding trough at the start of the week, and the amount remaining at the end of the week was weighed in order to measure feed intake. Feed was weighed in on a Monday and the orts were weighed out the following Monday. At the end of the six-week feeding period, three hens were randomly selected from each treatment group and slaughtered. The hens were eviscerated and the gut contents examined. The weights of the de-feathered carcass and the entire gastrointestinal tract (GIT) were determined. The gizzard, small intestine, caecum and colon were weighed while still containing digesta and again after cleaning. The fat pad was removed and weighed. The lengths of the small intestine, caecum and colon were measured.

4.2.5. Feed and diluent analysis

The feeds were analysed with the same methods used in the first trial (Chapter 3) and all analyses were done in duplicate. The methods used to analyse the feeds were:

- Water-displacement method,
- Dry-density method,
- Centrifugation to determine the water-holding capacity.

These are described in detail in Chapter 3. The feeds were also analysed for CF, ADF and NDF. All the fibre analysis was done by the Nutrient Analysis Laboratory, Discipline of Animal and Poultry Science, University of KwaZulu-Natal. Crude fibre (CF) and acid detergent fibre (ADF) were analysed on a Dosi-Fibre machine using the AOAC Official Method 920.39 and AOAC Official Method 973.18, respectively. Neutral netergent fibre (NDF) was analyzed on a Dosi-Fibre machine according to the method described by Van Soest *et al.* (1991).

4.2.6. Measurements

The weekly feed intake, daily rate of lay, egg weight on three days each week and body weights of the hen at the start, and after each three-week period were recorded. From these measurements, the change in body weight of the hen could be determined. Those hens whose body weight had dropped below 1000 g were removed from the trial. On the day of slaughter, the feed was removed from the hens in the morning. The hens were then tagged for carcass identification. The hens were rendered unconscious by stunning before exsanguination. The carcasses were bled out before evisceration. The carcasses were eviscerated and the components examined.

4.3. RESULTS AND DISCUSSION

4.3.1. Physical and chemical properties of dietary treatments

Measurements were made of crude fibre (CF), acid detergent fibre (ADF) and neutral detergent fibre (NDF) as well as the mean water-holding capacity (WHC) and dry and wet densities of each feed and the diluents used. These values for each of the feeds used are presented in Table 4.3, and for the diluents, in Table 4.2.

Table 4.2: *The bulk measurements of the individual, unmixed diluents used.*

Diluent	WHC (g water/g dry feed)	Dry density (g/ml)	Wet density (g/ml)	CF (g/kg)	ADF (g/kg)	NDF (g/kg)
Basal feed	3.80	0.744	1.39	39.7	49.4	118.4
Wheat bran	9.43	0.318	1.05	112.2	139.6	428.5
Potters clay	1.33	0.748	2.39	0	0	0
Unexpanded polystyrene	2.87	0.668	0.96	0	0	0
River Sand	1.29	1.403	2.55	0	0	0
Sawdust	8.07	0.212	0.93	689.0	768.7	874.5

Table 4.3: *Mean water-holding capacity (WHC) (g water/g dry feed), dry and wet density (g/ml), crude fibre (CF), acid detergent fibre (ADF) and neutral detergent fibre (NDF) (g/kg) of the mixed feeds.*

Diluent	Level (g/kg)	WHC (g water/g dry feed)	Dry density (g/ml)	Wet density (g/ml)	CF (g/kg)	ADF (g/kg)	NDF (g/kg)
Wheat bran	50	4.00	0.67	1.37	4.27	5.93	13.22
	100	4.17	0.67	1.36	4.39	6.32	14.17
	150	3.85	0.59	1.34	4.64	7.03	16.84
Potters clay	50	3.57	0.70	1.49	3.77	4.69	11.25
	100	3.70	0.67	1.49	3.57	4.46	10.66
	150	3.33	0.72	1.39	3.37	4.20	10.06
Unexpanded polystyrene	50	4.00	0.67	1.39	3.77	4.69	11.25
	100	4.00	0.71	1.31	3.57	4.46	10.66
	150	3.45	0.72	1.29	3.37	4.20	10.06
River sand	50	2.94	0.73	1.34	3.77	4.69	11.25
	100	4.17	0.73	1.45	3.57	4.46	10.66
	150	3.33	0.78	1.49	3.37	4.20	10.06
Sawdust	50	4.76	0.60	1.35	7.12	9.27	15.34
	100	4.76	0.51	1.30	9.62	12.87	20.22
	150	4.76	0.49	1.28	14.37	16.09	23.39

Each measure of bulk will be discussed in turn.

4.3.1.1. Crude fibre

Three of the diluents used in this trial had no crude fibre (CF) content, so it is unlikely that this measure of feed bulk could be used to predict when a feed would become too bulky for the bird to be able to meet its desired feed intake. As the CF contents of bran and sawdust are higher than that of the basal feed, the CF contents of the feeds diluted with these two diluents would have increased with each increment of the diluent. However, the relationship between the crude fibre content and feed intake (Figure 4.1) indicates that this chemical measure of bulk bears little relationship with feed intake, and is therefore not a worthwhile predictor of the bulkiness of the feed.

As the crude fibre content of the feed increased, so feed intake increased. The rate of increase in feed intake was not the same between diluents, suggesting that a factor other than CF was directly responsible for altering the feed intake of the hen.

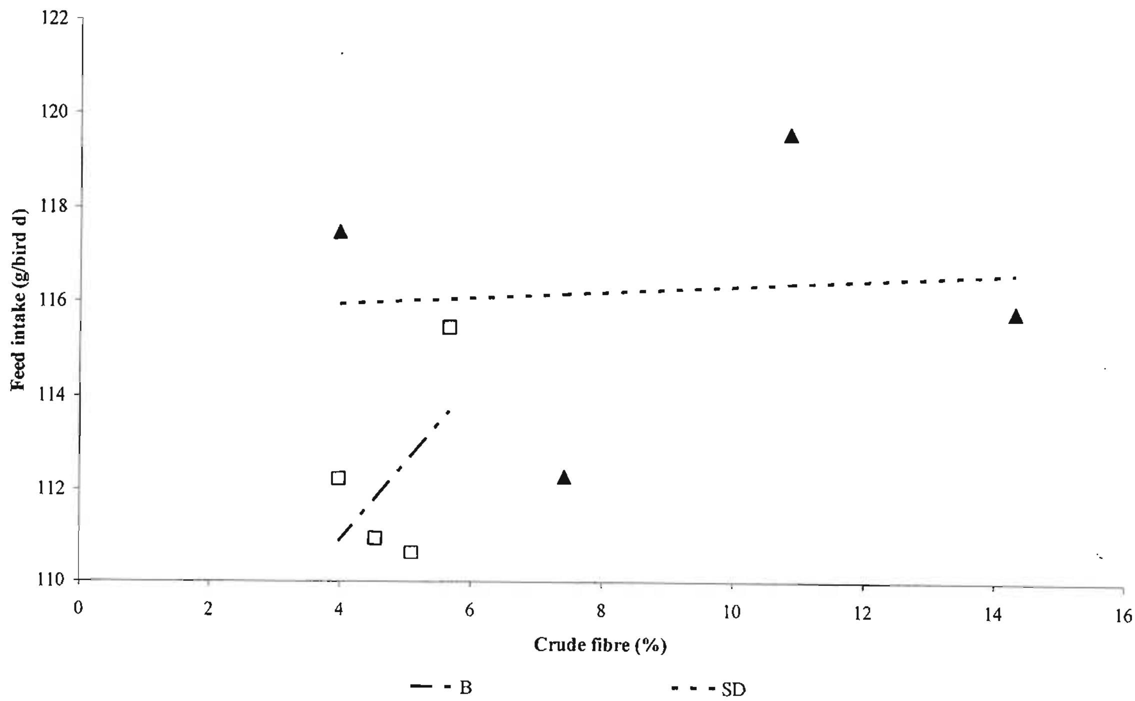

Figure 4.1: *The relationship between the fibre content of the feed and the feed intake in g/bird d. The observed values are shown as points: □=B, and ▲=SD. Where B and SD refer to wheat bran and sawdust respectively. SE = 6.15.*

4.3.1.2. Dry density

As the dry density of the feed increased, feed intake decreased for bran, clay and unexpanded polystyrene treatments, but increased for the sand and remained the same for sawdust (Figure 4.2). The sand was denser than all the other diluents which may explain why the intake increased and palatability may have played a role. As with crude fibre, this again suggests that the dry density of the food is not a good measure for predicting the constraining effects of the food on feed intake as there seems to be no explanatory pattern.

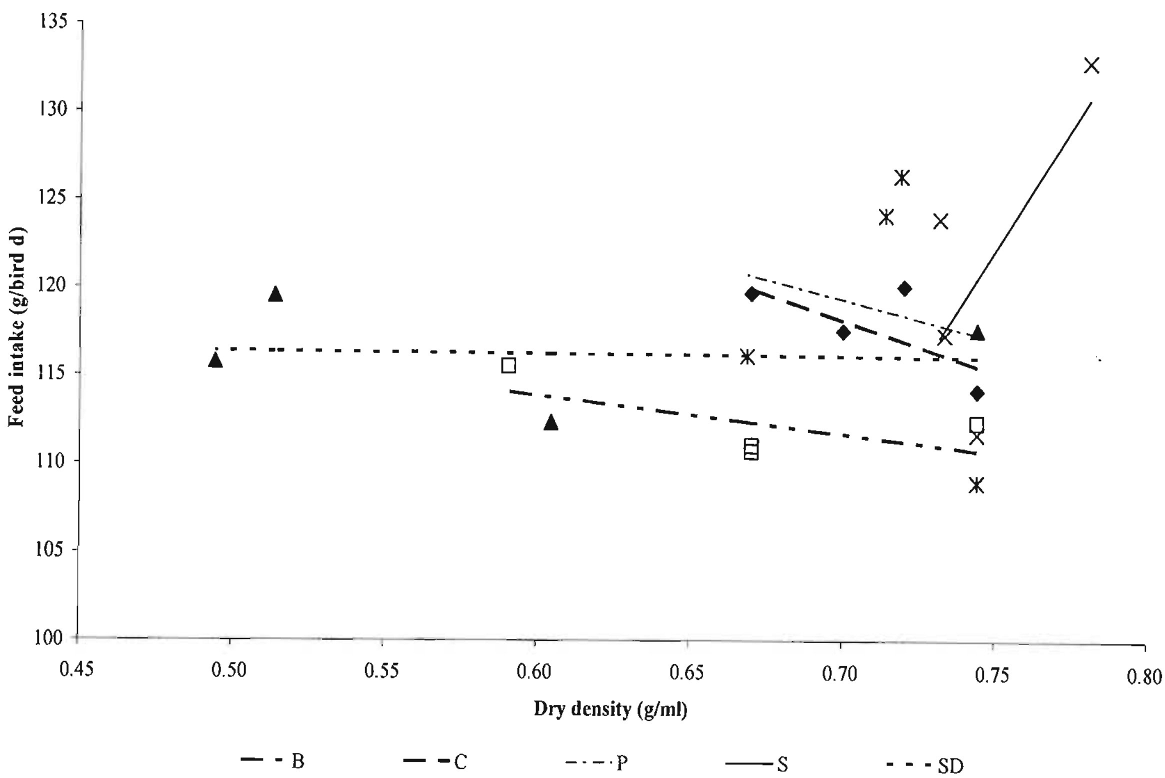

Figure 4.2: *The relationship between the dry density of a feed and feed intake in g/bird d. The observed values are shown as points: □=B, ♦=C, ▲=SD, ×=S and *=P, where B, C, SD, S and P refer to wheat bran, potter's clay, sawdust, river sand and unexpanded polystyrene, respectively. SE = 5.97.*

A significant difference ($p<0.05$) was observed between the dry density of the bran-diluted diets and the rest of the diluents.

4.3.2.3. Wet density

Figure 4.3 illustrates that no relationship exists between the wet density of the feed and the feed intake in Trial 2. In Trial 1 the relationship was distinctly positive, i.e. as the wet density of the feed increased, so the intake of the feed increased. Once again there was no significant difference ($p<0.05$) between the feed intakes of the different diluents. This indicates that the wet density of the feed had little effect on the feed intake of the hens at the diluent level of inclusion in Trial 2.

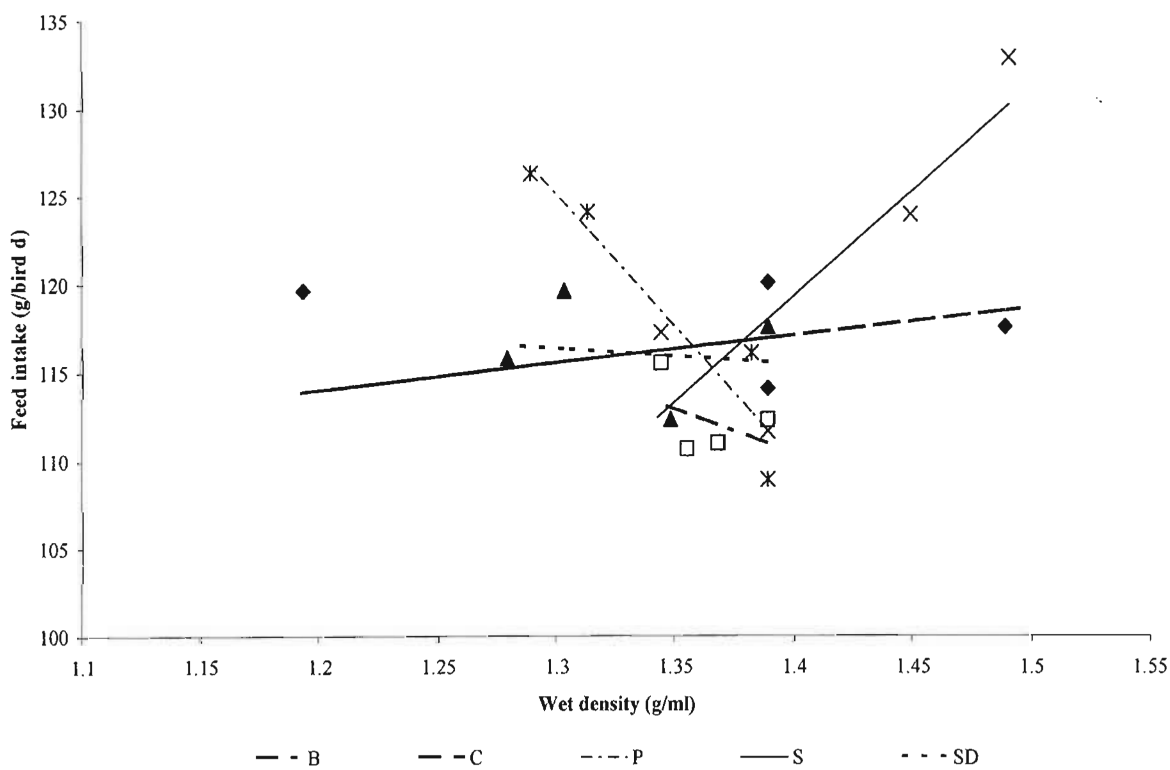

Figure 4.3: *The relationship between the wet density of the feed and feed intake in g/bird d. The observed values are shown as points: □=B, ♦=C, ▲=SD, ×=S and *=P, where B, C, SD, S and P refer to wheat bran, potter's clay, sawdust, river sand and unexpanded polystyrene, respectively.*

4.3.1.4. Water-holding capacity

In the previous chapter, it was found that the scaled feed intake of the hen is positively related to the inverse of the measured water-holding capacity (WHC). Kyriazakis and Emmans (1994) found the relationship between the scaled feed intake and the reciprocal of water-holding capacity to be linear in pigs and, in Trial 1, Figure 3.5 shows this to be true in laying hens. The y-intercept differs between all treatments, but the regression analysis showed that no significant difference ($p<0.05$) in feed intake existed between diluents (Figure 3.5).

In Figure 4.4 the separation between lines exists because of the difference in the intakes of the basal feed, which can be attributed to the differences in the average weight of the hens in each treatment. Another improvement of data analyses, as mentioned earlier, may be to include the hen's lean mass as a covariate, which may then show a better adaptation pattern to the treatments and decrease the separation between the lines.

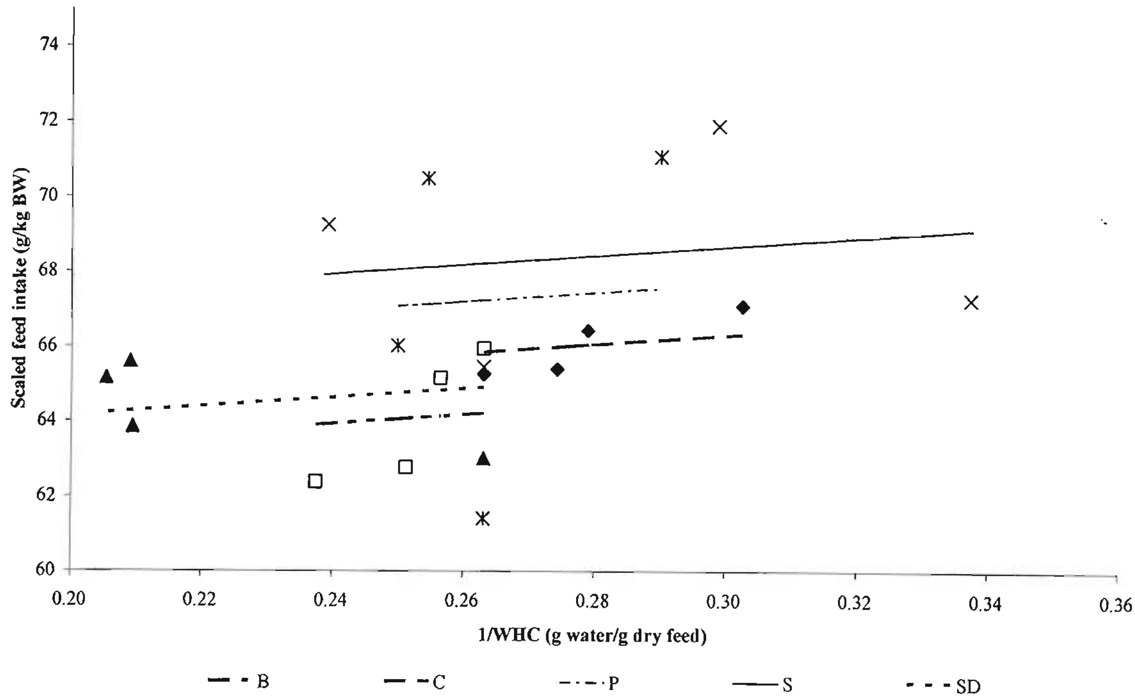

Figure 4.4: *A graphic representation of the relationship between 1/WHC of the feed and the scaled feed intake in g/bird d. The observed values are shown as points: □=B, ♦=C, ▲=SD, ×=S and *=P, where B, C, SD, S and P refer to wheat bran, potter's clay, sawdust, river sand and unexpanded polystyrene, respectively.*

4.3.2. Feed intake

The mean feed intake (g/bird d) on each of the dietary treatments is presented in Table 4.4 in g/bird d. Feed intake increased for all diluents and levels from the average feed intake. The relationship between feed intake and the level of inclusion of diluent in the feed was linear in all cases and the coefficients of the regressions are shown in Table 4.5.

Table 4.4: *The mean feed intakes in g/bird d for each treatment over the six week period, showing the SE values, the main effects of the diluent and level, the interaction between diluent and level of inclusion, and comparing the mean recorded feed intakes with the calculated desired feed intakes*

Diluent	Dilution rate (g/kg)				Main effect-
(SE = 4.17)	0	50	100	150	diluent (SE=2.08)
Wheat bran	112.2^{ab}	111.0^{a}	110.6^{a}	115.4^{b}	112.3^{a}
Potter's clay	114.0^{a}	117.4^{ab}	119.6^{b}	119.9^{b}	117.7^{b}
Unexpanded polystyrene	108.9^{a}	116.0^{b}	124.0^{c}	126.2^{c}	118.8^{bc}
River sand	111.6^{a}	117.2^{b}	123.8^{c}	132.6^{d}	121.3^{c}
Sawdust	117.5^{b}	112.3^{a}	119.5^{b}	115.8^{ab}	116.3^{b}
Main effect-level (SE=1.86)	112.8^{a}	114.8^{b}	119.5^{c}	122.0^{d}	
Calculated DFI	*113.0*	*118.0*	*124.0*	*130.0*	

Table 4.5: *The coefficient of the regression equations, of the form y = a + bx where x is the level of diluent in the feed, showing the relationship between the level of diluent in the feed and the feed intake of the laying hen.*

Diluent	a (SE = 2.19)	b (SE = 0.234)
Wheat bran	0.19	110.9
Potter's clay	0.40	114.7
Unexpanded polystyrene	1.19	109.9
River sand	1.39	110.8
Sawdust	0.04	115.9

Table 4.4 shows that when comparing the feed intake of birds on the various feeding treatments with those calculated as the desired feed intake (DFI) only those hens given feed diluted with river sand were able to consume sufficient of the feed to meet their nutrient requirements at all inclusion rates of the diluent. Hens given feeds diluted with

potter's clay and polystyrene were able to consume sufficient of the feed at a dilution rate of 50 g/kg but, at 100 g/kg the feed diluted with potters clay became constraining and desired feed intake was not achieved (Table 4.4). However, in only one treatment (sawdust at a dilution of 150 g/kg) was egg output significantly reduced, i.e. feed intake was sufficient in all other cases to sustain egg output over the six-week period and intake continue to increase as the level of dilution increased (Figure 4.5). Mean egg output for each of the dietary treatments is recorded in Table 4.6.

Table 4.6: *The calculated mean egg output (g/100 birds) for hens over the total six week period, not including the data from the adaptation week. Means with different superscripts differ significantly (P<0.05).*

Diluent	Dilution rate (g/kg)				Mean
	0	50	100	150	
Wheat bran	57.50	56.78	55.08	58.24	56.85
Potter's clay	57.36	59.15	54.84	58.32	57.44
Unexpanded polystyrene	57.13	57.97	57.43	59.26	57.99
River sand	56.64	60.56	57.42	59.17	58.46
Sawdust	58.64[a]	57.83[a]	58.56[a]	51.64[b]	56.64
Mean	57.53	58.44	26.69	57.28	

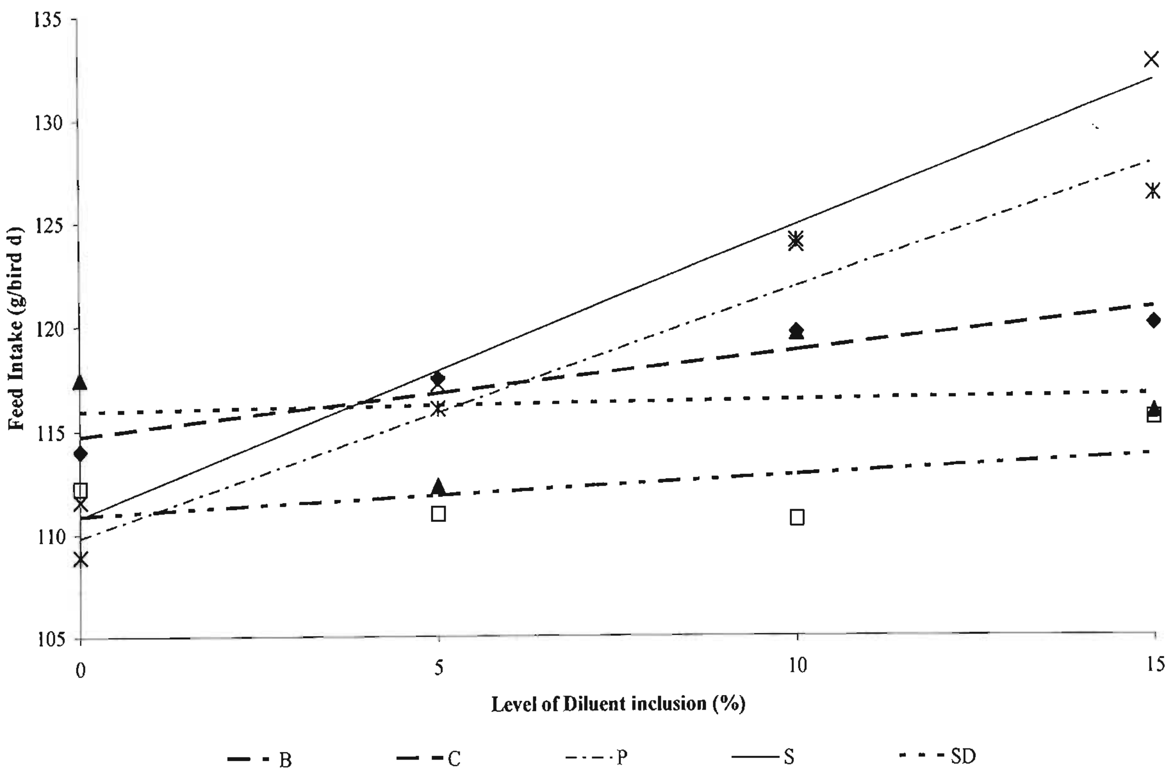

Figure 4.5: *The linear regression relationship between feed intake (g/bird.d) and the rate of inclusion (%) of the diluent in the feed, where B, C, P, S and SD refer to the wheat bran, potter's clay, unexpanded polystyrene, river sand and sawdust treatments, respectively. The calculated means are represented as* ▲ = *wheat bran,* ▲ = *sawdust,* ♦ = *potter's clay,* × = *river sand, and* * = *unexpanded polystyrene*

The egg output (EO) of the hens was calculated from the rate of lay (ROL) and the egg weight (EW); EO = ROL × EW. Table 4.6 reports the EO in g/100 birds. No significant difference was shown between the EW and the ROL for all diluents and levels of inclusion, except the 150g/kg sawdust-diluted diet, which had a significantly lower egg weight (SE = 0.949) and rate of lay (SE = 1.142) than the lower inclusion levels. The egg weight and rate of lay was not analysed because of the lack of effect of the treatments on both parameters. The recorded data is available in the Appendix.

Feed intake was recorded weekly and is represented graphically for each of the treatments in Figure 4.6. Mean feed intake over all diluents increased substantially during the second week of the trial, i.e. immediately after the diluted feeds were introduced. Feed intake then decreased for the following three weeks and then increased once more. This suggests that the hens did not become acclimatised to the bulky feeds, which would have been evident had the intakes increased steadily throughout the six-week period. The hen's intake should have increased rapidly to compensate for the dilution of nutrients, but the rate of intake would slow as the hen's capacity for intake increased to adapt to the 'bulkier' feed. The hens should have also increased their overall intake of feed. This may have been observed had the trial run for longer (Kyriazakis and Emmans, 1994).

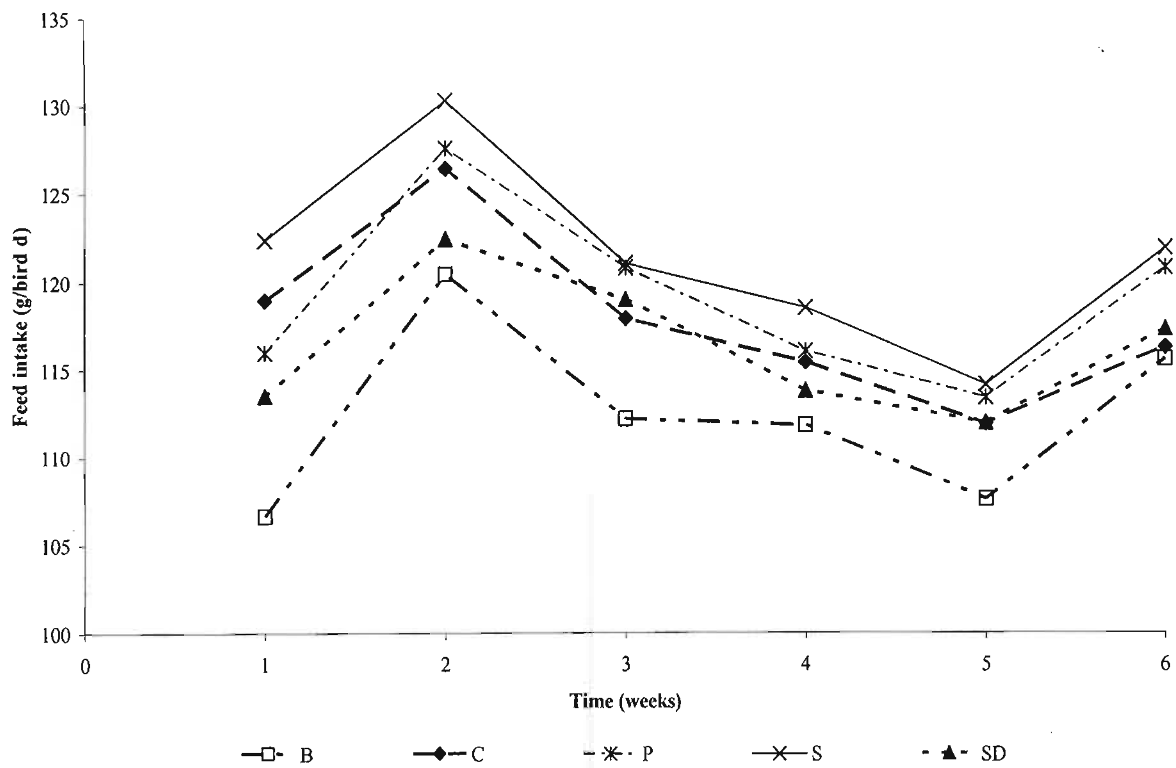

Figure 4.6: *Relationship between feed intake in g/bird d and time in weeks in Trial 2. The calculated means are represented as* □ *= wheat bran,* ▲ *= sawdust,* ♦ *= potter's clay,* × *= river sand, and* * *= unexpanded polystyrene*

Egg production was not decreased significantly by the dietary treatments; therefore, the data collected in this trial cannot be used to determine the maximum gut capacity of the hens, except in the case of the sawdust at 150 g/kg dilution where egg production was constrained. Feed intake increased for all diluents and levels from the average feed intake of 101.7 g/bird d in the adaptation week. The levels of inclusion were dropped from those used in Chapter 3 to determine the point at which the intake would stop increasing and either even out or decrease.

It is now evident that the inclusion levels of the diluents in this trial were not sufficient to constrain the feed intake other than the sawdust-diluted feed at an inclusion rate of 150 g/kg. The feeds in Trial 1 did constrain feed intake and the equation derived would, therefore, predict the constrained feed intake. This line was added to Figure 4.4. Feed intake is predicted to be constrained above this line as can be seen from Figure 4.4 and very few of the observations made in this trial lie above the line y = 46.3 + 83.5x.

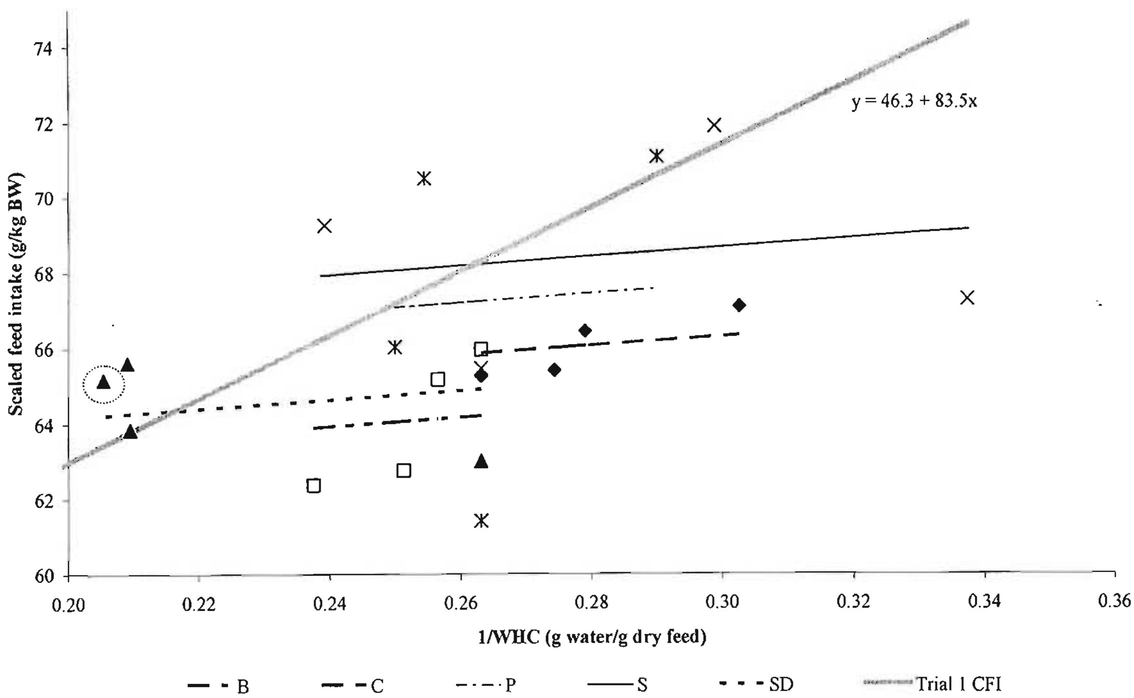

Figure 4.7: *A graphic representation of the relationship between 1/WHC of a feed and the scaled feed intake in g/bird.d. The observed values are shown as points: □=B, ♦=C, ▲=SD, ×=S and *=P, where B, C, SD, S and P refer to wheat bran, potter's clay, sawdust, river sand and unexpanded polystyrene, respectively. The feint line represents the equation y = 46.3 + 83.5x.*

4.4. PROCESSING OF BIRDS

The weights of the gastric content of the different portions of the gastrointestinal tract (GIT) are given in Table 4.7, and the empty weights of the same components of the gastro intestinal tract are given in Table 4.8. The GIT was removed and weighed full (Table 4.7). It was then divided and cut into the different components and weighed, the contents weight was calculated by difference of the empty and full weights of the components (Table 4.7). The contents were then removed and the components washed and then weighed again (Table 4.8).

Table 4.7: *Table showing the mean weight (g) of material contained in the entire gastrointestinal tract (GIT), and the distribution of the contents throughout the different components of the GIT.*

		Full weight (g)	Weight of contents (g)			
Diluent	*Level (g)*	*GIT*	*Gizzard*	*Small intestine*	*Colon*	*Caecum*
Basal		155.8	13.9	30.4	5.1	7.6
Wheat bran	50	159.3	15.1	35.2	2.1	7.1
	100	164.0	9.3	48.6	2.3	11.4
	150	152.0	12.8	38.4	2.5	5.9
Potter's clay	50	148.4	12.4	36.6	3.7	5.7
	100	143.5	11.6	33.7	2.4	8.4
	150	177.8	17.5	40.8	1.6	8.6
Unexpanded polystyrene	50	135.6	10.2	27.3	2.3	8.0
	100	144.7	13.9	28.1	1.0	7.3
	150	132.2	10.2	31.2	0.9	4.6
River sand	50	143.9	24.6	29.6	2.0	5.7
	100	150.2	23.0	25.3	2.1	8.9
	150	152.4	36.8	37.1	1.0	7.4
Sawdust	50	150.1	28.7	29.8	5.2	7.2
	100	157.1	22.0	33.0	2.2	7.6
	150	141.3	13.7	26.2	2.2	5.7

The weights of the gizzard and small intestine contents of the river sand-diluted feeds were significantly higher than all the other feeds, but the weights of the colon and caecum contents were similar to the other feeds. The gut contents of the 150 g/kg sawdust-diluted feed were the lowest of all the observations, and the observations of the sawdust-diluted feeds decreased from the 50 g/kg level to the 150 g/kg level for all observations. The type of diluent had an effect on the weight of the contents of the gastrointestinal tract. The sand, sawdust, bran and clay-diluted feeds all had heavier gastrointestinal tracts, and contents, than the polystyrene-diluted feeds, but this could be due to the weight of the digesta within the full tract and the size of the birds.

Table 4.8: *Table of means of empty weights measured in g and lengths measured in cm of the components of the digestive tract*

Diluent	Level	Empty Weights (g)				Lengths (cm)		
		Gizzard	*Small intestine*	*Colon*	*Caecum*	*Small intestine*	*Colon*	*Caecum*
Basal		41.6	41.9	4.2	11.2	158.0	8.7	35.3
Wheat bran	5	40.0	41.0	3.2	10.1	164.0	8.7	40.3
	10	40.4	35.9	4.0	12.0	152.7	8.7	34.7
	15	41.0	37.6	3.4	10.5	153.3	7.7	37.0
Potter's clay	5	37.5	40.5	2.9	8.9	156.0	7.5	35.7
	10	32.4	38.2	4.1	7.3	141.7	8.2	35.3
	15	38.1	38.1	2.8	11.0	149.3	7.7	34.3
Unexpanded polystyrene	5	35.9	39.1	3.6	9.2	149.3	8.7	39.3
	10	43.0	37.6	4.2	9.6	148.0	9.3	36.7
	15	38.3	33.9	3.3	9.3	152.7	8.2	32.3
River sand	5	37.7	40.5	4.1	9.2	143.3	7.8	32.7
	10	41.6	39.3	4.6	10.1	146.7	8.7	36.3
	15	37.3	37.0	3.2	11.9	155.3	7.0	37.0
Sawdust	5	40.6	39.5	4.7	9.4	153.3	10.0	38.3
	10	41.6	41.4	3.1	9.4	146.7	7.8	38.0
	15	43.0	36.0	4.9	9.7	142.7	9.0	35.0

Statistical analysis of the processing data showed no significant effects of the feed on the changes to the GIT and was not investigated further. Feed bulk had no effect on the empty weights or the lengths of the components of the gastrointestinal tract. There was no change caused by the feed on these components. This could be because the feeds were not very limiting on the voluntary feed intake of the hens. Had the same process been exercised in Trial 1 a different pattern may have resulted, due to the higher inclusion rate of the diluents. The diluent inclusion rates in Trials 1 were more limiting on the feed intake than the diluent inclusion levels used in Trial 2. These results do not agree with the results reported by Kyriazakis and Emmans (1994), who found that, in pigs, the progressive increase of wheat-bran in the feed resulted in a significant *($P<0.05$)* increase in the weights of the stomach and large intestine, but a significant decrease *($P<0.05$)* in the weight of the small intestine. This discrepancy could be due to the effect that the gizzard has on the digesta, which is not present in the pig. The grinding of the feed could cause this discrepancy, allowing for a faster flow rate of the digesta.

4.5. CONCLUSIONS

The feed intakes in this trial increased as the level of the diluent in the feed increased, but there was no significant decrease in production, other than in one case, meaning that the hens consumed sufficient nutrients to maintain their level of production except where the food was diluted with 150 g sawdust/kg feed (circled in Figure 4.4).

When the feed intake during the trial was compared over time in weeks no significant adaptation to the feeds was evident because the feeds were not constraining. In fact, feed intake decreased after the initial rise, possibly due to high temperatures experienced at that time. However, temperature was not recorded.

As with the first trial, the crude fibre, dry density and wet density proved to be poor measures for the prediction feed intake, bearing no relation to the amount of feed consumed by the hens. The water-holding capacity of the feeds, however, appeared to afford some measure of predictability in that the equation derived in Trial 1 to predict constrained feed intake, demonstrated that few of the feeds in Trial 2 would have constrained feed intake.

It is clear that the water-holding capacity of the feed is not an infallible means of determining when the bulkiness of a feed will be such that the desired feed intake cannot be achieved, but it does appear to give a reasonable estimate of the constraining effect of a feed. In order to test the accuracy of the estimated equation (Equation 34) derived in the previous chapter, data from the two trials conducted here, and from a previous trial at this University (Williams, 1993) could profitably be combined. This will be done in the following chapter of this thesis.

CHAPTER 5

GENERAL DISCUSSION AND CONCLUSIONS

5.1. SUMMARY

The aim of this study was to determine a suitable method of measuring and predicting feed bulk, such that this could be used to predict when a laying hen would be unable to consume sufficient of a given feed to meet her nutrient requirements. Two trials were conducted using a number of diluents, with each being included over a range of concentrations, and voluntary feed intake of hens housed individually was measured. In both trials, it was concluded that the water holding capacity of the feed was the best measure of feed bulk for the desired purpose.

In the first trial, five diluents were used, namely, cellulose, plasterer' sand, sunflower husks, sawdust and vermiculite, and these were included at 100, 250 and 500 g/kg into a commercial layer feed which was used as the basal feed. The trial was divided into three phases of 21 days each. After each phase, either the diluent fed was changed or the inclusion level of the diluent was changed. It was observed that as the water-holding capacity of the feed increased, so the feed intake decreased. At the greatest dilution of the basal feed, there was a substantial reduction in voluntary feed intake. Intakes on the intermediate foods were greater than those on the basal foods. The constraining effect of feed bulk was expressed as decreased production by the hens. A significant difference in feed intake was observed when the diluents fed to the hen were changed. The scaled feed intake of the hens was fitted to the reciprocal of the water-holding capacity (WHC) to give a linear relationship represented by:

$$SFI\ (g/kg\ BW) = 46.3\ (\pm\ 12.2) + 83.5\ (\pm\ 60.8)\ .1/WHC \qquad (33)$$

This regression was the best fit, representing the maximum amount of feed that the laying hen could consume when the constraint is measured as the reciprocal of WHC. However, Tsaras *et al.* (1998) have argued that such a regression should pass through the origin (no constant term), so a second regression line was fitted to the data, this time with no constant term, and the relationship in this case was;

$$\text{SFI (g/kg BW)} = 272.4\ (\pm\ 8.9)\ .\ 1/\text{WHC} \qquad (34)$$

The equivalent regression coefficient obtained by Tsaras *et al.* (1998), for pigs, was 234.6, this value being lower than the above coefficient obtained with laying hens. Of prime importance when fitting such a regression to the data is to exclude any points where the feed intake is patently not constraining, so of all the treatments applied in the first trial, only those with a WHC value greater than 4 g water/g dry feed appeared to constrain feed intake, as measured by a reduced rate of egg output. If only these data points are included in the regression analysis above the equation becomes:

$$\text{SFI (g/kg BW)} = 313.6\ (\pm\ 8.9)\ .\ 1/\text{WHC} \qquad (36)$$

The objective of the second trial was to identify physical characteristics of the feed that best describe the bulkiness of the feed, and to determine the extent to which, and the rate at which, the laying hen can adapt to feeds that are high in bulk. Once again five diluents were used, namely, wheat bran, potter's clay, unexpanded polystyrene, river sand and sawdust, but in this trial the dilution rates were lower than the first trial, being 50, 100 and 150 g/kg. The trial was not divided into phases and the hens were fed the same feed for six weeks. The voluntary feed intake of the hens in Trial 2 was sufficient on all but one treatment to maintain production, the exception being the treatment in which 150 g of sawdust was used per kg feed. The equation derived from Trial 1 (Equation 36) was fitted to the data from Trial 2 and the trend showed few of the treatments to be constraining.

Feeds shown to be constraining from Trials 1 and 2, along with data from Williams (1993), were combined, and the results of this are shown in Figure 5.1, to obtain a more accurate assessment of the relationship between scaled feed intake and 1/WHC than could be obtained from just one trial. Although the best fitting regression through these data includes a constant term the intercept was not significantly different from zero, so the regression of the SFI on 1/WHC was recalculated with the intercept suppressed. The line is represented by the equation:

$$\text{SFI (g/kg BW)} = 301.4 \,.\, 1/\text{WHC} \qquad (37)$$

This regression represents the upper limit to feed intake when a hen is offered a bulky feed. As an example, if a 2 kg hen were offered a feed with a water-holding capacity of 6.667 (1/WHC = 0.15) her intake on that feed would be 90 g/d (= 2 × 45g/kg BW).

Standard commercial feeds have a water-holding capacity of around 4 g water/g dry feed (1/WHC = 0.25), so feeds with values for 1/WHC greater than 0.25 are unlikely to constrain feed intake due to their bulkiness, except in highly unusual circumstances. Consequently, the graph presented in Figure 5.1, was drawn to include only feeds, from Trial 1, Trial 2 and Williams (1993), with values for 1/WHC less than 0.25.

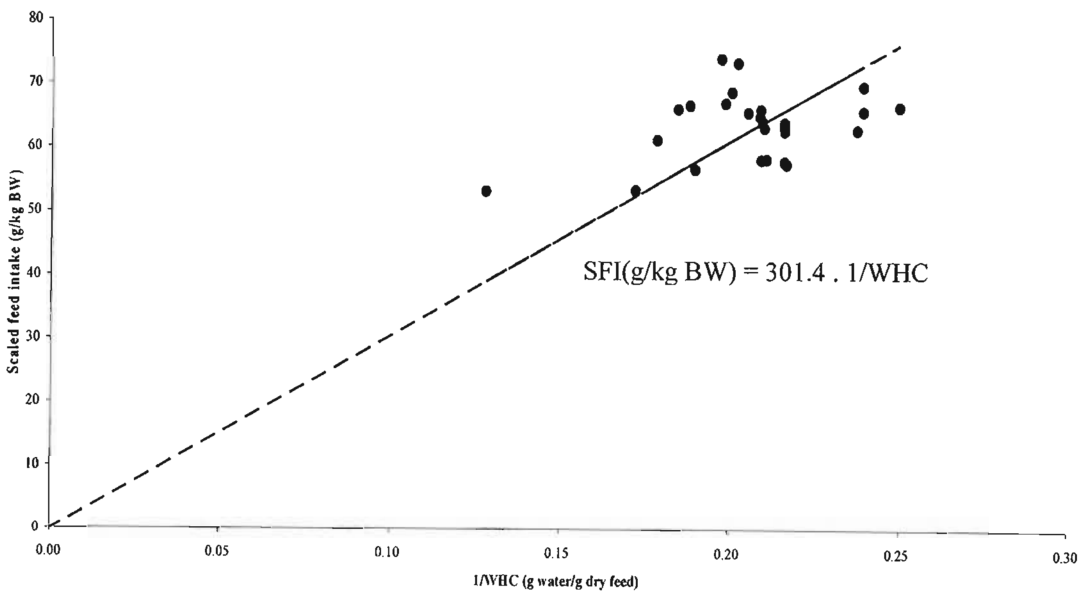

Figure 5.1: *The relationship between scaled feed intake (SFI, g/kg BW) and the reciprocal of water-holding capacity for data collected in Trials 1 and 2, and Williams (1993); including values for 1/WHC of 0.25 and less.*

The discrepancy that exists between the equations derived here and that from Trial 1 could be due to a difference in the methodology used to determine the water-holding capacity. Robertson and Eastwood (1981) reported that the methods of drying fibre before determining the water-holding capacity of a material affect its structure and that the changes can affect the water-holding capacity values. Tsaras *et al.* (1998) reported a discrepancy in their results when using freeze-drying and oven-drying, and the values determined by Williams (1993) were not freeze-dried after centrifugation, but oven dried, and all values determined in this thesis were from freeze-dried samples. This would have caused a difference in results.

5.2. Calculation of Bulk Constraint

A feed is formulated according to the estimated feed intake of the hen. The feed intake is an average of a population, meaning that some hens may eat more and others less depending on their body weight and potential egg output. When predicting voluntary feed intake of a hen when presented with a given feed, it is relatively simple to predict what the feed intake would need to be (desired) in order for the hen to meet her nutrient requirements, but it is as important, but more difficult, to determine whether the hen would be able to consume the desired amount of food. For this purpose it is necessary to determine whether the gut capacity of the hen would be capable of accommodating the food bulk. The equation given above will give a reasonable prediction of how much of the given food she would be capable of consuming and, if this is less than the desired feed intake, feed intake will be constrained, and her performance would be adjusted downward accordingly.

If a given feed were diluted with a diluent with a water-holding capacity of 10 g water/g dry feed (1/WHC = 0.1) then the constrained feed intake could be calculated from the proportions of the basal feed and diluent added together, i.e.:

> If the basal feed has a calculated 1/WHC of 0.26 and the desired feed intake (DFI) of the basal feed is 110 g/bird d, this can be converted to a scaled feed intake (SFI) of 58 g/kg body weight (BW) for a 1.9 kg bird. If the basal feed is diluted with a diluent at the rate of 100 g/kg, then the scaled constrained feed intake (CFI) can be calculated as;
>
> $$\text{CFI (g/bird.d) (10\% dilution)} = (0.9 \times 0.26) + (0.1 \times 0.1)$$

By including a value for WHC in a feed composition matrix, the value for a mixed feed would be calculated automatically. Table 5.1 presents some hypothetical values to illustrate this theory, which are presented in Figure 5.2. The values were chosen to represent a range of WHC values. The lowest value, $1/WHC_1$ was chosen to represent a feed with a very high WHC, i.e. cellulose.

Table 5.1: *Calculation of the constrained feed intake (CFI) of a 1.9 kg laying hen from the effect of bulk, expressed as the inverse of WHC, on the desired feed intake (DFI) over a range of hypothetical bulk values.*

Dilution Rate	DFI	Scaled DFI	$1/WHC_1 = 0.07$	CFI_1	$1/WHC_2 = 0.1$	CFI_2	$1/WHC_3 = 0.2$	CFI_3	$1/WHC_4 = 0.3$	CFI_4
0	110	58	0.26	78.4	0.26	78.4	0.26	78.4	0.26	78.4
5	116	61	0.25	75.5	0.25	76.0	0.26	77.5	0.26	79.0
10	121	64	0.24	72.6	0.24	73.5	0.25	76.6	0.26	79.6
15	127	67	0.23	69.8	0.24	71.3	0.25	75.7	0.27	80.2
25	138	72	0.21	64.1	0.22	66.3	0.25	73.8	0.27	81.4
50	165	87	0.17	49.7	0.18	54.3	0.23	69.3	0.28	84.4

The raw materials used to formulate the basal feed used in Trial 2 were individually analysed to determine their WHC's. These results were then added into the WinFeed formulation programme (EFG Software) matrix and the feed was formulated according to the same specifications as in Trial 2. However, the calculated WHC of the feed formulated was not the same as the measured WHC, being 2.97 g water/g dry feed and 3.8 g water/g dry feed, respectively. The difference could be due to the fact that the error in measurement would be greater when a number of measurements were added together. Also the sample taken and measured may not have been from the same batch of raw materials that was used during the mixing of the feed and could have slightly different properties. However, the formulation shows that the WHC is additive.

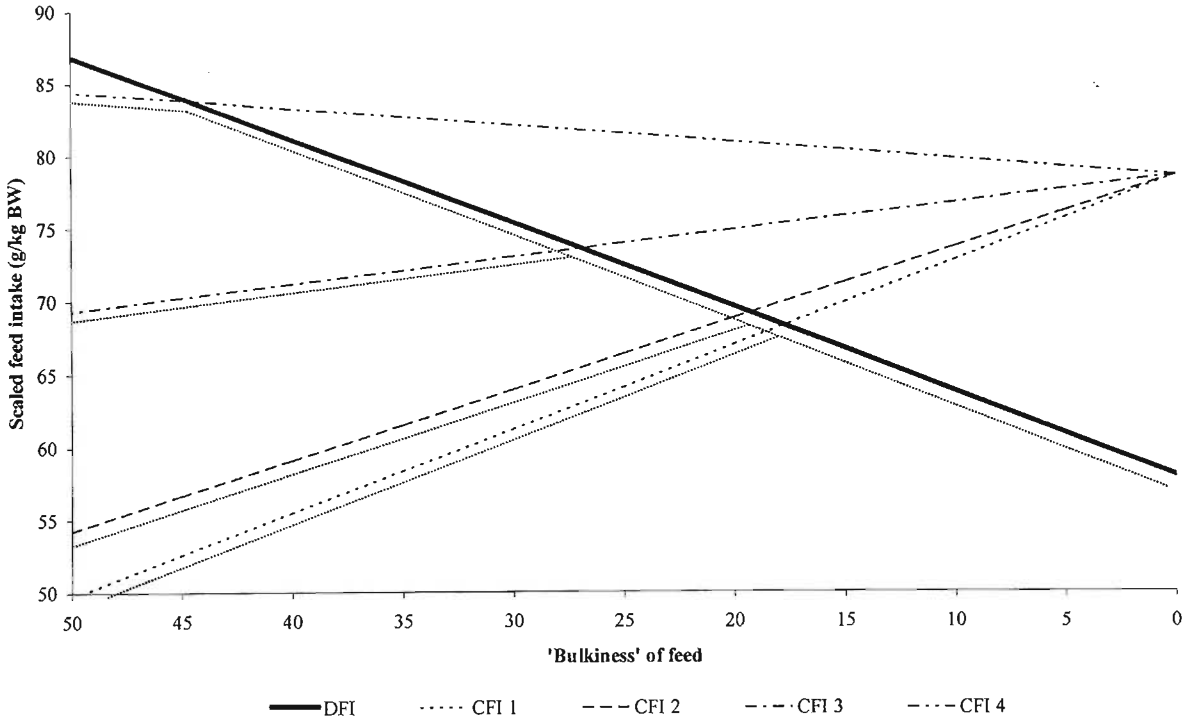

Figure 5.2: *Graphic representation of the effect of diluting a feed with four inert fillers with WHC's of 3.3, 5, 10 and 14.3 (g water/g dry feed) respectively on constrained (CFI), desired (DFI) and actual feed intake (AFI, represented by the feint dotted lines); where CFI_1 represents a feed with a WHC of 14, CFI_2 of 10, CFI_3 of 5 and CFI_4 of 3.3 g water/g dry feed*

The actual feed intake (AFI) is then the lesser of the DFI and the CFI. This represents the actual pattern of consumption of the hen when constrained by the bulk of the feed and is represented in Figure 5.2 as the feint dotted lines. As was expected, the AFI of the hen decreases as the water-holding capacity of the feed increases.

The equation developed in Figure 5.2 does not predict the desired feed intake of the hen. The desired feed intake is predicted by determining the limiting nutrient requirement of the hen and dividing this by the content of this nutrient in the feed on offer. If the constrained feed intake, calculated by means of the equation, is greater than the desired feed intake, then, in this case, the actual feed intake is the DFI. Where the CFI is less than the DFI the actual feed intake will be insufficient to meet the requirements of the hen for her potential egg output, and this will necessarily suffer as a result.

It is understood that the equation developed is not perfect, as there are points on either side of the regression line, meaning that in some cases the hens were capable of consuming more than was predicted by the equation, and other times less. This represents the individual variation in gut capacity, or the way in which feed intake was scaled. It might be more accurate to scale the feed intake to the lean tissue content of the hen to give a more accurate result. An inaccuracy may also be present in the measurement of the WHC, which is evident in the variation between the calculated and measured WHC of the basal feed in Trial 2, as well as the variation in the calculated WHC for the feeds in the previous chapter.

5.3. Conclusions

The prediction of the effect of feed bulk on the voluntary feed intake of the hen is an important aspect for accurately predicting the feed intake of the hen and formulating a 'perfect' diet. The results obtained in the two trials conducted for this thesis conform well to previous work in this Discipline, but the variation in constrained intakes was not accurately predicted by the WHC of the feed, although this measure of bulkiness was considerably better than any of the other measures applied. Until such time as a better measure of feed bulk is obtained, the equation developed in this thesis may be used to give a reasonable idea of when feed bulk will constrain feed intake in laying hens.

REFERENCES

ARMSBY, H.P. and Moulton, C.R. (1925) The Animal as a Converter of Matter and Energy. The Chemical Catalog Co. Inc., New York.

Association of Analytical Chemists (2002) Official methods of analysis. AOAC, Washington DC, USA.

BELLAIRS, R. (1964) Biological aspects of the yolk of the hen's egg. In: Advances in Morphogenesis. Abercrombie, M. and Bratchet, J (eds) pp 217-272. Academic Press, New York.

BROUNS, F., Edwards, S.A. and English, P.R. (1991) Fibrous raw materials in sow diets: effects on voluntary feed intake, digestibility and diurnal activity patterns. *Animal Production* 52, 598 (abstr.)

CHERRY, J.A., Jones, D.E., Calabotta, D.F. and Zelenka, D.J. (1983) Feed intake responses of mature White Leghorn chickens to changes in feed density. *Poultry Science.* 62, 1846-1849.

CONNELLY, C and Taborsky, G. (1961) Chromatographic Fractionation of phosvitin. *Journal of Biological Chemistry.* 236, 1364-1368.

CUNNINGHAM, F.E., Cotterhill, O.J. and Funk, E.M. (1960) The effect of season and age of bird. 1. On egg size, quality and yield. *Poultry Science.* 39, 289-299.

Winfeed 2.0 (2003) EFG Software, Pietermaritzburg, KwaZulu-Natal, South Africa.

EMMANS, G.C. (1981(a)) A model of the growth and feed intake of ad libitum fed animals, particularly poultry. In: Computers in Animal Production. pp 103-110. Occasional Publication No. 5. British Society of Animal Production. Thames Ditton, Surrey.

EMMANS, G.C. (1981(b)) Computer simulation in poultry nutrition. 3rd European Symposium on Poultry Nutrition. Peebles, Scotland.

EMMANS, G.C. (1987) Growth, body compositon and feed intake. *World's Poultry Science.* 43, 208-227.

EMMANS, G.C. (1989) The growth of turkeys. In: Recent advances in turkey science. Poultry Science Symposium, No. 21. Nixey, C. and Grey, T.C. (eds). Pp 135-166. Butterworths, London.

EMMANS, G.C. (1994) Effective energy: a concept of energy utilization applied across species. *British Journal of Nutrition.* 71, 801-821.

EMMANS, G.C. and Fisher, C. (1986). Problems in nutritional theory. In: Nutrient Requirements of Poultry and Nutritional Research 19. Fisher, C. and Boorman, K.N. (eds), pp 9-39. Butterworths, London.

EMMANS, G.C. and Oldham, J.D. (1988) Modeling of growth and nutrition in different species. In: Modeling of livestock production systems. Karver, S. and van Ardendonk, J.A.M. (eds), pp 13-21. Kluwer Academic Publishers, Dordrecht.

Excel ® Spreadsheet Software (2000) © 2006 Microsoft Corporation, Redmond, Washington D.C., USA.

FEENEY, R.E. and Allison, R.G. (1969). Evolutionary Biochemistry of Proteins. John Wiley and Sons, New York.

FISHER, C., Morris, T.R. and Jennings, R.C. (1973) A model for the description and prediction of the response of laying hens to amino acid intake. *British Poultry Science.* 14, 469-484.

FISHER, C. (1976) Protein in the diet of the pullet and laying bird. In: Protein metabolism and nutrition. Cole, D.J.A., Boorman, K.N., Buttery, P.J., Lewis, D., Neale, R.J. and Swan, H. (eds) pp 323-351. Butterworths, London.

Genstat executable (2002) Genstat Statistical Software, Release 6.1. Lawes Agricultural Trust, Rothamstead Experimental Station, Clarendon Press, Oxford.

GILBERT, A.B. (1969) A reassessment of certain factors which affect egg production in the domestic fowl. *Worlds Poultry Science*. 25(3), 239-258.

GILBERT, A.B. (1972) The activity of the ovary in relation to egg production. In: Egg formation and production. Freeman, B.M. and Lake, P.E. (eds) pp 3-21. British Poultry Science Ltd, Edinburgh.

GILBERT, A.B. and Wood-Gush, D.G. (1976) The effects of exogenous oestrogen and progesterone on laying and nesting behaviour in the hen. *British Poultry Science.* 17(1), 13-15.

GOUS, R.M. (2004) Personal communication.

HUGHES, B.O. (1980) Feather damage in hens caged individually. *British Poultry Science.* 21, 149-154.

Hy-Line Commercial Management Guide (2004) Hy-Line International, West Des Moines, Iowa, USA.

JAFFÉ, W.P. (1964) The relationship between egg weight and yolk weight. *British Poultry Science.* 5, 295-298.

JOHNSTON, S.A. and Gous, R.M. (2003) An improved model of the ovulatory cycle of the laying hen. *British Poultry Science*. 44(5), 752-760.

JøRGENSEN, H., Zhao, X., Knudsen, K.E.B. and Eggum, B.O. (1996) The influence of dietary fibre source and level on the development of the gastrointestinal tract, digestibility and energy metabolism in broilers. *British Journal of Nutrition.* 75, 379-395.

KONDRA, P.A., Sell, J.L. and Guenter, W. (1974) Response of meat and egg type chickens to a high fibre diet. *Canadian Journal of Animal Science.* 54, 651-658.

KYRIAZAKIS, I. and Emmans, G.C. (1994) The voluntary feed intake of pigs given feeds based on wheat bran, dried citrus pulp and grass meal, in relation to measurements of feed bulk. *British Journal of Nutrition.* 73, 191-207.

LEESON, S. and Morrison, W.D. (1978) Effect of feather cover on feed efficiency in laying birds. *Poultry Science.* 57, 1094-1096.

LEESON, S. and Summers, J.D. (1983) Growth and carcass characteristics of broilers fed Salinomycin in diets containing graded levels of methionine and energy. *Canadian Journal of Animal Science.* 63, 409-419.

LUNVEN, P. and Le Clement De St Marcq, C. (1973) Amino acid composition of hen's egg. *British Journal of Nutrition.* 30, 189-194.

MARSDEN, A. and Morris, T.R. (1987) Quantitative review of the effects of environmental temperature on feed intake, egg output and energy balance in laying pullets. *British Poultry Science.* 28, 693-704.

MCDONALD, M.W. and Morris, T.R. (1985). Quantitative review of optimum amino acid intakes for young laying pullets. *British Poultry Science,* 26, 253-264.

MCDONALD, P., Edwards, R.A., Grennhalgh, J.F.D. and Morgan, C.A. (1995) Animal nutrition 5th edition. Prentice Hall. Pearson Education Limited, Edinburgh Gate, Harlow, Essex, CM20 2JE, UK.

MORRIS, T.R. (1985) The manipulation of egg size and egg quality. *South African Journal of Animal Science.* 15, 120-122.

MORRIS, T.R. (2004) Nutrition of chicks and layers. *World's Poultry Science.* 60, 5-18.

MORRIS, T.R. (1999) Experimental design and analyses in animal sciences. CABI Publishing, CAB International, Wallingford, UK.

MORRIS, T.R. and Blackburn, H.A. (1982) The shape of the response curve relating protein intake to egg output for flocks of laying hens. *British Poultry Science.* 23, 405-424.

MORRIS, T.R. and Gous, R.M. (1988) Partitioning of the response to protein between egg number and egg weight. *British Poultry Science.* 29, 93-99.

MOUGHAN, P.J., Annison, G., Rutherfurd, S.M. and Wiseman, J. (1999) The chemical and physical description of feedstuffs. In: A quantitative biology of the pig. Kyriazakis, I (ed.) CABI Publishing, CAB International, Wallingford, UK.

MOUNT, L.E. (1979) The concept of thermal neutrality. In: Heat loss from animals and man, assessment and control. Monteith, J.L. and Mount, L.E. (eds) pp 425-439. Butterworths, London.

MRAZ, F.R., Boucher, R.V. and McCartney, M.G. (1957) The influence of energy:volume ratio on growth response in chickens. *Poultry Science* 36, 1217-1221.

National Research Council. (1987) Predicting feed intake of food producing animals. Report of the Subcommittee on Feed Intake, Committee on Animal Nutrition, Board on Agriculture. National Academy Press, Washington, D.C., USA.

PETERSON, A.D. and Baumgardt, B.R. (1971) Food and energy intake of rats fed diets varying in energy concentration and density. *Journal of Nutrition* 101, 1057-1068.

POLIN, D. and Wolford, J.H. (1973) Factors influencing food intake and caloric balance in chickens. Federation Proceedings. *Federation of American Societies for Experimental Biology.* 32, 1720-1726.

RICHARDSON, A.J. (1972) The effect of duodenal constriction on food intake and water intake of Brown Leghorn cockerels. *British Poultry Science* 13, 175-177.

ROBERTSON, J.A. and Eastwood, M.A. (1981) An examination of factors that may affect water holding capacity of dietary fibre. *British Journal of Nutrition.* 45, 83-87.

ROMANOFF, A.L. and Romanoff, A.J. (1949). The Avian Egg. J. Wiley and Sons, New York.

SAVORY, C.J. (1980) Meal occurrence in Japanese quail in relation to particle size and nutrient density. *Animal Behavior*. 28, 160-171.

SELL, J.L. and Johnson, R.L. (1974) Low protein rations based on wheat and soybean meal or corn and soybean meal for laying hens. *British Poultry Science.* 15, 43-49.

SHENSTONE, F.S. (1968). Egg Quality: A Study of the Hens Egg. Carter, T.C. (ed). pp 26-58. Oliver and Boyd, Edinburgh.

SUMMERS, J.D. and Leeson, S. (1977) Sequential effects of restricted feeding and force molting on laying hen performance. *Poultry Science.* 56, 600-604.

SUMMERS, J.D. and Leeson, S. (1986) Influence of nutrient density on feed consumption, weight gain and gut capacity of broilers, Leghorns and turkeys reared to 26 days of age. *Animal Feed Science and Technology.* 16, 129-141.

SYKES, A.H. (1986) Effect of changes in dietary energy intake and environmental temperature on heat tolerance in the fowl. *British Poultry Science.* 27, 687-693.

TSARAS, L.N., Kyriazakis, I. and Emmans, G.C. (1998) The prediction of the voluntary feed intake of pigs on poor quality foods. *Animal Science.* 66, 713-723.

VAN SOEST, P.J., Robertson, J.B. and Lewis, B.G., 1991. Methods for dietary fibre, neutral detergent fibre and non-starch polysaccharide in relation to animal nutrition. *Journal of Dairy Science.* 74, 3583-3597

WHITTEMORE, E.C., Emmans, G.C. and Kyriazakis, I. (2003) the relationship between live weight and the intake of bulky foods in pigs. *Animal Science.* 76, 89-100.

WILLIAMS, B.A. (1993) Determination of bulk density and its constraining effect on feed intake in poultry and pigs. MSc Thesis, University of Natal.

YOUNG, M.B. (1998) An evaluation of effective energy in the formulation of diets for laying hens. MSc Thesis, University of Natal.

APPENDICES

APPENDIX A: TRIAL 1 BODY WEIGHT DATA

PEN	TREAT.	INITIAL	WEEK 3	BW change	BW change/day	WEEK 6	BW change	BW change/day	WEEK 9	BW change	BW change/day
1	9	1637	1567	-70	-3.3	1619	52	2.5	1667	48	2.3
2	6	1943	1730	-213	-10.1	1206	-524	-25.0	1791	585	27.9
3	11	1860	1698	-162	-7.7	1609	-89	-4.2	1601	-8	-0.4
4	10	1760	1705	-55	-2.6	1337	-368	-17.5	1666	329	15.7
5	18	1865	1819	-46	-2.2	1579	-240	-11.4	1959	380	18.1
6	2	1792	1750	-42	-2.0	1406	-344	-16.4	1649	243	11.6
7	14	1817	1803	-14	-0.7	1715	-88	-4.2	1736	21	1.0
8	10	1925	1887	-38	-1.8	1561	-326	-15.5	1912	351	16.7
9	20	1908	1695	-213	-10.1	1890	195	9.3	1659	-231	-11.0
10	19	1886	1677	-209	-10.0	1736	59	2.8	1808	72	3.4
11	16	1858	1708	-150	-7.1	1780	72	3.4	1183	-597	-28.4
12	12	1525	1183	-342	-16.3	1466	283	13.5	1163	-303	-14.4
13	17	1892	1839	-53	-2.5	1886	47	2.2	1834	-52	-2.5
14	11	1954	1637	-317	-15.1	1622	-15	-0.7	1694	72	3.4
15	4	2053	1505	-548	-26.1	1845	340	16.2	1391	-454	-21.6
16	1	1851	1713	-138	-6.6	1808	95	4.5	1818	10	0.5
17	13	1645	1629	-16	-0.8	1610	-19	-0.9	1616	6	0.3
18	20	1724	1457	-267	-12.7	1684	227	10.8	1425	-259	-12.3
19	18	2065	1755	-310	-14.8	1445	-310	-14.8	1655	210	10.0
20	12	1990	1427	-563	-26.8	1791	364	17.3	1291	-500	-23.8
21	15	1874	1740	-134	-6.4	1730	-10	-0.5	1313	-417	-19.9
22	5	1591	1531	-60	-2.9	1589	58	2.8	1611	22	1.0
23	7	2002	1580	-422	-20.1	1255	-325	-15.5	1700	445	21.2
24	17	1963	1911	-52	-2.5	1876	-35	-1.7	1770	-106	-5.0
25	9	1929	1918	-11	-0.5	1943	25	1.2	1979	36	1.7
26	4	1538	1160	-378	-18.0	1413	253	12.0	1070	-343	-16.3
27	3	1834	1862	28	1.3	1760	-102	-4.9	1712	-48	-2.3
28	2	1864	1868	4	0.2	1469	-399	-19.0	1825	356	17.0

PEN	TREAT.	INITIAL	WEEK 3	BW change	BW change/day	WEEK 6	BW change	BW change/day	WEEK 9	BW change	BW change/day
29	6	2019	1939	-80	-3.8	1356	-583	-27.8	1892	536	25.5
30	16	1805	1631	-174	-8.3	1794	163	7.8	1277	-517	-24.6
31	3	1822	1655	-167	-8.0	1688	33	1.6	1647	-41	-2.0
32	1	1703	1695	-8	-0.4	1697	2	0.1	1725	28	1.3
33	19	1967	1702	-265	-12.6	1684	-18	-0.9	1772	88	4.2
34	5	2014	1933	-81	-3.9	2001	68	3.2	2020	19	0.9
35	8	2159	1556	-603	-28.7	2051	495	23.6	2058	7	0.3
36	8	2006	1389	-617	-29.4	1830	441	21.0	1806	-24	-1.1
37	13	1972	1911	-61	-2.9	1965	54	2.6	1997	32	1.5
38	7	1840	1425	-415	-19.8	1337	-88	-4.2	1856	519	24.7
39	15	1936	1947	11	0.5	1864	-83	-4.0	1455	-409	-19.5
40	14	1791	1690	-101	-4.8	1662	-28	-1.3	1803	141	6.7
41	10	1819	1681	-138	-6.6	1418	-263	-12.5	1687	269	12.8
42	15	1835	1752	-83	-4.0	1773	21	1.0	1351	-422	-20.1
43	3	1778	1784	6	0.3	1680	-104	-5.0	1651	-29	-1.4
44	3	2150	1835	-315	-15.0	1777	-58	-2.8	1819	42	2.0
45	11	1980	1668	-312	-14.9	1625	-43	-2.0	1692	67	3.2
46	17	1956	1850	-106	-5.0	1900	50	2.4	1844	-56	-2.7
47	16	2005	1898	-107	-5.1	1941	43	2.0	1489	-452	-21.5
48	20	1861	1406	-455	-21.7	1670	264	12.6	1480	-190	-9.0
49	7	1555	1114	-441	-21.0	926	-188	-9.0	1542	616	29.3
50	9	1605	1637	32	1.5	1672	35	1.7	1648	-24	-1.1
51	4	1678	1394	-284	-13.5	1611	217	10.3	1284	-327	-15.6
52	4	1973	1562	-411	-19.6	1870	308	14.7	1489	-381	-18.1
53	10	1665	1473	-192	-9.1	1278	-195	-9.3	1316	38	1.8
54	6	1657	1422	-235	-11.2	867	-555	-26.4	1509	642	30.6
55	19	1862	1576	-286	-13.6	1658	82	3.9	1763	105	5.0
56	20	1903	1595	-308	-14.7	1814	219	10.4	1563	-251	-12.0
57	15	1732	1589	-143	-6.8	1744	155	7.4		-1744	-83.0
58	11	1935	1781	-154	-7.3	1601	-180	-8.6	1566	-35	-1.7

PEN	TREAT.	INITIAL	WEEK 3	BW change	BW change/day	WEEK 6	BW change	BW change/day	WEEK 9	BW change	BW change/day
59	16	2215	1945	-270	-12.9	1942	-3	-0.1	1382	-560	-26.7
60	8	1696	1038	-658	-31.3	1353	315	15.0	1712	359	17.1
61	13	1441	1448	7	0.3	1478	30	1.4	1485	7	0.3
62	18	1905	1810	-95	-4.5	1499	-311	-14.8	1829	330	15.7
63	18	1819	1707	-112	-5.3	1365	-342	-16.3	1739	374	17.8
64	14	1785	1651	-134	-6.4	1662	11	0.5	1550	-112	-5.3
65	1	1684	1724	40	1.9	1731	7	0.3	1880	149	7.1
66	6	1942	1764	-178	-8.5	1305	-459	-21.9	1783	478	22.8
67	17	2448	2300	-148	-7.0	2260	-40	-1.9	2261	1	0.0
68	5	2103	2159	56	2.7	2121	-38	-1.8	2209	88	4.2
69	14	1532	1530	-2	-0.1	1529	-1	0.0	1496	-33	-1.6
70	1	1726	1644	-82	-3.9	1655	11	0.5	1651	-4	-0.2
71	2	1868	1787	-81	-3.9	1636	-151	-7.2	1743	107	5.1
72	5	1899	1892	-7	-0.3	1914	22	1.0	1931	17	0.8
73	12	1862	1420	-442	-21.0	1742	322	15.3	1377	-365	-17.4
74	2	2010	2029	19	0.9	1641	-388	-18.5	2003	362	17.2
75	8	1916	1448	-468	-22.3	1650	202	9.6	1931	281	13.4
76	9	1885	1935	50	2.4	1971	36	1.7	2020	49	2.3
77	12	1648	1248	-400	-19.0	1515	267	12.7	1240	-275	-13.1
78	19	1955	1673	-282	-13.4	1578	-95	-4.5	1612	34	1.6
79	13	1634	1548	-86	-4.1	1563	15	0.7	1670	107	5.1
80	7	1843	1571	-272	-13.0	1344	-227	-10.8	1810	466	22.2
81	3	1922	1764	-158	-7.5	1777	13	0.6	1633	-144	-6.9
82	5	1768	1789	21	1.0	1770	-19	-0.9	1840	70	3.3
83	1	2031	1963	-68	-3.2	1990	27	1.3	2067	77	3.7
84	6	1767	1626	-141	-6.7	1782	156	7.4	1689	-93	-4.4
85	15	1787	1736	-51	-2.4	1728	-8	-0.4	1314	-414	-19.7
86	17	1805	1741	-64	-3.0	1679	-62	-3.0	1616	-63	-3.0
87	20	1423	1139	-284	-13.5	1346	207	9.9	1199	-147	-7.0
88	14	1881	1840	-41	-2.0	1600	-240	-11.4	1787	187	8.9

PEN	TREAT.	INITIAL	WEEK 3	BW change	BW change/day	WEEK 6	BW change	BW change/day	WEEK 9	BW change	BW change/day
89	8	1634	1073	-561	-26.7	1398	325	15.5	1615	217	10.3
90	5	1675	1568	-107	-5.1	1674	106	5.0	1694	20	1.0
91	12	1774	1164	-610	-29.0	1583	419	20.0	1038	-545	-26.0
92	4	1919	1564	-355	-16.9	1772	208	9.9	1486	-286	-13.6
93	3	1807	1593	-214	-10.2	1636	43	2.0	1578	-58	-2.8
94	14	1697	1652	-45	-2.1	1556	-96	-4.6	1562	6	0.3
95	7	1706	1363	-343	-16.3	1074	-289	-13.8	1730	656	31.2
96	10	1747	1587	-160	-7.6	1204	-383	-18.2	1672	468	22.3
97	2	1930	1862	-68	-3.2	1742	-120	-5.7	1954	212	10.1
98	16	1802	1629	-173	-8.2	1745	116	5.5	1197	-548	-26.1
99	9	2001	1944	-57	-2.7	2054	110	5.2	2038	-16	-0.8
100	16	1886	1474	-412	-19.6	1741	267	12.7	1261	-480	-22.9
101	1	1794	1773	-21	-1.0	1765	-8	-0.4	1815	50	2.4
102	19	1745	1543	-202	-9.6	1513	-30	-1.4	1516	3	0.1
103	6	1793	1781	-12	-0.6	1157	-624	-29.7	1806	649	30.9
104	9	1709	1707	-2	-0.1	1647	-60	-2.9	1728	81	3.9
105	20	2017	1706	-311	-14.8	1872	166	7.9	1623	-249	-11.9
106	13	2012	1921	-91	-4.3	1995	74	3.5	1984	-11	-0.5
107	8	1926	1317	-609	-29.0	1842	525	25.0	1836	-6	-0.3
108	18	1765	1600	-165	-7.9	1398	-202	-9.6	1604	206	9.8
109	4	2221	1837	-384	-18.3	2033	196	9.3	1867	-166	-7.9
110	13	2350	2164	-186	-8.9	2258	94	4.5	2293	35	1.7
111	7	1827	1484	-343	-16.3	1251	-233	-11.1	1783	532	25.3
112	17	1650	1412	-238	-11.3	1233	-179	-8.5	717	-516	-24.6
113	15	2072	1840	-232	-11.0	2018	178	8.5	1623	-395	-18.8
114	11	1816	1555	-261	-12.4	1442	-113	-5.4	1405	-37	-1.8
115	2	1694	1562	-132	-6.3	1405	-157	-7.5	1571	166	7.9
116	11	1869	1432	-437	-20.8	1345	-87	-4.1	1141	-204	-9.7
117	10	2071	1930	-141	-6.7	1588	-342	-16.3	1771	183	8.7
118	19	1872	1555	-317	-15.1	1650	95	4.5	1677	27	1.3

PEN	TREAT.	INITIAL	WEEK 3	BW change	BW change/day	WEEK 6	BW change	BW change/day	WEEK 9	BW change	BW change/day
119	12	2003	1514	-489	-23.3	1859	345	16.4	1546	-313	-14.9
120	18	1972	1868	-104	-5.0	1522	-346	-16.5	1923	401	19.1
121	5	2325	2182	-143	-6.8	2142	-40	-1.9	2123	-19	-0.9
122	2	1830	1576	-254	-12.1	1352	-224	-10.7	1618	266	12.7
123	19	1864	1478	-386	-18.4	1431	-47	-2.2	1472	41	2.0
124	17	1892	1686	-206	-9.8	1652	-34	-1.6	1690	38	1.8
125	9	1932	1907	-25	-1.2	1919	12	0.6	1939	20	1.0
126	10	2010	1794	-216	-10.3	1448	-346	-16.5	1712	264	12.6
127	11	1886	1570	-316	-15.0	1629	59	2.8	1570	-59	-2.8
128	1	1653	1619	-34	-1.6	1652	33	1.6	1602	-50	-2.4
129	8	1777	1230	-547	-26.0	1636	406	19.3	1712	76	3.6
130	20	1639	1318	-321	-15.3	1592	274	13.0	1350	-242	-11.5
131	11	1942	1681	-261	-12.4	1675	-6	-0.3	1695	20	1.0
132	20	1917	1555	-362	-17.2	1739	184	8.8	1614	-125	-6.0
133	7	1925	1471	-454	-21.6	1331	-140	-6.7	1920	589	28.0
134	18	2001	1851	-150	-7.1	1502	-349	-16.6	1970	468	22.3
135	7	2164	1576	-588	-28.0	1365	-211	-10.0	2097	732	34.9
136	3	2083	1749	-334	-15.9	1719	-30	-1.4	1728	9	0.4
137	14	2034	1941	-93	-4.4	1771	-170	-8.1	1809	38	1.8
138	12	2032	1589	-443	-21.1	1812	223	10.6	1505	-307	-14.6
139	8	2033	1442	-591	-28.1	1886	444	21.1	1841	-45	-2.1
140	16	2001	1780	-221	-10.5	1909	129	6.1	1392	-517	-24.6
141	2	1989	1962	-27	-1.3	1438	-524	-25.0	1737	299	14.2
142	9	2310	2168	-142	-6.8	2252	84	4.0	2298	46	2.2
143	18	2069	1897	-172	-8.2	1550	-347	-16.5	1963	413	19.7
144	5	1957	1783	-174	-8.3	1751	-32	-1.5	1757	6	0.3
145	15	1844	1664	-180	-8.6	1697	33	1.6	1359	-338	-16.1
146	17	2009	2000	-9	-0.4	1964	-36	-1.7	1956	-8	-0.4
147	13	1825	1746	-79	-3.8	1835	89	4.2	1787	-48	-2.3
148	12	1962	1443	-519	-24.7	1890	447	21.3	1473	-417	-19.9

PEN	TREAT.	INITIAL	WEEK 3	BW change	BW change/day	WEEK 6	BW change	BW change/day	WEEK 9	BW change	BW change/day
149	3	1836	1571	-265	-12.6	1542	-29	-1.4	1476	-66	-3.1
150	13	1734	1680	-54	-2.6	1642	-38	-1.8	1618	-24	-1.1
151	15	1911	1785	-126	-6.0	1810	25	1.2	1456	-354	-16.9
152	4	2071	1780	-291	-13.9	1849	69	3.3	1517	-332	-15.8
153	1	2424	2323	-101	-4.8	2372	49	2.3	2401	29	1.4
154	14	2010	1936	-74	-3.5	1897	-39	-1.9	1842	-55	-2.6
155	16	2083	1877	-206	-9.8	1907	30	1.4	1407	-500	-23.8
156	4	1861	1381	-480	-22.9	1641	260	12.4	1297	-344	-16.4
157	19	1683	1410	-273	-13.0	1429	19	0.9	1442	13	0.6
158	6	1734	1562	-172	-8.2	1127	-435	-20.7	1659	532	25.3
159	6	2390	1932	-458	-21.8	1405	-527	-25.1	1905	500	23.8
160	10	1871	1732	-139	-6.6	1347	-385	-18.3	1874	527	25.1

APPENDIX B: TRIAL 1 FEED INTAKE DATA

PERIOD 1: 01/09/2003 - 22/09/2003

PEN	TREAT.	DILUENT	LEVEL	FEED IN	FEED OUT	INTAKE1	INTAKE/DAY	FEED IN	FEED OUT	INTAKE2	INTAKE/DAY	FEED IN	FEED OUT	INTAKE3	INTAKE/DAY	AVE FI/DAY	WEEK 3 BW	SFI	AVE WK2+3
1	9	V	0	1360.8	711.3	649.5	92.8	1026.8	413.9	612.9	87.6	1594.6	840.3	754.3	107.8	96.0	1567	61.3	97.7
2	6	C	10	1441.3	822.3	619.0	88.4	1044.8	507.5	537.3	76.8	1588.8	949.9	638.9	91.3	85.5	1730	49.4	84.0
3	11	V	25	1213.8	692.5	521.3	74.5	1029.4	402.1	627.3	89.6	1165.2	420.4	744.8	106.4	90.2	1698	53.1	98.0
4	10	V	10	1223.4	463.6	759.8	108.5	1047.8	345.2	702.6	100.4	1376.2	496.4	879.8	125.7	111.5	1705	65.4	113.0
5	18	SD	10	1230.1	435.4	794.7	113.5	1021.9	524.9	497.0	71.0	1320.9	467.3	853.6	121.9	102.2	1819	56.2	96.5
6	2	SF	10	1201.0	365.4	835.6	119.4	1240.9	502.5	738.4	105.5	187.5	623.7	-436.2	-62.3	54.2	1750	31.0	21.6
7	14	S	10	1256.4	521.3	735.1	105.0	1007.6	304.6	703.0	100.4	1107.5	256.4	851.1	121.6	109.0	1803	60.5	111.0
8	10	V	10	1298.0	483.9	814.1	116.3	1019.4	228.5	790.9	113.0	1160.7	182.6	978.1	139.7	123.0	1887	65.2	126.4
9	20	SD	50	884.6	245.6	639.0	91.3	991.3	235.5	755.8	108.0	965.2	195.8	769.4	109.9	103.1	1695	60.8	108.9
10	19	SD	25	1147.1	358.9	788.2	112.6	1141.9	368.9	773.0	110.4	1012.5	211.1	801.4	114.5	112.5	1677	67.1	112.5
11	16	S	50	1716.4	541.5	1174.9	167.8	1534.4	426.5	1107.9	158.3	1668.5	281.1	1387.4	198.2	174.8	1708	102.3	178.2
12	12	V	50	1046.8	718.1	328.7	47.0	989.7	398.5	591.2	84.5	952.4	345.2	607.2	86.7	72.7	1183	61.5	85.6
13	17	SD	0	1221.9	376.7	845.2	120.7	1089.7	337.1	752.6	107.5	1001.2	159.7	841.5	120.2	116.2	1839	63.2	113.9
14	11	V	25	1114.0	500.6	613.4	87.6	1033.4	406.6	626.8	89.5	1070.7	412.8	657.9	94.0	90.4	1637	55.2	91.8
15	4	SF	50	1007.0	1024.1	-17.1	-2.4	1024.1	1046.1	-22.0	-3.1	1046.1	232.8	813.3	116.2	36.9	1505	24.5	56.5
16	1	SF	0	1289.0	488.2	800.8	114.4	1274.8	624.1	650.7	93.0	810.6	491.7	318.9	45.6	84.3	1713	49.2	69.3
17	13	S	0	1373.7	707.1	666.6	95.2	1064.3	442.8	621.5	88.8	1170.7	351.1	819.6	117.1	100.4	1629	61.6	102.9
18	20	SD	50	932.0	314.6	617.4	88.2	951.1	317.9	633.2	90.5	1029.5	181.8	847.7	121.1	99.9	1457	68.6	105.8
19	18	SD	10	1213.0	708.7	504.3	72.0	1036.7	912.7	124.0	17.7	1266.1	683.4	582.7	83.2	57.7	1755	32.9	50.5
20	12	V	50	978.4	732.7	245.7	35.1	954.1	589.2	364.9	52.1	840.6	450.2	390.4	55.8	47.7	1427	33.4	54.0
21	15	S	25	1382.1	382.3	999.8	142.8	1210.4	368.2	842.2	120.3	1398.7	254.3	1144.4	163.5	142.2	1740	81.7	141.9
22	5	C	0	1356.2	694.2	662.0	94.6	1192.5	694.7	497.8	71.1	1190.3	485.0	705.3	100.8	88.8	1531	58.0	85.9
23	7	C	25	1503.5	1313.7	189.8	27.1	1313.7	1227.2	86.5	12.4	1227.2	926.0	301.2	43.0	27.5	1580	17.4	27.7
24	17	SD	0	1209.5	471.0	738.5	105.5	1007.3	356.7	650.6	92.9	1051.3	236.3	815.0	116.4	105.0	1911	54.9	104.7
25	9	V	0	1614.0	794.0	820.0	117.1	1185.4	486.0	699.4	99.9	1128.5	343.6	784.9	112.1	109.7	1918	57.2	106.0
26	4	SF	50	1000.2	981.2	19.0	2.7	981.2	710.6	270.6	38.7	879.6	411.0	468.6	66.9	36.1	1160	31.1	52.8
27	3	SF	25	1001.3	513.2	488.1	69.7	1011.3	349.7	661.6	94.5	1627.1	535.3	1091.8	156.0	106.7	1862	57.3	125.2
28	2	SF	10	1199.5	332.2	867.3	123.9	1202.5	366.2	836.3	119.5	1220.7	229.7	991.0	141.6	128.3	1868	68.7	130.5
29	6	C	10	1494.7	900.1	594.6	84.9	1148.3	408.6	739.7	105.7	1117.8	296.1	821.7	117.4	102.7	1939	52.9	111.5
30	16	S	50	2048.4	1163.2	885.2	126.5	1163.2	375.4	787.8	112.5	1342.2	532.3	809.9	115.7	118.2	1631	72.5	114.1
31	3	SF	25	1000.2	352.4	647.8	92.5	1039.5	233.4	806.1	115.2	1254.0	211.9	1042.1	148.9	118.9	1655	71.8	132.0
32	1	SF	0	1263.8	547.7	716.1	102.3	1177.3	454.8	722.5	103.2	1230.4	330.8	899.6	128.5	111.3	1695	65.7	115.9
33	19	SD	25	1127.6	276.8	850.8	121.5	1061.3	257.3	804.0	114.9	1222.3	197.7	1024.6	146.4	127.6	1702	75.0	130.6
34	5	C	0	1303.2	550.4	752.8	107.5	1000.8	408.9	591.9	84.6	1036.9	373.0	663.9	94.8	95.6	1933	49.5	89.7
35	8	C	50	1303.1	1363.0	-60.0	-8.6	1363.0	1176.6	186.5	26.6	952.2	803.2	149.1	21.3	13.1	1556	8.4	24.0
36	8	C	50	1270.7	1266.2	4.5	0.6	1266.2	1056.5	209.7	30.0	1018.9	842.3	176.6	25.2	18.6	1389	13.4	27.6
37	13	S	0	1268.8	457.6	811.2	115.9	1027.8	296.5	731.3	104.5	1135.8	225.5	910.3	130.0	116.8	1911	61.1	117.3
38	7	C	25	1423.5	1253.6	169.9	24.3	1253.6	1115.4	138.2	19.7	949.2	651.1	298.1	42.6	28.9	1425	20.3	31.2
39	15	S	25	1393.7	375.4	1018.3	145.5	1017.7	542.8	474.9	67.8	1340.9	580.4	760.5	108.6	107.3	1947	55.1	88.2
40	14	S	10	1466.4	775.0	691.4	98.8	1091.1	405.0	686.1	98.0	1156.2	229.3	926.9	132.4	109.7	1690	64.9	115.2
41	10	V	10	1273.9	603.0	670.9	95.8	1031.5	384.1	647.4	92.5	1076.7	279.5	797.2	113.9	100.7	1681	59.9	103.2
42	15	S	25	1589.1	530.0	1059.1	151.3	1075.4	365.1	710.3	101.5	1067.6	586.0	481.6	68.8	107.2	1752	61.2	85.1
43	3	SF	25	1072.6	382.0	690.6	98.7	1007.1	405.2	601.9	86.0	1212.9	250.9	962.0	137.4	107.4	1784	60.2	111.7
44	3	SF	25	1087.0	356.4	730.6	104.4	1097.1	426.5	670.6	95.8	1265.4	227.8	1037.6	148.2	116.1	1835	63.3	122.0
45	11	V	25	1178.6	424.5	754.1	107.7	1012.0	375.3	636.7	91.0	1450.2	528.1	922.1	131.7	110.1	1668	66.0	111.3
46	17	SD	0	1044.8	436.8	608.0	86.9	1094.7	530.6	564.1	80.6	1045.6	289.7	755.9	108.0	91.8	1850	49.6	94.3
47	16	S	50	2155.4	667.3	1488.1	212.6	1370.9	111.7	1259.2	179.9	1387.0	277.8	1109.2	158.5	183.6	1898	96.8	169.2
48	20	SD	50	970.0	623.8	346.2	49.5	943.6	336.8	606.8	86.7	851.8	174.3	677.5	96.8	77.6	1406	55.2	91.7
49	7	C	25	1335.7	1111.9	223.8	32.0	1111.9	1054.5	57.4	8.2	1017.0	784.7	232.3	33.2	24.5	1114	21.9	20.7
50	9	V	0	1559.8	765.6	794.2	113.5	1097.9	341.3	756.6	108.1	1289.4	446.1	843.3	120.5	114.0	1637	69.6	114.3
51	4	SF	50	1035.3	590.9	444.4	63.5	940.9	532.3	408.6	58.4	772.8	174.9	597.9	85.4	69.1	1394	49.6	71.9
52	4	SF	50	1092.2	632.8	459.4	65.6	927.2	479.9	447.3	63.9	778.7	154.3	624.4	89.2	72.9	1562	46.7	76.6
53	10	V	10	1300.6	691.4	609.2	87.0	1026.4	396.0	630.4	90.1	999.4	367.9	631.5	90.2	89.1	1473	60.5	90.1
54	6	C	10	1521.6	1441.5	80.1	11.4	1441.5	1057.6	383.9	54.8	1057.6	533.8	523.8	74.8	47.0	1422	33.1	64.8
55	19	SD	25	1221.3	533.8	687.5	98.2	1037.4	578.1	459.3	65.6	979.1	201.8	777.3	111.0	91.6	1576	58.1	88.3
56	20	SD	50	911.8	460.7	451.1	64.4	902.4	420.8	481.6	68.8	996.0	228.4	767.6	109.7	81.0	1595	50.8	89.2
57	15	S	25	1477.0	406.4	1070.6	152.9	1025.0	288.2	736.8	105.3	1094.0	110.4	983.6	140.5	132.9	1589	83.6	122.9
58	11	V	25	1109.5	433.2	676.3	96.6	1007.0	381.4	625.6	89.4	1165.7	222.2	943.5	134.8	106.9	1781	60.0	112.1
59	16	S	50	1950.0	1794.5	155.5	22.2	1794.5	836.1	958.4	136.9	1038.5	368.8	669.7	95.7	84.9	1945	43.7	116.3
60	8	C	50	1363.9	779.8	584.1	83.4	1039.5	840.4	199.2	28.5	812.3	647.3	165.0	23.6	45.2	1038	43.5	26.0
61	13	S	0	1390.8	769.3	621.5	88.8	1102.6	542.2	560.4	80.1	1230.9	477.0	753.9	107.7	92.2	1448	63.7	93.9
62	18	SD	10	1215.7	353.2	862.5	123.2	1048.2	340.1	708.1	101.2	1171.7	196.2	975.5	139.4	121.2	1810	67.0	120.3
63	18	SD	10	1198.1	347.5	850.6	121.5	1070.6	325.2	745.4	106.5	1179.6	184.3	995.3	142.2	123.4	1707	72.3	124.3
64	14	S	10	1371.4	605.7	765.7	109.4	1075.6	543.4	532.2	76.0	1056.1	163.1	893.0	127.6	104.3	1651	63.2	101.8
65	1	SF	0	1386.3	535.5	850.8	121.5	1223.7	404.3	819.4	117.1	1357.8	478.7	879.1	125.6	121.4	1724	70.4	121.3
66	6	C	10	1637.9	1051.4	586.5	83.8	1218.7	592.7	626.0	89.4	1097.3	383.3	714.0	102.0	91.7	1764	52.0	95.7
67	17	SD	0	1119.1	328.0	791.1	113.0	1005.0	319.2	685.8	98.0	1245.3	288.0	957.3	136.8	115.9	2300	50.4	117.4
68	5	C	0	1355.8	497.1	858.7	122.7	1079.0	267.6	811.4	115.9	1576.4	574.0	1002.4	143.2	127.3	2159	58.9	129.6

PEN	TREAT.	DILUENT	LEVEL	FEED IN	FEED OUT	INTAKE1	INTAKE/DAY	FEED IN	FEED OUT	INTAKE2	INTAKE/DAY	FEED IN	FEED OUT	INTAKE3	INTAKE/DAY	AVE FI/DAY	WEEK 3 BW	SFI	AVE WK2+3
69	14	S	10	1300.5	559.1	741.4	105.9	1003.2	321.1	682.1	97.4	1218.9	353.0	865.9	123.7	109.0	1530	71.3	110.6
70	1	SF	0	1366.9	628.3	738.6	105.5	1190.7	792.0	398.7	57.0	1040.9	314.5	726.4	103.8	88.7	1644	54.0	80.4
71	2	SF	10	1208.9	355.9	853.0	121.9	1212.0	432.0	780.0	111.4	1258.2	275.0	983.2	140.5	124.6	1787	69.7	125.9
72	5	C	0	1361.3	507.5	853.8	122.0	1007.2	266.8	740.4	105.8	1484.0	537.0	947.0	135.3	121.0	1892	64.0	120.5
73	12	V	50	970.5	593.1	377.4	53.9	929.3	436.2	493.1	70.4	812.5	213.0	599.5	85.6	70.0	1420	49.3	78.0
74	2	SF	10	1255.7	456.3	799.4	114.2	1280.6	368.9	911.7	130.2	1473.8	414.4	1059.4	151.3	131.9	2029	65.0	140.8
75	8	C	50	1250.4	1264.5	-14.2	-2.0	1264.5	972.1	292.4	41.8	910.1	675.1	235.1	33.6	24.4	1448	16.9	37.7
76	9	V	0	1559.9	761.1	798.8	114.1	1067.9	291.1	776.8	111.0	1497.9	430.7	1067.2	152.5	125.8	1935	65.0	131.7
77	12	V	50	927.0	524.8	402.2	57.5	941.5	564.7	376.8	53.8	776.4	207.2	569.2	81.3	64.2	1248	51.4	67.6
78	19	SD	25	1121.7	364.9	756.8	108.1	1027.5	431.4	596.1	85.2	1233.7	187.2	1046.5	149.5	114.3	1673	68.3	117.3
79	13	S	0	1327.4	608.5	718.9	102.7	986.8	476.0	510.8	73.0	1119.3	291.1	828.2	118.3	98.0	1548	63.3	95.6
80	7	C	25	1506.6	1278.6	228.0	32.6	1278.6	1164.5	114.1	16.3	946.5	663.9	282.6	40.4	29.7	1571	18.9	28.3
81	3	SF	25	1124.0	396.1	727.9	104.0	1014.3	338.5	675.8	96.5	1177.9	204.6	973.3	139.0	113.2	1764	64.2	117.8
82	5	C	0	1446.3	625.6	820.7	117.2	1133.5	461.2	672.3	96.0	1180.3	229.8	950.5	135.8	116.4	1789	65.0	115.9
83	1	SF	0	1276.3	526.7	749.6	107.1	1123.5	387.6	735.9	105.1	1243.1	367.1	876.0	125.1	112.5	1963	57.3	115.1
84	6	C	10	1592.5	1141.0	451.5	64.5	1357.0	927.6	429.4	61.3	1035.3	350.3	685.0	97.9	74.6	1626	45.9	79.6
85	15	S	25	1593.7	633.5	960.2	137.2	1043.7	557.4	486.3	69.5	965.9	235.0	730.9	104.4	103.7	1736	59.7	86.9
86	17	SD	0	1212.7	525.2	687.5	98.2	1077.8	566.3	511.5	73.1	1372.3	592.4	779.9	111.4	94.2	1741	54.1	92.2
87	20	SD	50	931.6	874.0	57.6	8.2	1039.6	612.4	427.2	61.0	363.9	270.9	93.0	13.3	27.5	1139	24.2	37.2
88	14	S	10	1405.7	511.9	893.8	127.7	1056.8	362.1	694.7	99.2	1490.8	523.4	967.4	138.2	121.7	1840	66.1	118.7
89	8	C	50	1257.0	1192.9	64.1	9.2	1192.9	1025.8	167.1	23.9	835.4	677.5	157.9	22.6	18.5	1073	17.3	23.2
90	5	C	0	1462.8	719.8	743.0	106.1	1102.6	427.9	674.7	96.4	1015.4	181.9	833.5	119.1	107.2	1568	68.4	107.7
91	12	V	50	889.3	675.5	213.8	30.5	973.8	675.7	298.1	42.6	855.4	391.8	463.6	66.2	46.5	1164	39.9	54.4
92	4	SF	50	975.6	411.8	563.8	80.5	717.6	282.9	434.7	62.1	1107.2	161.3	945.9	135.1	92.6	1564	59.2	98.6
93	3	SF	25	1123.8	477.3	646.5	92.4	1082.1	266.3	815.8	116.5	1198.3	173.6	1024.7	146.4	118.4	1593	74.3	131.5
94	14	S	10	1278.6	387.6	891.0	127.3	1024.6	225.4	799.2	114.2	1529.1	533.7	995.4	142.2	127.9	1652	77.4	128.2
95	7	C	25	1486.9	1299.9	187.0	26.7	1299.9	1157.6	142.3	20.3	1157.6	972.6	185.0	26.4	24.5	1363	18.0	23.4
96	10	V	10	1349.4		1349.4	192.8	1013.0	290.1	722.9	103.3	948.1	191.2	756.9	108.1	134.7	1587	84.9	105.7
97	2	SF	10	1228.9	654.6	574.3	82.0	1285.6	502.4	783.2	111.9	1185.4	236.8	948.6	135.5	109.8	1862	59.0	123.7
98	16	S	50	2008.3	649.4	1358.9	194.1	1547.8	416.2	1131.6	161.7	1171.3	182.3	989.0	141.3	165.7	1629	101.7	151.5
99	9	V	0	1380.0	450.8	929.2	132.7	1138.9	228.9	910.0	130.0	1058.5	215.0	843.5	120.5	127.7	1944	65.7	125.3
100	16	S	50	1821.1	732.5	1088.6	155.5	1359.8	416.4	943.4	134.8	953.7	106.1	847.6	121.1	137.1	1474	93.0	127.9
101	1	SF	0	1325.4	565.9	759.5	108.5	1301.3	510.2	791.1	113.0	1140.8	307.9	832.9	119.0	113.5	1773	64.0	116.0
102	19	SD	25	1083.6	369.9	713.7	102.0	1014.8	369.3	645.5	92.2	1364.7	526.6	838.1	119.7	104.6	1543	67.8	106.0
103	6	C	10	1647.1	971.5	675.6	96.5	1218.6	582.1	636.5	90.9	1557.9	711.5	846.4	120.9	102.8	1781	57.7	105.9
104	9	V	0	1438.9	747.7	691.2	98.7	1141.1	387.6	753.5	107.6	1017.1	243.4	773.7	110.5	105.6	1707	61.9	109.1
105	20	SD	50	902.3	675.4	226.9	32.4	959.5	459.9	499.6	71.4	1007.9	203.7	804.2	114.9	72.9	1706	42.7	93.1
106	13	S	0	1292.9	615.5	677.4	96.8	1003.7	343.2	660.5	94.4	1038.5	226.5	812.0	116.0	102.4	1921	53.3	105.2
107	8	C	50	1295.3	1223.6	71.7	10.2	1223.6	1072.3	151.4	21.6	750.4	614.2	136.2	19.5	17.1	1317	13.0	20.5
108	18	SD	10	1212.9	468.2	744.7	106.4	1048.1	469.8	578.3	82.6	1056.2	286.1	770.1	110.0	99.7	1600	62.3	96.3
109	4	SF	50	1005.7	591.0	414.7	59.2	853.9	293.5	560.4	80.1	1495.6	407.3	1088.3	155.5	98.3	1837	53.5	117.8
110	13	S	0	1389.2	649.9	739.3	105.6	1003.6	340.5	663.1	94.7	1015.6	270.7	744.9	106.4	102.3	2164	47.3	100.6
111	7	C	25	1572.6	1228.6	344.0	49.1	1228.6	1150.3	78.3	11.2	1150.3	878.3	272.0	38.9	33.1	1484	22.3	25.0
112	17	SD	0	1298.2	969.3	328.9	47.0	1094.7	1241.9	-147.2	-21.0	1241.9	871.8	370.1	52.9	26.3	1412	18.6	15.9
113	15	S	25	1488.9	523.0	965.9	138.0	1092.9	744.4	348.5	49.8	948.5	161.8	786.7	112.4	100.1	1840	54.4	81.1
114	11	V	25	1154.9	408.6	746.3	106.6	1034.1	782.9	251.2	35.9	1008.5	177.1	831.4	118.8	87.1	1555	56.0	77.3
115	2	SF	10	1229.2	519.2	710.0	101.4	1120.1	998.6	121.5	17.4	1211.2	333.9	877.3	125.3	81.4	1562	52.1	71.3
116	11	V	25	1149.7	939.8	209.9	30.0	1047.1	1184.1	-137.0	-19.6	897.1	666.1	231.0	33.0	14.5	1432	10.1	6.7
117	10	V	10	1239.5	503.1	736.4	105.2	1028.5	632.4	396.1	56.6	994.8	219.7	775.1	110.7	90.8	1930	47.1	83.7
118	19	SD	25	1174.2	417.3	756.9	108.1	1047.9	306.6	741.3	105.9	835.1	157.4	677.7	96.8	103.6	1555	66.6	101.4
119	12	V	50	900.2	500.7	399.5	57.1	928.4	502.0	426.4	60.9	766.4	304.1	462.3	66.0	61.3	1514	40.5	63.5
120	18	SD	10	1226.0	344.4	881.6	125.9	1115.1	246.1	869.0	124.1	1195.5	250.2	945.3	135.0	128.4	1868	68.7	129.6
121	5	C	0	1368.3	585.4	782.9	111.8	1158.3	414.9	743.4	106.2	1179.0	261.8	917.2	131.0	116.4	2182	53.3	118.6
122	2	SF	10	1261.8	613.8	648.0	92.6	1139.2	893.4	245.8	35.1	893.4	193.0	700.4	100.1	75.9	1576	48.2	67.6
123	19	SD	25	1181.8	831.2	350.6	50.1	1029.8	553.0	476.8	68.1	979.3	305.8	673.5	96.2	71.5	1478	48.4	82.2
124	17	SD	0	1146.3	478.8	667.5	95.4	1021.5	344.2	677.3	96.8	996.0	220.0	776.0	110.9	101.0	1686	59.9	103.8
125	9	V	0	1417.7	578.6	839.1	119.9	1234.5	430.6	803.9	114.8	1157.9	273.5	884.4	126.3	120.4	1907	63.1	120.6
126	10	V	10	1305.2	525.8	779.4	111.3	1014.4	253.8	760.6	108.7	989.3	177.1	812.2	116.0	112.0	1794	62.4	112.3
127	11	V	25	1135.0	329.8	805.2	115.0	1026.3	231.8	794.5	113.5	979.2	160.6	818.6	116.9	115.2	1570	73.3	115.2
128	1	SF	0	1390.9	765.3	625.6	89.4	1428.8	792.8	636.0	90.9	1501.9	771.8	730.1	104.3	94.8	1619	58.6	97.6
129	8	C	50	1412.7	1452.6	-39.9	-5.7	1452.6	1288.0	164.6	23.5	846.4	685.9	160.6	22.9	13.6	1230	11.0	23.2
130	20	SD	50	968.3	562.7	405.6	57.9	913.1	412.6	500.5	71.5	823.9	184.4	639.5	91.4	73.6	1318	55.8	81.4
131	11	V	25	1113.5	376.1	737.4	105.3	1017.4	208.3	809.1	115.6	1404.1	533.5	870.6	124.4	115.1	1681	68.5	120.0
132	20	SD	50	954.0	537.7	416.3	59.5	918.0	280.1	637.9	91.1	1032.5	204.3	828.2	118.3	89.6	1555	57.6	104.7
133	7	C	25	1507.3	1346.6	160.7	23.0	1346.6	1176.6	170.0	24.3	1176.6	884.8	291.8	41.7	29.6	1471	20.2	33.0
134	18	SD	10	1207.8	412.9	794.9	113.6	1055.8	323.7	732.1	104.6	1082.4	182.1	900.3	128.6	115.6	1851	62.4	116.6
135	7	C	25	1414.4	1160.6	253.8	36.3	1160.6	1068.5	92.1	13.2	1068.5	942.5	126.0	18.0	22.5	1576	14.3	15.6
136	3	SF	25	924.9	372.1	552.8	79.0	1067.4	386.2	681.2	97.3	1056.1	200.1	856.0	122.3	99.5	1749	56.9	109.8

PEN	TREAT.	DILUENT	LEVEL	FEED IN	FEED OUT	INTAKE1	INTAKE/DAY	FEED IN	FEED OUT	INTAKE2	INTAKE/DAY	FEED IN	FEED OUT	INTAKE3	INTAKE/DAY	AVE FI/DAY	WEEK 3 BW	SFI	AVE WK2+3
137	14	S	10	1361.0	473.8	887.2	126.7	1052.2	233.0	819.2	117.0	1417.2	448.1	969.1	138.4	127.4	1941	65.6	127.7
138	12	V	50	1000.7	561.2	439.5	62.8	976.0	469.6	506.4	72.3	923.6	219.0	704.6	100.7	78.6	1589	49.5	86.5
139	8	C	50	1358.4	1346.4	12.0	1.7	1346.4	1167.7	178.7	25.5	998.6	813.6	185.1	26.4	17.9	1442	12.4	26.0
140	16	S	50	1976.0	980.6	995.4	142.2	1292.6	439.7	852.9	121.8	731.7	326.6	405.1	57.9	107.3	1780	60.3	89.9
141	2	SF	10	1165.1	299.2	865.9	123.7	1142.8	282.1	860.7	123.0	1338.9	394.7	944.2	134.9	127.2	1962	64.8	128.9
142	9	V	0	1690.3	882.2	808.1	115.4	1173.1	461.2	711.9	101.7	1039.7	224.5	815.2	116.5	111.2	2168	51.3	109.1
143	18	SD	10	1295.7	585.1	710.6	101.5	1020.8	323.1	697.7	99.7	1115.6	244.6	871.0	124.4	108.5	1897	57.2	112.1
144	5	C	0	1223.8	746.8	477.0	68.1	1314.6	722.9	591.7	84.5	1315.4	505.2	810.2	115.7	89.5	1783	50.2	100.1
145	15	S	25	1471.4	875.6	595.8	85.1	1151.4	529.2	622.2	88.9	1036.0	436.8	599.2	85.6	86.5	1664	52.0	87.2
146	17	SD	0	1214.3	359.4	854.9	122.1	1044.3	262.3	782.0	111.7	1233.9	380.0	853.9	122.0	118.6	2000	59.3	116.9
147	13	S	0	1507.4	763.1	744.3	106.3	1074.9	355.1	719.8	102.8	1054.3	204.1	850.2	121.5	110.2	1746	63.1	112.1
148	12	V	50	941.0	405.1	535.9	76.6	981.5	287.2	694.3	99.2	1409.5	648.6	760.9	108.7	94.8	1443	65.7	103.9
149	3	SF	25	955.0	250.3	704.7	100.7	1113.0	311.7	801.3	114.5	1256.8	230.2	1026.6	146.7	120.6	1571	76.8	130.6
150	13	S	0	1376.0	656.4	719.6	102.8	1035.0	485.7	549.3	78.5	1258.5	490.7	767.8	109.7	97.0	1680	57.7	94.1
151	15	S	25	1406.4	511.4	895.0	127.9	1000.4	280.5	719.9	102.8	1416.3	308.6	1107.7	158.2	129.6	1785	72.6	130.5
152	4	SF	50	1012.2	678.8	333.4	47.6	925.7	358.8	566.9	81.0	1243.6	288.8	954.8	136.4	88.3	1780	49.6	108.7
153	1	SF	0	1374.6	638.8	735.8	105.1	1396.0	527.1	868.9	124.1	1333.6	412.9	920.7	131.5	120.3	2323	51.8	127.8
154	14	S	10	1337.8	457.4	880.4	125.8	1157.2	337.1	820.1	117.2	1337.2	366.8	970.4	138.6	127.2	1936	65.7	127.9
155	16	S	50	1782.6	607.4	1175.2	167.9	1339.9	274.0	1065.9	152.3	882.7	404.2	478.5	68.4	129.5	1877	69.0	110.3
156	4	SF	50	1014.5	981.1	33.4	4.8	981.1	998.7	-17.6	-2.5	786.9	532.3	254.6	36.4	12.9	1381	9.3	16.9
157	19	SD	25	1156.4	567.2	589.2	84.2	1041.1	336.8	704.3	100.6	1136.3	165.0	971.3	138.8	107.8	1410	76.5	119.7
158	6	C	10	1411.1	944.0	467.1	66.7	1156.5	685.0	471.5	67.4	1065.7	504.5	561.2	80.2	71.4	1562	45.7	73.8
159	6	C	10	1550.7	1180.5	370.2	52.9	1180.5	872.9	307.6	43.9	872.9	324.6	548.3	78.3	58.4	1932	30.2	61.1
160	10	V	10	1203.7	465.7	738.0	105.4	1089.5	259.9	829.6	118.5	1402.4	377.1	1025.3	146.5	123.5	1732	71.3	132.5

PERIOD 2: 22/09/2003 - 13/10/2003

PEN	TREAT.	DILUENT	LEVEL	FEED IN	FEED OUT	INTAKE1	INTAKE/DAY	FEED IN	FEED OUT	INTAKE2	INTAKE/DAY	FEED IN	FEED OUT	INTAKE3	INTAKE/DAY	AVE FI/DAY	BW	SFI
1	9	V	0	1462.3	656.3	806.0	115.1	1608.9	769.9	839.0	119.9	1770.9	916.4	854.5	122.1	119.0	1619	73.5
2	6	C	50	1148.3	1037.6	110.7	15.8	1404.7	1157.7	247.0	35.3	1402.2	1153.9	248.3	35.6	28.9	1206	23.9
3	11	V	25	1155.1	321.0	834.1	119.2	1269.9	367.2	902.7	129.0	1290.8	397.1	893.7	127.7	125.3	1609	77.9
4	10	V	50	923.0	464.1	458.9	65.6	991.9	452.9	539.0	77.0	1115.3	559.3	556.0	79.4	74.0	1337	55.3
5	18	SD	50	960.9	312.1	648.8	92.7	990.1	249.8	740.3	105.8	1019.2	250.2	769.0	109.9	102.8	1579	65.1
6	2	SF	50	1046.9	509.8	537.1	76.7	1115.5	290.5	825.0	117.9	1134.0	426.0	708.0	101.1	98.6	1406	70.1
7	14	S	50	2197.2	1089.5	1107.7	158.2	2287.3	1018.4	1268.9	181.3	2339.2	958.3	1380.9	197.3	178.9	1715	104.3
8	10	V	50	912.0	310.3	601.7	86.0	1029.2	335.4	693.8	99.1	1106.8	381.8	725.0	103.6	96.2	1561	61.6
9	20	SD	10	1328.9	364.7	964.2	137.7	1504.5	476.2	1028.3	146.9	1553.0	521.1	1031.9	147.4	144.0	1890	76.2
10	19	SD	25	1124.5	278.8	845.7	120.8	1197.1	302.4	894.7	127.8	1324.3	337.7	986.6	140.9	129.9	1736	74.8
11	16	S	10	1376.1	401.4	974.7	139.2	1481.5	488.9	992.6	141.8	1580.6	571.4	1009.2	144.2	141.7	1780	79.6
12	12	V	10	1257.8	427.1	830.7	118.7	1455.0	632.5	822.5	117.5	1494.6	654.0	840.6	120.1	118.8	1466	81.0
13	17	SD	0	1121.5	203.5	918.0	131.1	1322.4	477.4	845.0	120.7	1415.9	548.8	867.1	123.9	125.2	1886	66.4
14	11	V	25	1062.7	339.1	723.6	103.4	1121.4	378.1	743.3	106.2	1262.6	385.9	876.7	125.2	111.6	1622	68.8
15	4	SF	10	1411.6	270.2	1141.4	163.1	1479.4	418.1	1061.3	161.6	1634.4	561.7	1072.7	153.2	156.0	1845	84.5
16	1	SF	0	1490.6	590.9	899.7	128.5	1572.0	710.5	861.5	123.1	1676.8	734.8	942.0	134.6	128.7	1808	71.2
17	13	S	0	1555.2	724.7	830.5	118.6	1568.4	839.0	729.4	104.2	1769.4	933.8	835.6	119.4	114.1	1610	70.9
18	20	SD	10	1286.9	301.6	985.3	140.8	1278.7	320.0	958.7	137.0	1592.4	498.3	1094.1	156.3	144.7	1684	85.9
19	18	SD	50	904.3	293.0	611.3	87.3	1050.8	435.7	615.1	87.9	1005.8	343.4	662.4	94.6	89.9	1445	62.2
20	12	V	10	1442.4	508.3	934.1	133.4	1367.3	360.7	1006.6	143.8	1523.2	549.6	973.6	139.1	138.8	1791	77.5
21	15	S	25	1308.9	362.0	946.9	135.3	1546.4	510.2	1036.2	148.0	1800.5	638.4	1162.1	166.0	149.8	1730	86.6
22	5	C	0	1610.2	801.0	809.2	115.6	1703.4	895.6	807.8	115.4	1676.9	874.5	802.4	114.6	115.2	1589	72.5
23	7	C	25	1360.9	992.0	368.9	52.7	1589.2	1303.5	285.7	40.8	1535.4	1184.7	350.7	50.1	47.9	1255	38.1
24	17	SD	0	1253.8	413.3	840.5	120.1	1333.6	647.0	686.6	98.1	1388.3	588.7	799.6	114.2	110.8	1876	59.1
25	9	V	0	1564.5	780.1	784.4	112.1	1647.9	988.8	659.1	94.2	1730.7	1068.2	662.5	94.6	100.3	1943	51.6
26	4	SF	10	1460.3	636.0	824.3	117.8	1323.9	729.6	594.3	84.9	1542.4	816.1	726.3	103.8	102.1	1413	72.3
27	3	SF	25	1215.9	197.9	1018.0	145.4	1253.1	369.1	884.0	126.3	1444.7	453.1	991.6	141.7	137.8	1760	78.3
28	2	SF	50	1075.8	632.1	443.7	63.4	1085.2	675.2	410.0	58.6	1183.5	598.4	585.1	83.6	68.6	1469	46.6
29	6	C	50	1070.6	882.0	188.6	26.9	1503.1	1158.5	344.7	49.2	1497.1	1167.0	330.2	47.2	41.1	1356	30.3
30	16	S	10	1286.4	485.0	801.4	114.5	1495.5	617.8	877.7	125.4	1582.4	678.2	904.2	129.2	123.0	1794	68.6
31	3	SF	25	1315.4	287.3	1028.1	146.9	1176.2	1884.7	-708.5	-101.2	1361.5	315.6	1045.9	149.4	65.0	1688	38.5
32	1	SF	0	1476.6	661.8	814.8	116.4	1647.0	849.6	797.4	113.9	1886.8	1015.4	871.4	124.5	118.3	1697	69.7
33	19	SD	25	1195.4	272.1	923.3	131.9	1219.8	179.0	1040.8	148.7	1386.5	217.9	1168.6	166.9	149.2	1684	88.6
34	5	C	0	1626.9	633.1	993.8	142.0	1744.3	823.3	921.0	131.6	1871.4	944.7	926.7	132.4	135.3	2001	67.6
35	8	C	10	1575.9	958.8	617.1	88.2	1652.8	688.9	963.9	137.7	1745.5	677.1	1068.4	152.6	126.2	2051	61.5
36	8	C	10	1517.7	668.2	849.5	121.4	1545.1	660.1	885.0	126.4	1682.3	773.6	908.7	129.8	125.9	1830	68.8
37	13	S	0	1605.4	722.5	882.9	126.1	1708.5	837.0	871.5	124.5	1821.8	910.3	911.5	130.2	126.9	1965	64.6
38	7	C	25	1316.1	857.8	458.3	65.5	1576.1	1239.2	336.9	48.1	1504.5	1266.7	237.8	34.0	49.2	1337	36.8
39	15	S	25	1537.7	458.6	1079.1	154.2	1460.8	367.9	1092.9	156.1	1708.1	535.7	1172.4	167.5	159.3	1864	85.4
40	14	S	50	1942.4	698.2	1244.2	177.7	1990.4	600.3	1390.1	198.6	2167.4	733.9	1433.5	204.8	193.7	1662	116.5
41	10	V	50	848.7	422.5	426.2	60.9	985.5	262.4	723.1	103.3	1121.9	311.3	810.6	115.8	93.3	1418	65.8
42	15	S	25	1452.4	479.4	973.0	139.0	1775.6	476.4	1299.2	185.6	1725.8	551.8	1174.0	167.7	164.1	1773	92.6
43	3	SF	25	1207.6	271.8	935.8	133.7	1238.6	318.6	920.0	131.4	1366.2	365.0	1001.2	143.0	136.0	1680	81.0
44	3	SF	25	1212.9	249.5	963.4	137.6	1156.7	211.1	945.6	135.1	1277.1	257.8	1019.3	145.6	139.4	1777	78.5
45	11	V	25	1119.6	255.6	864.0	123.4	1154.0	265.9	888.2	126.9	1209.1	310.2	898.9	128.4	126.2	1625	77.7
46	17	SD	0	1131.4	392.6	738.8	105.5	1361.4	563.7	797.7	114.0	1383.3	446.1	937.2	133.9	117.8	1900	62.0
47	16	S	10	1366.7	472.1	894.6	127.8	1304.9	400.8	904.1	129.2	1519.7	561.1	958.6	136.9	131.3	1941	67.6
48	20	SD	10	1315.9	298.5	1017.4	145.3	1379.0	355.6	1023.4	146.2	1626.6	636.8	989.8	141.4	144.3	1670	86.4
49	7	C	25	1341.0	1090.0	251.0	35.9	1498.9	1144.5	354.4	50.6	1560.7	1143.1	417.6	59.7	48.7	926	52.6
50	9	V	0	1534.0	725.5	808.5	115.5	1704.5	917.6	786.9	112.4	1798.5	1040.2	758.3	108.3	112.1	1672	67.0
51	4	SF	10	1515.6	548.7	966.9	138.1	1441.2	522.6	918.6	131.2	1571.1	636.4	934.7	133.5	134.3	1611	83.4
52	4	SF	10	1471.7	381.9	1089.8	155.7	1415.6	433.3	982.3	140.3	1469.5	482.7	986.8	141.0	145.7	1870	77.9
53	10	V	50	878.6	489.9	388.7	55.5	1036.5	442.1	594.4	84.9	1153.6	342.0	811.6	115.9	85.5	1278	66.9
54	6	C	50	1061.9	924.5	137.4	19.6	1462.1	1185.5	276.6	39.5	1461.6	1183.7	277.9	39.7	32.9	867	38.0
55	19	SD	25	1212.3	384.8	827.5	118.2	1145.8	409.1	736.7	105.2	1307.1	456.5	850.6	121.5	115.0	1658	69.4
56	20	SD	10	1325.3	291.8	1033.5	147.6	1426.2	577.4	848.8	121.3	1548.5	528.7	1019.8	145.7	138.2	1814	76.2
57	15	S	25	1313.3	236.6	1076.7	153.8	1515.0	441.2	1073.8	153.4	1734.4	577.1	1157.3	165.3	157.5	1744	90.3
58	11	V	25	1136.4	191.3	945.1	135.0	1150.8	320.6	830.2	118.6	1181.1	236.2	944.9	135.0	129.5	1601	80.9
59	16	S	10	1291.0	312.8	978.2	139.7	1413.0	248.1	1164.9	166.4	1366.2	280.4	1085.8	155.1	153.8	1942	79.2
60	8	C	10	1485.2	868.2	617.0	88.1	1656.4	1154.2	502.2	71.7	1777.3	1074.0	703.3	100.5	86.8	1353	64.1
61	13	S	0	1623.8	871.2	752.6	107.5	1605.7	888.4	717.3	102.5	1843.9	1160.9	683.0	97.6	102.5	1478	69.4
62	18	SD	50	883.7	564.6	319.1	45.6	953.9	489.3	464.6	66.4	1019.6	359.5	660.1	94.3	68.8	1499	45.9
63	18	SD	50	966.6	492.6	474.0	67.7	979.0	407.1	571.9	81.7	1009.9	428.4	581.5	83.1	77.5	1365	56.8

PEN	TREAT.	DILUENT	LEVEL	FEED IN	FEED OUT	INTAKE1	INTAKE/DAY	FEED IN	FEED OUT	INTAKE2	INTAKE/DAY	FEED IN	FEED OUT	INTAKE3	INTAKE/DAY	AVE FI/DAY	BW	SFI
64	14	S	50	2004.9	725.1	1279.8	182.8	1700.9	787.0	913.9	130.6	2042.8	629.5	1413.3	201.9	171.8	1662	103.3
65	1	SF	0	1606.1	849.9	756.2	108.0	1778.3	746.6	1031.7	147.4	1775.1	1106.0	669.1	95.6	117.0	1731	67.6
66	6	C	50	1122.8	945.1	177.7	25.4	1333.8	1043.4	290.4	41.5	1458.4	1155.2	303.2	43.3	36.7	1305	28.1
67	17	SD	0	1154.6	240.0	914.6	130.7	1262.8	462.7	800.1	114.3	1447.7	408.5	1039.2	148.5	131.1	2260	58.0
68	5	C	0	1586.7	593.1	993.6	141.9	1606.9	661.5	945.4	135.1	1794.4	743.6	1050.8	150.1	142.4	2121	67.1
69	14	S	50	1934.3	766.1	1168.2	166.9	1683.7	547.8	1135.9	162.3	1862.9	534.8	1328.1	189.7	173.0	1529	113.1
70	1	SF	0	1586.5	794.3	792.2	113.2	1685.7	871.6	814.1	116.3	1704.8	895.4	809.4	115.6	115.0	1655	69.5
71	2	SF	50	1065.1	306.2	758.9	108.4	1126.7	319.2	807.5	115.4	1161.3	178.0	983.3	140.5	121.4	1636	74.2
72	5	C	0	1611.9	693.2	918.7	131.2	1722.2	852.6	869.6	124.2	1824.4	913.0	911.4	130.2	128.6	1914	67.2
73	12	V	10	1432.3	428.6	1003.7	143.4	1381.4	561.0	820.4	117.2	1548.4	592.1	956.3	136.6	132.4	1742	76.0
74	2	SF	50	1023.7	429.6	594.1	84.9	1136.5	325.3	811.2	115.9	1073.7	251.1	822.6	117.5	106.1	1641	64.6
75	8	C	10	1549.9	753.4	796.5	113.8	1665.9	1151.6	514.3	73.5	1757.0	1014.0	743.0	106.1	97.8	1650	59.3
76	9	V	0	1620.4	636.6	983.8	140.5	1689.9	928.6	761.3	108.8	1798.2	814.0	984.2	140.6	130.0	1971	65.9
77	12	V	10	1387.9	582.1	805.8	115.1	1507.5	629.6	877.9	125.4	1532.6	653.9	878.7	125.5	122.0	1515	80.5
78	19	SD	25	1255.1	248.2	1006.9	143.8	1274.2	350.2	924.0	132.0	1229.2	308.1	921.1	131.6	135.8	1578	86.1
79	13	S	0	1552.7	698.2	854.5	122.1	1712.2	954.1	758.1	108.3	1825.0	1041.4	783.6	111.9	114.1	1563	73.0
80	7	C	25	1210.6	832.1	378.5	54.1	1538.0	1163.8	374.2	53.5	1690.1	1322.0	368.1	52.6	53.4	1344	39.7
81	3	SF	25	1240.6	326.2	914.4	130.6	1253.7	447.4	806.3	115.2	1306.8	331.2	975.6	139.4	128.4	1777	72.3
82	5	C	0	1606.2	696.4	909.8	130.0	1714.8	877.6	837.2	119.6	1824.5	950.9	873.6	124.8	124.8	1770	70.5
83	1	SF	0	1628.9	694.9	934.0	133.4	1814.2	833.3	980.9	140.1	1790.5	796.9	993.6	141.9	138.5	1990	69.6
84	6	C	50	1159.0	1104.1	54.9	7.8	1542.2	1261.2	281.0	40.1	1329.5	1089.7	239.8	34.3	27.4	1782	15.4
85	15	S	25	1461.4	487.2	974.2	139.2	1521.0	655.6	865.4	123.6	1788.7	769.3	1019.4	145.6	136.1	1728	78.8
86	17	SD	0	1127.5	434.8	692.7	99.0	1364.8	663.1	701.7	100.2	1404.2	641.2	763.0	109.0	102.7	1679	61.2
87	20	SD	10	1337.8	571.9	765.9	109.4	1424.0	791.9	632.1	90.3	1615.6	965.0	650.6	92.9	97.6	1346	72.5
88	14	S	50	2068.1	804.7	1263.4	180.5	1692.7	524.6	1168.1	166.9	1992.4	890.4	1102.0	157.4	168.3	1600	105.2
89	8	C	10	1502.6	1034.9	467.7	66.8	1502.0	816.2	685.8	98.0	1709.9	1096.6	613.3	87.6	84.1	1398	60.2
90	5	C	0	1508.3	581.8	926.5	132.4	1545.3	668.2	877.1	125.3	1714.5	858.0	856.5	122.4	126.7	1674	75.7
91	12	V	10	1491.1	490.0	1001.1	143.0	1315.0	274.9	1040.1	148.6	1441.6	525.9	915.7	130.8	140.8	1583	88.9
92	4	SF	10	1322.7	385.0	937.7	134.0	1361.9	426.0	935.9	133.7	1534.4	579.1	955.3	136.5	134.7	1772	76.0
93	3	SF	25	1192.7	175.7	1017.0	145.3	1321.6	302.3	1019.3	145.6	1307.3	311.5	995.8	142.3	144.4	1636	88.3
94	14	S	50	1852.3	460.2	1392.1	198.9	1884.0	382.4	1501.6	214.5	1941.8	472.4	1469.4	209.9	207.8	1556	133.5
95	7	C	25	1174.7	979.1	195.6	27.9	1696.7	1483.4	213.3	30.5	1483.4	1366.0	117.4	16.8	25.1	1074	23.3
96	10	V	50	942.3	574.0	368.3	52.6	1111.3	764.9	346.4	49.5	1114.6	817.3	297.3	42.5	48.2	1204	40.0
97	2	SF	50	1063.2	369.8	693.4	99.1	1028.2	146.6	881.6	125.9	1134.9	216.4	918.5	131.2	118.7	1742	68.2
98	16	S	10	1335.4	288.3	1047.1	149.6	1482.6	494.7	987.9	141.1	1545.1	612.8	932.3	133.2	141.3	1745	81.0
99	9	V	0	1493.4	532.8	960.6	137.2	1678.6	1000.7	677.9	96.8	1835.7	918.6	917.1	131.0	121.7	2054	59.2
100	16	S	10	1302.7	422.5	880.2	125.7	1600.4	916.1	684.3	97.8	1545.4	630.1	915.3	130.8	118.1	1741	67.8
101	1	SF	0	1672.0	797.5	874.5	124.9	1645.2	770.6	874.6	124.9	1709.3	884.5	824.8	117.8	122.6	1765	69.4
102	19	SD	25	1270.4	525.7	744.7	106.4	1277.5	526.3	751.2	107.3	1305.3	528.4	776.9	111.0	108.2	1513	71.5
103	6	C	50	1171.9	1124.9	47.0	6.7	1468.5	1181.6	286.9	41.0	1499.7	1306.8	192.9	27.6	25.1	1157	21.7
104	9	V	0	1451.8	932.9	518.9	74.1	1664.5	1057.0	607.5	86.8	1687.7	921.9	765.8	109.4	90.1	1647	54.7
105	20	SD	10	1325.7	502.9	822.8	117.5	1446.8	517.1	929.7	132.8	1512.8	585.3	927.5	132.5	127.6	1872	68.2
106	13	S	0	1400.7	593.7	807.0	115.3	1631.0	847.8	783.2	111.9	1715.3	890.4	824.9	117.8	115.0	1995	57.6
107	8	C	10	1433.4	705.1	728.3	104.0	1621.6	858.4	763.2	109.0	1748.7	823.6	925.1	132.2	115.1	1842	62.5
108	18	SD	50	937.9	332.3	605.6	86.5	1009.0	408.9	600.1	85.7	1068.0	431.0	637.0	91.0	87.7	1398	62.8
109	4	SF	10	1365.0	189.4	1175.6	167.9	1568.7	505.5	1063.2	151.9	1479.6	520.1	959.5	137.1	152.3	2033	74.9
110	13	S	0	1478.5	574.7	903.8	129.1	1742.4	849.5	892.9	127.6	1739.4	817.3	922.1	131.7	129.5	2258	57.3
111	7	C	25	1356.8	971.6	385.2	55.0	1548.1	1207.3	340.8	48.7	1544.5	1360.2	184.3	26.3	43.3	1251	34.7
112	17	SD	0	1076.6	874.9	201.7	28.8	1421.2	1260.9	160.3	22.9	1260.9	906.0	354.9	50.7	34.1	1233	27.7
113	15	S	25	1582.5	385.2	1197.3	171.0	1574.8	469.5	1105.3	157.9	1645.4	579.5	1065.9	152.3	160.4	2018	79.5
114	11	V	25	1079.6	235.6	844.0	120.6	1147.2	305.6	841.6	120.2	1248.6	391.7	856.9	122.4	121.1	1442	84.0
115	2	SF	50	1079.0	532.9	546.1	78.0	1073.5	437.7	635.8	90.8	1184.1	314.9	869.2	124.2	97.7	1405	69.5
116	11	V	25	1101.6	702.5	399.1	57.0	1281.9	863.0	418.9	59.8	1327.8	946.1	381.7	54.5	57.1	1345	42.5
117	10	V	50	993.0	506.5	486.5	69.5	1000.5	375.3	625.2	89.3	1123.2	653.0	470.2	67.2	75.3	1588	47.4
118	19	SD	25	1154.4	319.7	834.7	119.2	1279.3	366.1	913.2	130.5	1241.9	278.1	963.8	137.7	129.1	1650	78.3
119	12	V	10	1386.0	397.0	989.0	141.3	1485.2	575.8	909.4	129.9	1486.1	449.4	1036.7	148.1	139.8	1859	75.2
120	18	SD	50	940.6	855.6	85.0	12.1	1077.3	514.2	563.1	80.4	1053.9	189.6	864.3	123.5	72.0	1522	47.3
121	5	C	0	1535.0	587.7	947.3	135.3	1621.1	732.4	888.7	127.0	1784.1	841.6	942.5	134.6	132.3	2142	61.8
122	2	SF	50	1097.4	460.8	636.6	90.9	1113.0	594.7	518.3	74.0	1096.5	403.6	692.9	99.0	88.0	1352	65.1
123	19	SD	25	1263.0	495.9	767.1	109.6	1293.5	546.3	747.2	106.7	1307.1	492.7	814.4	116.3	110.9	1431	77.5
124	17	SD	0	1090.3	295.4	794.9	113.6	1189.9	408.5	781.4	111.6	1467.7	538.5	929.2	132.7	119.3	1652	72.2
125	9	V	0	1499.8	635.9	863.9	123.4	1707.4	860.2	847.2	121.0	1800.9	893.8	907.1	129.6	124.7	1919	65.0
126	10	V	50	921.8	537.6	384.2	54.9	1098.5	574.2	524.3	74.9	1140.4	528.6	611.8	87.4	72.4	1448	50.0

PEN	TREAT.	DILUENT	LEVEL	FEED IN	FEED OUT	INTAKE1	INTAKE/DAY	FEED IN	FEED OUT	INTAKE2	INTAKE/DAY	FEED IN	FEED OUT	INTAKE3	INTAKE/DAY	AVE FI/DAY	BW	SFI
127	11	V	25	1101.9	228.0	873.9	124.8	1144.2	275.5	868.7	124.1	1225.4	279.3	946.1	135.2	128.0	1629	78.6
128	1	SF	0	1618.1	840.8	777.3	111.0	1577.4	904.6	672.8	96.1	1765.1	1100.7	664.4	94.9	100.7	1652	61.0
129	8	C	10	1401.0	412.7	988.3	141.2	1582.3	846.9	735.4	105.1	1638.4	751.9	886.5	126.6	124.3	1636	76.0
130	20	SD	10	1362.2	412.8	949.4	135.6	1540.8	678.1	862.7	123.2	1522.7	598.6	924.1	132.0	130.3	1592	81.8
131	11	V	25	1093.0	184.7	908.3	129.8	1138.4	277.1	861.3	123.0	1268.5	329.7	938.8	134.1	129.0	1675	77.0
132	20	SD	10	1270.9	355.5	915.4	130.8	1579.4	711.6	867.8	124.0	1555.5	635.4	920.1	131.4	128.7	1739	74.0
133	7	C	25	1430.4	896.5	533.9	76.3	1589.0	1180.0	409.0	58.4	1512.2	1239.4	272.8	39.0	57.9	1331	43.5
134	18	SD	50	900.3	305.7	594.6	84.9	1006.9	356.8	650.1	92.9	972.7	384.5	588.2	84.0	87.3	1502	58.1
135	7	C	25	1244.9	906.9	338.0	48.3	1561.7	1342.8	218.9	31.3	1342.8	1251.8	91.0	13.0	30.9	1365	22.6
136	3	SF	25	1207.2	303.2	904.0	129.1	1332.8	362.7	970.1	138.6	1408.3	403.7	1004.6	143.5	137.1	1719	79.7
137	14	S	50	1943.0	344.3	1598.7	228.4	1866.5	594.0	1272.5	181.8	2034.2	471.6	1562.6	223.2	211.1	1771	119.2
138	12	V	10	1379.4	454.1	925.3	132.2	1365.4	444.2	921.2	131.6	1487.0	521.2	965.8	138.0	133.9	1812	73.9
139	8	C	10	1285.1	698.3	586.8	83.8	1755.6	950.7	804.9	115.0	1708.6	939.5	769.1	109.9	102.9	1886	54.6
140	16	S	10	1287.6	309.1	978.5	139.8	1434.4	519.7	914.7	130.7	1552.5	637.8	914.7	130.7	133.7	1909	70.0
141	2	SF	50	1086.1	591.6	494.5	70.6	1094.0	524.4	569.6	81.4	1149.4	441.6	707.8	101.1	84.4	1438	58.7
142	9	V	0	1531.2	675.7	855.5	122.2	1523.9	672.8	851.1	121.6	1694.1	809.5	884.6	126.4	123.4	2252	54.8
143	18	SD	50	848.8	543.6	305.2	43.6	1056.1	579.8	476.3	68.0	1048.9	574.2	474.7	67.8	59.8	1550	38.6
144	5	C	0	1589.1	710.7	878.4	125.5	1669.2	906.4	762.8	109.0	1784.1	876.2	907.9	129.7	121.4	1751	69.3
145	15	S	25	1435.4	447.0	988.4	141.2	1527.8	573.3	954.5	136.4	1632.4	707.5	924.9	132.1	136.6	1697	80.5
146	17	SD	0	1167.5	240.6	926.9	132.4	1337.1	425.2	911.9	130.3	1343.7	450.6	893.1	127.6	130.1	1964	66.2
147	13	S	0	1478.7	527.8	950.9	135.8	1491.2	594.5	896.7	128.1	1667.5	730.9	936.6	133.8	132.6	1835	72.3
148	12	V	10	1442.0	282.1	1159.9	165.7	1496.4	554.5	941.9	134.6	1467.1	391.7	1075.4	153.6	151.3	1890	80.1
149	3	SF	25	1173.7	177.2	996.5	142.4	1224.6	235.5	989.1	141.3	1257.7	227.6	1030.1	147.2	143.6	1542	93.1
150	13	S	0	1358.6	610.8	747.8	106.8	1718.6	1190.7	527.9	75.4	1752.3	990.0	762.3	108.9	97.0	1642	59.1
151	15	S	25	1471.3	310.4	1160.9	165.8	1493.9	421.5	1072.4	153.2	1571.9	454.8	1117.1	159.6	159.5	1810	88.1
152	4	SF	10	1478.9	391.6	1087.3	155.3	1402.2	458.4	943.8	134.8	1536.7	551.8	984.9	140.7	143.6	1849	77.7
153	1	SF	0	1587.4	646.4	941.0	134.4	1690.2	768.7	921.5	131.6	1764.0	798.0	966.0	138.0	134.7	2372	56.8
154	14	S	50	1998.7	704.6	1294.1	184.9	1970.8	663.9	1306.9	186.7	1964.9	429.0	1535.9	219.4	197.0	1897	103.8
155	16	S	10	1301.5	256.6	1044.9	149.3	1506.0	598.3	907.7	129.7	1550.5	499.0	1051.5	150.2	143.1	1907	75.0
156	4	SF	10	1339.4	439.9	899.5	128.5	1451.7	676.1	775.6	110.8	1571.3	649.2	922.1	131.7	123.7	1641	75.4
157	19	SD	25	1148.8	358.4	790.4	112.9	1327.3	536.0	791.3	113.0	1279.1	212.7	1066.4	152.3	126.1	1429	88.2
158	6	C	50	1097.6	1063.7	33.9	4.8	1378.5	1130.2	248.3	35.5	1438.4	1161.4	277.0	39.6	26.6	1127	23.6
159	6	C	50	1150.4	998.4	152.0	21.7	1385.9	1112.4	273.5	39.1	1358.8	1115.5	243.3	34.8	31.8	1405	22.7
160	10	V	50	919.2	706.0	213.2	30.5	991.8	642.8	349.0	49.9	1145.3	668.1	477.2	68.2	49.5	1347	36.7

PERIOD 3: 13/10/2003-03/11/2003																		
PEN	TREAT.	DILUENT	LEVEL	FEED IN	FEED OUT	INTAKE1	INTAKE/DAY	FEED IN	FEED OUT	INTAKE2	INTAKE/DAY	FEED IN	FEED OUT	INTAKE3	INTAKE/DAY	AVE FI/DAY	BW	SFI
1	9	V	0	1476.5	711.8	764.7	109.2	1729.9	954.3	775.6	110.8	1650.5	769.7	880.8	125.8	115.3	1667	69.2
2	6	S	10	1797.6	846.1	951.5	135.9	2016.1	826.4	1189.7	170.0	1808.9	605	1203.9	172.0	159.3	1791	88.9
3	11	V	25	1095.1	306.2	788.9	112.7	1197.5	437.6	759.9	108.6	1240.8	284.3	956.5	136.6	119.3	1601	74.5
4	10	V	10	1796.7	798.9	997.8	142.5	1571.2	798.8	772.4	110.3	1507.3	466.1	1041.2	148.7	133.9	1666	80.4
5	18	SF	10	1461.6	700.5	761.1	108.7	1648.8	810	838.8	119.8	1547.7	474.3	1073.4	153.3	127.3	1959	65.0
6	2	SD	10	1470.2	632.3	837.9	119.7	1516.4	827.6	688.8	98.4	1609.6	643	966.6	138.1	118.7	1649	72.0
7	14	C	10	1313.6	724.3	589.3	84.2	1402.2	725.1	677.1	96.7	1335.4	571.2	764.2	109.2	96.7	1736	55.7
8	10	V	10	1893.9	712.7	1181.2	168.7	1570.1	874.5	695.6	99.4	1559	445.1	1113.9	159.1	142.4	1912	74.5
9	20	SF	50	1023.0	381.1	641.9	91.7	1071.8	526.1	545.7	78.0	1069.4	176.2	893.2	127.6	99.1	1659	59.7
10	19	SF	25	1275.2	401.3	873.9	124.8	1382.8	667.5	715.3	102.2	1385.3	373.3	1012	144.6	123.9	1808	68.5
11	16	C	50	1138.9	1014.91	124.0	17.7	1205.3	1079.41	125.9	18.0	1139.2	1020.99	118.21	16.9	17.5	1183	14.8
12	12	V	50	931.1	469.6	461.5	65.9	1117.5	603.2	514.3	73.5	1079.2	370.4	708.8	101.3	80.2	1163	69.0
13	17	SF	0	1228.9	425.7	803.2	114.7	1347.6	521.3	826.3	118.0	1270.2	396	874.2	124.9	119.2	1834	65.0
14	11	V	25	1038.3	303.8	734.5	104.9	1252.8	508.8	744.0	106.3	1470.1	546.4	923.7	132.0	114.4	1694	67.5
15	4	SD	50	922.9	386.8	536.1	76.6	1020.5	570	450.5	64.4	962.8	206.3	756.3	108.0	83.0	1391	59.7
16	1	SD	0	1513.2	501.6	1011.6	144.5	1637.1	919	718.1	102.6	1698.8	728.3	970.5	138.6	128.6	1818	70.7
17	13	C	0	1473.3	665.2	808.1	115.4	1594.3	897	697.3	99.6	1667.9	876.2	791.7	113.1	109.4	1616	67.7
18	20	SF	50	1067.8	475.1	592.7	84.7	1104.3	553.1	551.2	78.7	1115.5	243.5	872	124.6	96.0	1425	67.4
19	18	SF	10	1514.4	930.2	584.2	83.5	1578.2	1071.6	506.6	72.4	1486.7	719	767.7	109.7	88.5	1655	53.5
20	12	V	50	900.7	655.6	245.1	35.0	1082.2	712	370.2	52.9	1133.2	706.3	426.9	61.0	49.6	1291	38.4
21	15	C	25	1341.7	1245.9	95.8	13.7	1245.9	1023.6	222.3	31.8	1290.5	1146.6	143.9	20.6	22.0	1313	16.8
22	5	S	0	1620.5	809.6	810.9	115.8	1738.1	1019.5	718.6	102.7	1710.2	822.2	888	126.9	115.1	1611	71.5
23	7	S	25	2107.3	903.9	1203.4	171.9	2195.6	1000.2	1195.4	170.8	2240	922.3	1317.7	188.2	177.0	1700	104.1
24	17	SF	0	1203.1	444.7	758.4	108.3	1303.1	674.7	628.4	89.8	1368.4	479.4	889	127.0	108.4	1770	61.2
25	9	V	0	1463.7	717.1	746.6	106.7	1578.1	888.6	689.5	98.5	1682.5	948.7	733.8	104.8	103.3	1979	52.2
26	4	SD	50	910.4	635.1	275.3	39.3	1047.8	583.7	464.1	66.3	1019.6	516.6	503	71.9	59.2	1070	55.3
27	3	SD	25	1231.2	294.7	936.5	133.8	1270.7	507.3	763.4	109.1	1325.4	230.4	1095	156.4	133.1	1712	77.7
28	2	SD	10	1458.9	551.5	907.4	129.6	1529.7	697.5	832.2	118.9	1570.3	305.5	1264.8	180.7	143.1	1825	78.4
29	6	S	10	1669.9	601.5	1068.4	152.6	1918.7	876.7	1042.0	148.9	2362.5	1004.3	1358.2	194.0	165.2	1892	87.3
30	16	C	50	1153.6	959.07	194.5	27.8	1153.8	945.41	208.4	29.8	1045.2	885.96	159.24	22.7	26.8	1277	21.0
31	3	SD	25	1180.3	209.6	970.7	138.7	1180.9	193.2	987.7	141.1	1377.8	264.3	1113.5	159.1	146.3	1647	88.8
32	1	SD	0	1499.0	558.9	940.1	134.3	1712.6	860.8	851.8	121.7	1657.9	797	860.9	123.0	126.3	1725	73.2
33	19	SF	25	1301.8	274.8	1027.0	146.7	1387.1	556.8	830.3	118.6	1455.9	283.8	1172.1	167.4	144.3	1772	81.4
34	5	S	0	1622.2	651.5	970.7	138.7	1807.7	898.5	909.2	129.9	1611	683	928	132.6	133.7	2020	66.2
35	8	S	50	2410.2	458.8	1951.4	278.8	2682.7	1073.1	1609.6	229.9	2946.4	1149.5	1796.9	256.7	255.1	2058	124.0
36	8	S	50	2451.2	548.8	1902.4	271.8	2613.0	1202.8	1410.2	201.5	2539.9	679.8	1860.1	265.7	246.3	1806	136.4
37	13	C	0	1498.9	593.3	905.6	129.4	1723.2	828.2	895.0	127.9	1577.4	624.7	952.7	136.1	131.1	1997	65.7
38	7	S	25	2021.1	674.4	1346.7	192.4	2209.3	932.4	1276.9	182.4	2566.2	1265.4	1300.8	185.8	186.9	1856	100.7
39	15	C	25	1268.7	1072.7	196.0	28.0	1072.7	932.1	140.6	20.1	1233.1	1170.5	62.6	8.9	19.0	1455	13.1
40	14	C	10	1294.9	630.8	664.1	94.9	1354.0	644.8	709.2	101.3	1639	634.6	1004.4	143.5	113.2	1803	62.8
41	10	V	10	1773.7	751.7	1022.0	146.0	1645.7	821.2	824.5	117.8	1599.5	710.9	888.6	126.9	130.2	1687	77.2
42	15	C	25	1254.2	1135.4	118.8	17.0	1135.4	980.7	154.7	22.1	1295.4	1143.2	152.2	21.7	20.3	1351	15.0
43	3	SD	25	1139.2	231	908.2	129.7	1381.8	661.3	720.5	102.9	1274.1	303.6	970.5	138.6	123.8	1651	75.0
44	3	SD	25	1156.4	187.5	968.9	138.4	1301.0	620.5	680.5	97.2	1247.6	405.2	842.4	120.3	118.7	1819	65.2
45	11	V	25	1680.3	969.9	710.4	101.5	1299.6	627.7	671.9	96.0	1284.9	272.2	1012.7	144.7	114.0	1692	67.4
46	17	SF	0	1203.2	460.7	742.5	106.1	1432.6	760.9	671.7	96.0	1500.4	511.3	989.1	141.3	114.4	1844	62.1
47	16	C	50	1108.1	942.46	165.6	23.7	1132.5	921.73	210.8	30.1	1021.5	872.36	149.14	21.3	25.0	1489	16.8
48	20	SF	50	1103.3	456.7	646.6	92.4	988.4	534.3	454.1	64.9	1742.3	333.4	1408.9	201.3	119.5	1480	80.7
49	7	S	25	•	•	•	•	•	•	•	•	•	•	•	•	•	1542	
50	9	V	0	1548.9	733.4	815.5	116.5	1663.2	950.7	712.5	101.8	1904	1048.2	855.8	122.3	113.5	1648	68.9
51	4	SD	50	930.6	530.1	400.5	57.2	1035.7	658.6	377.1	53.9	996.1	360.1	636	90.9	67.3	1284	52.4
52	4	SD	50	924.3	499.9	424.4	60.6	1026.7	546.8	479.9	68.6	1011.5	235.7	775.8	110.8	80.0	1489	53.7
53	10	V	10	1859.9	822.6	1037.3	148.2	1579.2	723.3	855.9	122.3	1211.2	763.9	447.3	63.9	111.5	1316	84.7
54	6	S	10	•	•	•	•	•	•	•	•	•	•	•	•	•	1509	
55	19	SF	25	1299.6	760.7	538.9	77.0	1384.0	642	742.0	106.0	1361.7	431.5	930.2	132.9	105.3	1763	59.7
56	20	SF	50	1049.8	685.4	364.4	52.1	1071.0	522	549.0	78.4	1146.5	283.7	862.8	123.3	84.6	1563	54.1
57	15	C	25	1271.8	1005.8	266.0	38.0	1340.4	1141.5	198.9	28.4	1141.5		1141.5	163.1	76.5		
58	11	V	25	1614.3	477	1137.3	162.5	1346.9	561.1	785.8	112.3	1248.8	215.7	1033.1	147.6	140.8	1566	89.9
59	16	C	50	1120.2	877.14	243.1	34.7	1039.2	852.76	186.4	26.6	1020.4	820.68	199.72	28.5	30.0	1382	21.7
60	8	S	50	2186.8	981.3	1205.5	172.2	2522.2	1093	1429.2	204.2	2779.5	1215.7	1563.8	223.4	199.9	1712	116.8
61	13	C	0	1575.4	794.9	780.5	111.5	1827.6	1135.1	692.5	98.9	1874	1207	667	95.3	101.9	1485	68.6
62	18	SF	10	1592.5	748.2	844.3	120.6	1754.3	818.8	935.5	133.6	1611.3	717.4	893.9	127.7	127.3	1829	69.6
63	18	SF	10	1529.4	832.5	696.9	99.6	1752.1	825.9	926.2	132.3	1553.6	584.6	989	141.3	124.4	1739	71.5
64	14	C	10	1316.7	729.6	587.1	83.9	1303.4	674.9	628.5	89.8	1288	726.3	561.7	80.2	84.6	1550	54.6
65	1	SD	0	1444.6	541.2	903.3	129.0	1740.8	905.7	835.1	119.3	1774	915.8	858.2	122.6	123.6	1880	65.8

PEN	TREAT.	DILUENT	LEVEL	FEED IN	FEED OUT	INTAKE1	INTAKE/DAY	FEED IN	FEED OUT	INTAKE2	INTAKE/DAY	FEED IN	FEED OUT	INTAKE3	INTAKE/DAY	AVE FI/DAY	BW	SFI
66	6	S	10	1810.3	831.8	978.5	139.8	1929.7	913.4	1016.3	145.2	1470.5	490.8	979.7	140.0	141.6	1783	79.4
67	17	SF	0	1194.9	415.9	779.0	111.3	1430.7	596.8	833.9	119.1	1456.7	405.4	1051.3	150.2	126.9	2261	56.1
68	5	S	0	1606.2	793.1	813.1	116.2	1790.2	720.9	1069.3	152.8	1684.2	584.6	1099.6	157.1	142.0	2209	64.3
69	14	C	10	1258.4	657.7	600.7	85.8	1342.8	710.7	632.1	90.3	1175.9	474.3	701.6	100.2	92.1	1496	61.6
70	1	SD	0	1509.4	725.9	783.5	111.9	1769.1	1471.5	297.6	42.5	1441.8	827.2	614.6	87.8	80.7	1651	48.9
71	2	SD	10	1554.8	567.9	986.9	141.0	1471.5	587.9	883.6	126.2	1809.2	442.7	1366.5	195.2	154.1	1743	88.4
72	5	S	0	1607.9	628.5	979.4	139.9	1701.6	803.3	898.2	128.3	1147	1053	94	13.4	93.9	1931	48.6
73	12	V	50	980.5	480.7	499.8	71.4	1105.0	430.9	674.1	96.3	1561.7	378	1183.7	169.1	112.3	1377	81.5
74	2	SD	10	1484.2	533.3	950.9	135.8	1643.0	542.7	1100.3	157.2	1893.8	498.4	1395.4	199.3	164.1	2003	81.9
75	8	S	50	2403.2	841.8	1561.4	223.1	2425.7	1032.3	1393.4	199.1	2398.2	980.2	1418	202.6	208.2	1931	107.8
76	9	V	0	1630.1	535.2	1094.9	156.4	1685.5	771.5	914.0	130.6	1101	709.4	391.6	55.9	114.3	2020	56.6
77	12	V	50	950.6	414.5	536.1	76.6	1157.8	560	597.8	85.4	1312.9	379.4	933.5	133.4	98.4	1240	79.4
78	19	SF	25	1324.1	371.4	952.7	136.1	1415.2	565	850.2	121.5	1306.4	313.5	992.9	141.8	133.1	1612	82.6
79	13	C	0	1461.4	680.1	781.3	111.6	1753.8	956.5	797.3	113.9	1747.9	999.6	748.3	106.9	110.8	1670	66.4
80	7	S	25	1930.1	537.9	1392.2	198.9	1934.5	672.9	1261.6	180.2	2023.9	723.7	1300.2	185.7	188.3	1810	104.0
81	3	SD	25	1184.7	404.2	780.5	111.5	1246.1	490.7	755.4	107.9	1184.8	235.6	949.2	135.6	118.3	1633	72.5
82	5	S	0	1700.8	645.8	1055.0	150.7	1810.8	924	886.8	126.7	1660.9	864.9	796	113.7	130.4	1840	70.9
83	1	SD	0	1363.5	398.4	965.1	137.9	1652.1	705.4	946.7	135.2	1680.7	647.6	1033.1	147.6	140.2	2067	67.8
84	6	S	10	1800.5	921	879.5	125.6	1802.3	966.2	836.1	119.4	1836.4	606.2	1230.2	175.7	140.3	1689	83.1
85	15	C	25	1244.0	1089.5	154.5	22.1	1089.5	936.3	153.2	21.9	1185.2	1039.2	146	20.9	21.6	1314	16.4
86	17	SF	0	1307.5	511.2	796.3	113.8	1376.6	806.4	570.2	81.5	1325.6	598	727.6	103.9	99.7	1616	61.7
87	20	SF	50	1023.4	518.1	505.3	72.2	1106.3	708.6	397.7	56.8	1077.2	394	683.2	97.6	75.5	1199	63.0
88	14	C	10	1248.5	677.1	571.4	81.6	1433.1	746.5	686.6	98.1	1267.9	448.9	819	117.0	98.9	1787	55.3
89	8	S	50	2266.1	1070.8	1195.3	170.8	2629.4	1207.8	1421.6	203.1	1740	710.9	1029.1	147.0	173.6	1615	107.5
90	5	S	0	1596.7	683.9	912.8	130.4	1776.6	917.1	859.5	122.8	1654.5	806.6	847.9	121.1	124.8	1694	73.7
91	12	V	50	938.3	791	147.3	21.0	1229.2	1017.4	211.8	30.3	1122	890.8	231.2	33.0	28.1	1038	27.1
92	4	SD	50	898.7	332.6	566.1	80.9	958.8	448.3	510.5	72.9	996	183.1	812.9	116.1	90.0	1486	60.5
93	3	SD	25	1194.0	260.6	933.4	133.3	1247.8	464.2	783.6	111.9	1181.5	202.1	979.4	139.9	128.4	1578	81.4
94	14	C	10	1298.4	734.6	563.8	80.5	1325.6	716.7	608.9	87.0	1243.6	429.3	814.3	116.3	94.6	1562	60.6
95	7	S	25	2080.8	838.8	1242.0	177.4	2293.7	1052.4	1241.3	177.3	2190.9	753.2	1437.7	205.4	186.7	1730	107.9
96	10	V	10	2027.9	780.5	1247.4	178.2	1580.0	730.3	849.7	121.4	1516.6	498.8	1017.8	145.4	148.3	1672	88.7
97	2	SD	10	1505.5	635.9	869.6	124.2	1513.6	641.8	871.8	124.5	1438.2	471	967.2	138.2	129.0	1954	66.0
98	16	C	50	1159.9	975.25	184.7	26.4	1087.7	877.43	210.3	30.0	1059.9	873.34	186.56	26.7	27.7	1197	23.1
99	9	V	0	1645.4	647.7	997.7	142.5	1719.2	765.7	953.5	136.2	1684.4	689.7	994.7	142.1	140.3	2038	68.8
100	16	C	50	1081.2	922.84	158.4	22.6	1087.0	894.69	192.3	27.5	1047.1	891.34	155.76	22.3	24.1	1261	19.1
101	1	SD	0	1549.1	599	950.1	135.7	1699.0	914.9	784.1	112.0	1676.8	819.4	857.4	122.5	123.4	1815	68.0
102	19	SF	25	1278.1	393.8	884.3	126.3	1276.3	567.5	708.8	101.3	1344.2	447.8	896.4	128.1	118.5	1516	78.2
103	6	S	10	1814.0	702.9	1111.1	158.7	2009.3	757.7	1251.6	178.8	2120.8	756.6	1364.2	194.9	177.5	1806	98.3
104	9	V	0	1657.7	801.1	856.6	122.4	1663.8	885.1	778.7	111.2	1599.2	838.6	760.6	108.7	114.1	1728	66.0
105	20	SF	50	1032.5	452.2	580.3	82.9	1063.4	413.1	650.3	92.9	1084.6	175.8	908.8	129.8	101.9	1623	62.8
106	13	C	0	1483.1	681.6	801.5	114.5	1623.7	828.9	794.8	113.5	1720.9	841.7	879.2	125.6	117.9	1984	59.4
107	8	S	50	2467.1	734.3	1732.8	247.5	2604.7	907.9	1696.8	242.4	2459.6	835.5	1624.1	232.0	240.7	1836	131.1
108	18	SF	10	1567.9	781.8	786.1	112.3	1627.1	784.5	842.6	120.4	1412.4	508.8	903.6	129.1	120.6	1604	75.2
109	4	SD	50	920.2	811.5	108.7	15.5	1056.1	430.9	625.2	89.3	1670.4	244.6	1425.8	203.7	102.8	1867	55.1
110	13	C	0	1372.5	429.3	943.2	134.7	1514.9	626.4	888.5	126.9	1670.8	734.6	936.3	133.8	131.8	2293	57.5
111	7	S	25	2130.5	732.7	1397.8	199.7	1945.1	722.4	1222.7	174.7	2239.3	638.2	1601.1	228.7	201.0	1783	112.7
112	17	SF	0	1274.9	1001.8	273.1	39.0	1529.8	1257.7	272.1	38.9	1257.7	1134.7	123	17.6	31.8	717	44.4
113	15	C	25	1182.2	1062.5	119.7	17.1	1375.0	1191.7	183.3	26.2	1191.7	1057	134.7	19.2	20.8	1623	12.8
114	11	V	25	1660.4	565.5	1094.9	156.4	1261.3	509.1	752.2	107.5	1223.1	267.8	955.3	136.5	133.4	1405	95.0
115	2	SD	10	1610.8	863.2	747.6	106.8	1608.5	805.3	803.2	114.7	1650.9	742.5	908.4	129.8	117.1	1571	74.5
116	11	V	25	1044.1	985.2	58.9	8.4	1347.4	1025.7	321.7	46.0	1363.1	809.8	553.3	79.0	44.5	1141	39.0
117	10	V	10	1757.7	847.7	910.0	130.0	1664.5	858.7	805.8	115.1	1460	551.6	908.4	129.8	125.0	1771	70.6
118	19	SF	25	1153.4	350.5	802.9	114.7	1357.0	519.8	837.2	119.6	1412.5	313.6	1098.9	157.0	130.4	1677	77.8
119	12	V	50	952.7	439.7	513.0	73.3	1177.7	550.3	627.4	89.6	1070.7	248	822.7	117.5	93.5	1546	60.5
120	18	SF	10	1516.6	441	1075.6	153.7	1682.4	725.8	956.6	136.7	1476.7	465.5	1011.2	144.5	144.9	1923	75.4
121	5	S	0	1621.4	630.3	991.1	141.6	1723.8	906.8	817.0	116.7	1670.2	780.1	890.1	127.2	128.5	2123	60.5
122	2	SD	10	1524.6	698.6	826.0	118.0	1524.7	842.9	681.8	97.4	1497.5	518.9	978.6	139.8	118.4	1618	73.2
123	19	SF	25	1202.9	702.3	500.6	71.5	1458.6	704.8	753.8	107.7	1427.8	572.2	855.6	122.2	100.5	1472	68.3
124	17	SF	0	1272.4	407	865.4	123.6	1489.3	662.1	827.2	118.2	1991.7	887.3	1104.4	157.8	133.2	1690	78.8
125	9	V	0	1641.4	625	1016.4	145.2	1778.1	876.4	901.7	128.8	1700.3	849.6	850.7	121.5	131.8	1939	68.0
126	10	V	10	1995.9	922.9	1073.0	153.3	1590.5	647.8	942.7	134.7	1434.9	586.2	848.7	121.2	138.4	1712	79.7
127	11	V	25	1582.3	441.9	1140.4	162.9	1172.8	382.3	790.5	112.9	1206.2	202.2	1004	143.4	139.8	1570	89.0
128	1	SD	0	1530.3	971.3	559.0	79.9	1837.6	1192.7	644.9	92.1	1701.2	1021.8	679.4	97.1	89.7	1602	56.0
129	8	S	50	2185.5	964	1221.5	174.5	2406.9	1057.1	1349.8	192.8	2634	1010.4	1623.6	231.9	199.8	1712	116.7
130	20	SF	50	1010.9	564	446.9	63.8	1086.0	629.4	458.6	65.2	1120.7	572.2	548.5	78.4	69.1	1350	51.2

PEN	TREAT.	DILUENT	LEVEL	FEED IN	FEED OUT	INTAKE1	INTAKE/DAY	FEED IN	FEED OUT	INTAKE2	INTAKE/DAY	FEED IN	FEED OUT	INTAKE3	INTAKE/DAY	AVE FI/DAY	BW	SFI
131	11	V	25	1709.0	471.5	1237.5	176.8	1317.3	416.7	900.6	128.7	1230.1	211.4	1018.7	145.5	150.3	1695	88.7
132	20	SF	50	1007.7	524.4	483.3	69.0	1047.4	428.6	618.8	88.4	1788.1	474.8	1313.3	187.6	115.0	1614	71.3
133	7	S	25	2080.2	827.5	1252.7	179.0	2144.3	745.7	1398.6	199.8	2065.9	726.3	1339.6	191.4	190.0	1920	99.0
134	18	SF	10	1593.7	871.1	722.6	103.2	1597.6	740.5	857.1	122.4	2088.2	860.9	1227.3	175.3	133.7	1970	67.9
135	7	S	25	1963.6	711.3	1252.3	178.9	1965.6	645.8	1319.8	188.5	2110	409.8	1700.2	242.9	203.4	2097	97.0
136	3	SD	25	1251.6	644.3	607.3	86.8	1341.2	661	680.2	97.2	1901.2	632.9	1268.3	181.2	121.7	1728	70.4
137	14	C	10	1262.7	606.3	656.4	93.8	1435.4	640.1	795.3	113.6	1234.7	322.6	912.1	130.3	112.6	1809	62.2
138	12	V	50	954.8	467.7	487.1	69.6	1125.3	482.4	642.9	91.8	1131.3	231.4	899.9	128.6	96.7	1505	64.2
139	8	S	50	2451.8	1170.3	1281.5	183.1	2721.1	1092.4	1628.7	232.7	2627.4	1050.9	1576.5	225.2	213.7	1841	116.1
140	16	C	50	1160.7	1020.1	140.6	20.1	1170.7	1050.35	120.4	17.2	988.7	857.31	131.39	18.8	18.7	1392	13.4
141	2	SD	10	1458.5	456.1	1002.4	143.2	1523.7	625.5	898.2	128.3	1365.5	327.4	1038.1	148.3	139.9	1737	80.6
142	9	V	0	1486.6	536.6	950.0	135.7	1613.9	753.5	860.4	122.9	1587.1	680.5	906.6	129.5	129.4	2298	56.3
143	18	SF	10	1546.8	676.9	869.9	124.3	1613.3	663.5	949.8	135.7	1519.3	571.6	947.7	135.4	131.8	1963	67.1
144	5	S	0	1669.4	897.1	772.3	110.3	1783.6	1438.5	345.1	49.3	1438.5	666.8	771.7	110.2	90.0	1757	51.2
145	15	C	25	1315.6	1097.4	218.2	31.2	1313.9	1116.9	197.0	28.1	1362.4	1199.5	162.9	23.3	27.5	1359	20.3
146	17	SF	0	1312.9	413.5	899.4	128.5	1445.9	610	835.9	119.4	1353.6	337.7	1015.9	145.1	131.0	1956	67.0
147	13	C	0	1396.4	883.7	512.7	73.2	1613.4	790.4	823.0	117.6	1577.3	710.8	866.5	123.8	104.9	1787	58.7
148	12	V	50	932.4	375.4	557.0	79.6	1057.2	452.2	605.0	86.4	1090.9	373.2	717.7	102.5	89.5	1473	60.8
149	3	SD	25	1198.9	213.5	985.4	140.8	1205.8	534.5	671.3	95.9	1193.1	232.2	960.9	137.3	124.6	1476	84.4
150	13	C	0	1434.8	622.6	812.2	116.0	1704.6	918.7	785.9	112.3	1636.9	891	745.9	106.6	111.6	1618	69.0
151	15	C	25	1138.7	956.8	181.9	26.0	1312.3	1039.8	272.5	38.9	1257.8	1049.8	208	29.7	31.5	1456	21.7
152	4	SD	50	924.6	386.6	538.0	76.9	958.9	516.9	442.0	63.1	1007.2	210.9	796.3	113.8	84.6	1517	55.8
153	1	SD	0	1519.9	501.9	1018.0	145.4	1648.7	698.7	950.0	135.7	1598.8	632.8	966	138.0	139.7	2401	58.2
154	14	C	10	1301.0	645.9	655.1	93.6	1253.6	555.9	697.7	99.7	1266.5	619.2	647.3	92.5	95.2	1842	51.7
155	16	C	50	1115.5	973.07	142.4	20.3	1082.2	977.13	105.1	15.0	1043.8	938.37	105.43	15.1	16.8	1407	11.9
156	4	SD	50	958.1	587.7	370.4	52.9	1025.4	595.4	430.0	61.4	1021.8	441.1	580.7	83.0	65.8	1297	50.7
157	19	SF	25	1154.8	297.9	856.9	122.4	1291.2	553.2	738.0	105.4	1409.5	353.2	1056.3	150.9	126.2	1442	87.6
158	6	S	10	1866.2	729.8	1136.4	162.3	1753.3	687.5	1065.8	152.3	1652.2	522.8	1129.4	161.3	158.6	1659	95.6
159	6	S	10	1783.6	779.2	1004.4	143.5	1649.2	790.3	858.9	122.7	1688	349.3	1338.7	191.2	152.5	1905	80.0
160	10	V	10	1730.4	536.1	1194.3	170.6	1634.6	710.3	924.3	132.0	1509.4	447.5	1061.9	151.7	151.5	1874	80.8

APPENDIX C: TRIAL 1 EGG PRODUCTION DATA

Phase 1:

PEN	TREAT	DILUENT	LEVEL	FREQ1	FREQ2	FREQ3	ROL	AVE EW	AVE EO
2	6	C	10	5	5	3	61.9	51.4	31.8
22	5	C	0	6	5	5	76.2	55.5	42.3
23	7	C	25	3	1	0	19.0	36.2	6.9
29	6	C	10	5	6	6	81.0	42.4	34.3
34	5	C	0	6	6	6	85.7	55.3	47.4
35	8	C	50	2	0	0	9.5	15.0	1.4
36	8	C	50	2	0	0	9.5	18.8	1.8
38	7	C	25	2	0	0	9.5	20.3	1.9
49	7	C	25	3	2	0	23.8	18.7	4.5
54	6	C	10	3	3	1	33.3	34.8	11.6
60	8	C	50	3	0	0	14.3	18.2	2.6
66	6	C	10	6	4	6	76.2	59.6	45.4
68	5	C	0	5	4	5	66.7	65.3	43.5
72	5	C	0	5	6	6	81.0	59.4	48.1
75	8	C	50	3	0	0	14.3	10.1	1.4
80	7	C	25	2	0	0	9.5	9.4	0.9
82	5	C	0	5	5	5	71.4	71.0	50.7
84	6	C	10	5	3	0	38.1	40.9	15.6
89	8	C	50	4	0	0	19.0	11.8	2.3
90	5	C	0	5	6	7	85.7	58.3	49.9
95	7	C	25	3	0	0	14.3	18.6	2.7
103	6	C	10	5	6	5	76.2	59.7	45.5
107	8	C	50	3	0	0	14.3	10.4	1.5
111	7	C	25	3	1	0	19.0	13.6	2.6
121	5	C	0	5	4	5	66.7	65.5	43.7
129	8	C	50	4	0	1	23.8	19.1	4.6
133	7	C	25	4	0	0	19.0	19.6	3.7
135	7	C	25	4	1	0	23.8	21.3	5.1
139	8	C	50	3	0	0	14.3	19.8	2.8
144	5	C	0	6	5	4	71.4	56.7	40.5
158	6	C	10	5	0	0	23.8	18.4	4.4
159	6	C	10	4	4	4	57.1	42.0	24.0
11	16	S	50	5	6	5	76.2	61.0	46.5
17	13	S	0	5	5	5	71.4	57.4	41.0
21	15	S	25	6	6	6	85.7	59.0	50.5
30	16	S	50	4	6	3	61.9	58.2	36.0
37	13	S	0	5	6	6	81.0	62.8	50.8
39	15	S	25	6	6	5	81.0	67.0	54.2
40	14	S	10	5	6	6	81.0	50.5	40.9
42	15	S	25	6	5	4	71.4	64.2	45.8
47	16	S	50	4	5	4	61.9	65.7	40.6
57	15	S	25	6	5	6	81.0	61.0	49.3
59	16	S	50	4	0	5	42.9	38.3	16.4
61	13	S	0	6	6	6	85.7	49.1	42.1
64	14	S	10	6	6	6	85.7	60.9	52.2
69	14	S	10	4	6	5	71.4	56.4	40.3

PEN	TREAT	DILUENT	LEVEL	FREQ1	FREQ2	FREQ3	ROL	AVE EW	AVE EO
79	13	S	0	5	6	5	76.2	64.8	49.4
85	15	S	25	6	6	5	81.0	60.2	48.7
88	14	S	10	6	7	6	90.5	51.8	46.9
94	14	S	10	6	7	7	95.2	63.0	60.0
98	16	S	50	6	7	6	90.5	54.6	49.4
100	16	S	50	5	4	3	57.1	51.0	29.2
106	13	S	0	5	7	6	85.7	59.8	51.3
110	13	S	0	5	6	7	85.7	55.3	47.4
113	15	S	25	6	6	6	85.7	62.4	53.5
137	14	S	10	6	6	6	85.7	65.4	56.1
140	16	S	50	5	5	5	71.4	54.1	38.6
145	15	S	25	5	4	3	57.1	67.4	38.5
147	13	S	0	6	5	7	85.7	63.3	54.2
150	13	S	0	6	6	4	76.2	60.5	46.1
151	15	S	25	6	5	5	76.2	52.1	39.7
154	14	S	10	5	7	6	85.7	62.6	53.6
155	16	S	50	5	6	4	71.4	49.2	35.1
5	18	SD	10	6	4	5	71.4	62.8	44.8
9	20	SD	50	5	0	0	23.8	18.7	4.5
10	19	SD	25	4	3	2	42.9	66.8	28.6
13	17	SD	0	5	6	5	76.2	62.3	47.5
18	20	SD	50	4	1	0	23.8	18.2	4.3
19	18	SD	10	5	4	0	42.9	36.1	15.5
24	17	SD	0	4	7	5	76.2	62.1	47.3
33	19	SD	25	5	6	6	81.0	61.7	50.0
46	17	SD	0	6	4	5	71.4	55.3	39.5
48	20	SD	50	3	0	3	28.6	27.5	7.8
55	19	SD	25	4	4	2	47.6	62.1	29.6
56	20	SD	50	3	0	0	14.3	19.5	2.8
62	18	SD	10	6	6	5	81.0	57.8	46.8
63	18	SD	10	6	6	6	85.7	63.7	54.6
67	17	SD	0	6	6	6	85.7	60.4	51.8
78	19	SD	25	6	6	5	81.0	57.7	46.7
86	17	SD	0	5	5	3	61.9	59.4	36.8
87	20	SD	50	2	0	0	9.5	16.7	1.6
102	19	SD	25	6	4	5	71.4	61.7	44.1
105	20	SD	50	3	0	0	14.3	6.1	0.9
108	18	SD	10	6	6	6	85.7	58.2	49.9
112	17	SD	0	4	2	0	28.6	35.7	10.2
118	19	SD	25	6	5	4	71.4	51.0	36.5
120	18	SD	10	5	7	6	85.7	59.3	50.8
123	19	SD	25	4	5	5	66.7	57.1	38.1
124	17	SD	0	5	6	5	76.2	63.1	48.1
130	20	SD	50	3	0	1	19.0	38.4	7.3
132	20	SD	50	4	4	1	42.9	41.0	17.6
134	18	SD	10	5	6	7	85.7	53.1	45.5
143	18	SD	10	5	6	6	81.0	56.3	45.6
146	17	SD	0	6	5	4	71.4	64.3	45.9
157	19	SD	25	5	6	5	76.2	50.6	38.5

PEN	TREAT	DILUENT	LEVEL	FREQ1	FREQ2	FREQ3	ROL	AVE EW	AVE EO
6	2	SF	10	6	6	6	85.7	65.2	55.9
15	4	SF	50	3	0	1	19.0	40.3	7.7
16	1	SF	0	6	7	7	95.2	57.5	54.7
26	4	SF	50	1	0	0	4.8	18.9	0.9
27	3	SF	25	3	4	4	52.4	57.6	30.2
28	2	SF	10	5	3	6	66.7	44.0	29.4
31	3	SF	25	4	6	6	76.2	64.0	48.7
32	1	SF	0	5	6	7	85.7	60.9	52.2
43	3	SF	25	5	3	0	38.1	44.7	17.0
44	3	SF	25	6	5	6	81.0	41.4	33.5
51	4	SF	50	2	0	0	9.5	19.3	1.8
52	4	SF	50	4	2	0	28.6	20.1	5.7
65	1	SF	0	6	6	6	85.7	52.4	44.9
70	1	SF	0	5	4	5	66.7	55.0	36.7
71	2	SF	10	6	4	6	76.2	67.8	51.7
74	2	SF	10	4	6	5	71.4	61.2	43.7
81	3	SF	25	5	5	5	71.4	60.8	43.4
83	1	SF	0	4	5	5	66.7	65.3	43.5
92	4	SF	50	5	3	1	42.9	21.2	9.1
93	3	SF	25	5	5	6	76.2	58.4	44.5
97	2	SF	10	3	1	5	42.9	24.1	10.3
101	1	SF	0	6	7	7	95.2	64.1	61.1
109	4	SF	50	5	5	4	66.7	49.0	32.7
115	2	SF	10	5	5	6	76.2	64.1	48.9
122	2	SF	10	5	3	6	66.7	58.0	38.6
128	1	SF	0	5	5	5	71.4	51.1	36.5
136	3	SF	25	5	3	7	71.4	66.7	47.6
141	2	SF	10	6	6	7	90.5	55.7	50.4
149	3	SF	25	6	5	6	81.0	46.7	37.8
152	4	SF	50	2	1	3	28.6	42.7	12.2
153	1	SF	0	5	6	7	85.7	67.3	57.7
156	4	SF	50	3	0	0	14.3	16.5	2.4
1	9	V	0	5	5	6	76.2	59.7	45.5
3	11	V	25	5	5	4	66.7	55.8	37.2
4	10	V	10	6	5	6	81.0	60.1	48.6
8	10	V	10	6	5	7	85.7	60.2	51.6
12	12	V	50	4	0	0	19.0	15.0	2.9
14	11	V	25	6	6	6	85.7	53.7	46.0
20	12	V	50	3	0	1	19.0	39.0	7.4
25	9	V	0	3	4	3	47.6	68.7	32.7
41	10	V	10	5	5	5	71.4	61.3	43.8
45	11	V	25	5	6	4	71.4	66.7	47.6
50	9	V	0	5	7	6	85.7	58.7	50.3
53	10	V	10	5	6	6	81.0	56.1	45.4
58	11	V	25	5	7	2	66.7	65.7	43.8
73	12	V	50	3	0	0	14.3	19.7	2.8
76	9	V	0	6	7	5	85.7	46.6	39.9
77	12	V	50	3	0	0	14.3	18.1	2.6
91	12	V	50	3	1	0	19.0	19.9	3.8

PEN	TREAT	DILUENT	LEVEL	FREQ1	FREQ2	FREQ3	ROL	AVE EW	AVE EO
96	10	V	10	6	5	4	71.4	54.1	38.6
99	9	V	0	6	6	6	85.7	66.2	56.8
104	9	V	0	5	7	6	85.7	52.4	44.9
114	11	V	25	6	5	6	81.0	55.9	45.2
116	11	V	25	2	0	0	9.5	21.4	2.0
117	10	V	10	4	6	5	71.4	63.8	45.6
119	12	V	50	4	1	0	23.8	18.6	4.4
125	9	V	0	6	7	7	95.2	58.4	55.6
126	10	V	10	6	5	6	81.0	57.4	46.5
127	11	V	25	5	5	5	71.4	58.6	41.9
131	11	V	25	4	6	5	71.4	66.6	47.6
138	12	V	50	4	0	0	19.0	19.9	3.8
142	9	V	0	5	6	7	85.7	59.0	50.6
148	12	V	50	4	2	3	42.9	17.7	7.6
160	10	V	10	6	6	7	90.5	59.4	53.8

Phase 2:

PEN	TREAT	DILUENT	LEVEL	FREQ4	FREQ5	FREQ6	ROL	AVE EW	AVE EO
2	6	C	50	2	0	0	9.5	42.9	4.1
22	5	C	0	5	6	6	81.0	58.2	47.1
23	7	C	25	0	0	0	0.0	44.9	0.0
29	6	C	50	3	0	0	14.3	22.0	3.1
34	5	C	0	6	7	7	95.2	55.8	53.1
35	8	C	10	1	0	3	19.0	38.0	7.2
36	8	C	10	0	0	6	28.6	39.9	11.4
38	7	C	25	0	0	0	0.0	37.6	0.0
49	7	C	25	0	0	0	0.0	0.0	0.0
54	6	C	50	2	0	0	9.5	0.0	0.0
60	8	C	10	0	1	0	4.8	0.0	0.0
66	6	C	50	3	0	0	14.3	48.5	6.9
68	5	C	0	5	5	6	76.2	59.3	45.2
72	5	C	0	6	6	5	81.0	58.8	47.6
75	8	C	10	0	0	0	0.0	19.2	0.0
80	7	C	25	0	0	0	0.0	20.0	0.0
82	5	C	0	6	5	5	76.2	61.3	46.7
84	6	C	50	0	0	0	0.0	50.3	0.0
89	8	C	10	0	1	0	4.8	17.4	0.8
90	5	C	0	6	7	7	95.2	39.9	38.0
95	7	C	25	0	0	0	0.0	20.4	0.0
103	6	C	50	1	0	0	4.8	41.3	2.0
107	8	C	10	0	0	0	0.0	38.3	0.0
111	7	C	25	0	0	0	0.0	44.9	0.0
121	5	C	0	7	4	7	85.7	60.7	52.0
129	8	C	10	0	0	2	9.5	44.6	4.2
133	7	C	25	0	0	1	4.8	41.1	2.0
135	7	C	25	0	1	0	4.8	66.2	3.2
139	8	C	10	0	0	1	4.8	18.8	0.9
144	5	C	0	7	7	7	100.0	36.5	36.5

PEN	TREAT	DILUENT	LEVEL	FREQ4	FREQ5	FREQ6	ROL	AVE EW	AVE EO
158	6	C	50	2	0	0	9.5	18.0	1.7
159	6	C	50	2	0	0	9.5	22.5	2.1
7	14	S	50	5	6	7	85.7	48.6	41.6
11	16	S	10	5	6	6	81.0	41.8	33.9
17	13	S	0	6	6	5	81.0	58.1	47.1
21	15	S	25	7	6	6	90.5	60.6	54.9
30	16	S	10	4	6	6	76.2	61.4	46.8
37	13	S	0	5	6	6	81.0	65.1	52.7
39	15	S	25	7	6	7	95.2	65.3	62.2
40	14	S	50	6	7	6	90.5	57.1	51.7
42	15	S	25	4	6	6	76.2	38.4	29.3
47	16	S	10	4	5	5	66.7	41.5	27.7
57	15	S	25	5	6	6	81.0	21.2	17.1
59	16	S	10	6	7	6	90.5	19.9	18.0
61	13	S	0	6	6	6	85.7	17.7	15.2
64	14	S	50	6	5	6	81.0	19.1	15.4
69	14	S	50	6	6	5	81.0	43.0	34.8
79	13	S	0	6	6	6	85.7	40.7	34.9
85	15	S	25	6	7	6	90.5	60.5	54.7
88	14	S	50	7	6	5	85.7	57.2	49.0
94	14	S	50	7	7	7	100.0	41.1	41.1
98	16	S	10	7	7	7	100.0	61.1	61.1
100	16	S	10	1	0	5	28.6	42.4	12.1
106	13	S	0	5	6	7	85.7	60.8	52.1
110	13	S	0	7	6	7	95.2	56.6	53.9
113	15	S	25	6	6	6	85.7	59.5	51.0
137	14	S	50	7	7	5	90.5	43.0	38.9
140	16	S	10	6	5	6	81.0	33.9	27.4
145	15	S	25	4	6	5	71.4	43.1	30.8
147	13	S	0	7	7	6	95.2	40.4	38.4
150	13	S	0	5	5	4	66.7	42.5	28.3
151	15	S	25	6	7	7	95.2	62.1	59.1
154	14	S	50	6	6	6	85.7	40.3	34.6
155	16	S	10	6	7	6	90.5	56.4	51.0
5	18	SD	50	4	0	0	19.0	47.8	9.1
9	20	SD	10	0	4	6	47.6	59.4	28.3
10	19	SD	25	1	4	4	42.9	37.4	16.0
13	17	SD	0	7	6	5	85.7	30.9	26.5
18	20	SD	10	0	2	6	38.1	43.2	16.5
19	18	SD	50	1	3	1	23.8	65.2	15.5
24	17	SD	0	7	6	6	90.5	58.1	52.6
33	19	SD	25	6	6	6	85.7	58.0	49.7
46	17	SD	0	4	5	6	71.4	41.6	29.7
48	20	SD	10	4	6	6	76.2	40.3	30.7
55	19	SD	25	2	3	2	33.3	19.1	6.4
56	20	SD	10	0	4	6	47.6	22.1	10.5
62	18	SD	50	4	1	0	23.8	0.0	0.0
63	18	SD	50	4	0	0	19.0	0.0	0.0
67	17	SD	0	6	6	5	81.0	58.8	47.6

PEN	TREAT	DILUENT	LEVEL	FREQ4	FREQ5	FREQ6	ROL	AVE EW	AVE EO
78	19	SD	25	6	7	6	90.5	41.4	37.5
86	17	SD	0	5	6	6	81.0	21.5	17.4
87	20	SD	10	0	0	5	23.8	38.7	9.2
102	19	SD	25	6	6	5	81.0	49.6	40.1
105	20	SD	10	0	3	7	47.6	39.9	19.0
108	18	SD	50	3	0	0	14.3	37.2	5.3
112	17	SD	0	0	0	0	0.0	40.9	0.0
118	19	SD	25	1	5	5	52.4	60.9	31.9
120	18	SD	50	4	0	0	19.0	40.4	7.7
123	19	SD	25	4	5	5	66.7	66.3	44.2
124	17	SD	0	6	6	6	85.7	61.0	52.3
130	20	SD	10	0	5	6	52.4	61.6	32.3
132	20	SD	10	0	6	6	57.1	60.4	34.5
134	18	SD	50	4	4	0	38.1	18.6	7.1
143	18	SD	50	5	0	0	23.8	17.4	4.2
146	17	SD	0	6	6	5	81.0	55.3	44.8
157	19	SD	25	5	5	5	71.4	35.6	25.4
6	2	SF	50	3	1	4	38.1	48.6	18.5
15	4	SF	10	0	0	5	23.8	20.4	4.9
16	1	SF	0	7	7	6	95.2	55.7	53.0
26	4	SF	10	0	2	5	33.3	17.5	5.8
27	3	SF	25	6	6	6	85.7	40.5	34.7
28	2	SF	50	3	3	0	28.6	37.6	10.7
31	3	SF	25	6	6	6	85.7	66.2	56.7
32	1	SF	0	6	6	7	90.5	39.8	36.0
43	3	SF	25	5	6	5	76.2	41.0	31.2
44	3	SF	25	6	7	6	90.5	41.7	37.8
51	4	SF	10	0	4	7	52.4	19.8	10.4
52	4	SF	10	0	4	6	47.6	19.9	9.5
65	1	SF	0	6	7	3	76.2	60.0	45.7
70	1	SF	0	6	5	6	81.0	55.3	44.8
71	2	SF	50	6	1	0	33.3	63.4	21.1
74	2	SF	50	5	2	2	42.9	39.2	16.8
81	3	SF	25	6	5	6	81.0	59.2	47.9
83	1	SF	0	7	6	7	95.2	67.6	64.3
92	4	SF	10	0	4	6	47.6	31.7	15.1
93	3	SF	25	6	6	6	85.7	39.6	33.9
97	2	SF	50	5	0	0	23.8	38.9	9.3
101	1	SF	0	7	6	7	95.2	56.4	53.8
109	4	SF	10	5	6	7	85.7	57.3	49.1
115	2	SF	50	5	2	0	33.3	69.1	23.0
122	2	SF	50	4	2	2	38.1	57.4	21.9
128	1	SF	0	7	6	6	90.5	55.2	49.9
136	3	SF	25	5	5	6	76.2	66.5	50.7
141	2	SF	50	5	4	4	61.9	17.9	11.1
149	3	SF	25	6	7	7	95.2	54.6	52.0
152	4	SF	10	5	6	6	81.0	60.8	49.2
153	1	SF	0	7	6	7	95.2	43.0	41.0
156	4	SF	10	0	4	7	52.4	39.8	20.8

PEN	TREAT	DILUENT	LEVEL	FREQ4	FREQ5	FREQ6	ROL	AVE EW	AVE EO
1	9	V	0	6	6	6	85.7	58.2	49.9
3	11	V	25	4	5	5	66.7	59.3	39.5
4	10	V	50	4	0	0	19.0	38.3	7.3
8	10	V	50	4	0	0	19.0	44.0	8.4
12	12	V	10	0	3	5	38.1	39.3	15.0
14	11	V	25	4	3	5	57.1	39.3	22.5
20	12	V	10	0	0	4	19.0	41.3	7.9
25	9	V	0	3	3	1	33.3	34.0	11.3
41	10	V	50	5	0	0	23.8	16.0	3.8
45	11	V	25	5	5	5	71.4	23.7	16.9
50	9	V	0	6	6	5	81.0	19.6	15.9
53	10	V	50	4	1	0	23.8	16.9	4.0
58	11	V	25	6	4	4	66.7	44.5	29.7
73	12	V	10	1	1	5	33.3	19.5	6.5
76	9	V	0	7	6	6	90.5	37.3	33.8
77	12	V	10	0	2	7	42.9	17.6	7.6
91	12	V	10	0	1	6	33.3	42.3	14.1
96	10	V	50	4	0	0	19.0	20.8	4.0
99	9	V	0	7	4	2	61.9	54.7	33.9
104	9	V	0	6	5	4	71.4	61.5	44.0
114	11	V	25	5	6	6	81.0	56.8	46.0
116	11	V	25	0	0	0	0.0	42.6	0.0
117	10	V	50	4	1	0	23.8	42.2	10.0
119	12	V	10	0	2	6	38.1	46.1	17.6
125	9	V	0	6	6	7	90.5	55.2	49.9
126	10	V	50	4	0	2	28.6	17.6	5.0
127	11	V	25	4	3	5	57.1	53.6	30.6
131	11	V	25	4	5	5	66.7	66.9	44.6
138	12	V	10	0	4	6	47.6	16.6	7.9
142	9	V	0	6	6	6	85.7	38.7	33.1
148	12	V	10	0	5	6	52.4	57.6	30.2
160	10	V	50	3	0	0	14.3	20.9	3.0

Phase 3:

PEN	TREAT	DILUENT	LEVEL	FREQ7	FREQ8	FREQ9	ROL	AVE EW	AVE EO
7	14	C	10	5	6	4	71.4	58.1	41.5
11	16	C	50	4	0	0	19.0	20.2	3.8
17	13	C	0	6	7	5	85.7	58.7	50.3
21	15	C	25	5	0	0	23.8	18.1	4.3
30	16	C	50	4	0	0	19.0	19.2	3.6
37	13	C	0	6	6	6	85.7	59.6	51.1
39	15	C	25	4	0	0	19.0	20.7	3.9
40	14	C	10	5	5	6	76.2	55.1	42.0
42	15	C	25	3	0	0	14.3	20.6	2.9
47	16	C	50	3	0	0	14.3	22.4	3.2
57	15	C	25	5	0	0	23.8	19.3	4.6
59	16	C	50	5	0	0	23.8	19.8	4.7
61	13	C	0	7	6	6	90.5	50.9	46.0

PEN	TREAT	DILUENT	LEVEL	FREQ7	FREQ8	FREQ9	ROL	AVE EW	AVE EO
64	14	C	10	6	6	4	76.2	59.7	45.5
69	14	C	10	5	4	4	61.9	57.7	35.7
79	13	C	0	5	4	5	66.7	65.0	43.3
85	15	C	25	5	0	0	23.8	20.5	4.9
88	14	C	10	5	4	0	42.9	36.9	15.8
94	14	C	10	5	5	5	71.4	57.6	41.2
98	16	C	50	6	0	0	28.6	17.6	5.0
100	16	C	50	5	0	0	23.8	18.8	4.5
106	13	C	0	6	6	6	85.7	61.3	52.6
110	13	C	0	7	7	7	100.0	54.5	54.5
113	15	C	25	5	0	1	28.6	39.5	11.3
137	14	C	10	7	4	6	81.0	67.7	54.8
140	16	C	50	5	0	0	23.8	19.3	4.6
145	15	C	25	3	0	0	14.3	21.9	3.1
147	13	C	0	7	5	6	85.7	64.8	55.5
150	13	C	0	6	5	7	85.7	64.9	55.6
151	15	C	25	4	0	0	19.0	19.0	3.6
154	14	C	10	6	5	2	61.9	61.2	37.9
155	16	C	50	3	0	0	14.3	19.2	2.7
2	6	S	10	0	0	4	19.0	15.5	3.0
22	5	S	0	6	6	6	85.7	54.3	46.6
23	7	S	25	0	0	0	0.0	0.0	0.0
29	6	S	10	1	2	7	47.6	17.2	8.2
34	5	S	0	6	7	7	95.2	55.1	52.4
35	8	S	50	6	7	6	90.5	57.6	52.1
36	8	S	50	5	6	6	81.0	58.5	47.4
38	7	S	25	0	0	6	28.6	19.1	5.5
49	7	S	25	0	0	5	23.8	17.2	4.1
54	6	S	10	0	0	4	19.0	17.8	3.4
60	8	S	50	0	0	0	0.0	0.0	0.0
66	6	S	10	0	0	6	28.6	19.1	5.5
68	5	S	0	5	5	6	76.2	64.9	49.4
72	5	S	0	6	6	5	81.0	59.4	48.1
75	8	S	50	0	0	0	0.0	0.0	0.0
80	7	S	25	0	0	6	28.6	18.9	5.4
82	5	S	0	6	5	7	85.7	74.7	64.0
84	6	S	10	0	0	1	4.8	0.0	0.0
89	8	S	50	0	0	0	0.0	0.0	0.0
90	5	S	0	5	7	6	85.7	58.0	49.7
95	7	S	25	1	0	0	4.8	19.6	0.9
103	6	S	10	0	0	2	9.5	0.0	0.0
107	8	S	50	3	6	6	71.4	60.3	43.0
111	7	S	25	0	2	7	42.9	18.9	8.1
121	5	S	0	6	5	6	81.0	67.1	54.3
129	8	S	50	4	6	6	76.2	57.6	43.9
133	7	S	25	0	0	2	9.5	0.0	0.0
135	7	S	25	0	0	0	0.0	0.0	0.0
139	8	S	50	5	6	5	76.2	60.2	45.9
144	5	S	0	7	3	0	47.6	31.3	14.9

PEN	TREAT	DILUENT	LEVEL	FREQ7	FREQ8	FREQ9	ROL	AVE EW	AVE EO
158	6	S	10	0	1	6	33.3	18.9	6.3
159	6	S	10	0	1	7	38.1	20.4	7.8
6	2	SD	10	3	7	5	71.4	62.8	44.9
15	4	SD	50	4	0	0	19.0	20.4	3.9
16	1	SD	0	7	7	7	100.0	57.6	57.6
26	4	SD	50	3	0	0	14.3	18.0	2.6
27	3	SD	25	6	5	4	71.4	59.7	42.6
28	2	SD	10	0	3	6	42.9	16.6	7.1
31	3	SD	25	6	6	6	85.7	59.2	50.7
32	1	SD	0	6	7	6	90.5	62.6	56.6
43	3	SD	25	6	5	1	57.1	66.2	37.8
44	3	SD	25	6	5	4	71.4	61.9	44.2
51	4	SD	50	3	0	0	14.3	18.2	2.6
52	4	SD	50	4	0	0	19.0	20.6	3.9
65	1	SD	0	0	3	5	38.1	38.4	14.6
70	1	SD	0	6	4	0	47.6	35.5	16.9
71	2	SD	10	4	5	6	71.4	67.6	48.3
74	2	SD	10	2	5	4	52.4	61.3	32.1
81	3	SD	25	5	5	6	76.2	58.5	44.5
83	1	SD	0	7	5	6	85.7	66.3	56.8
92	4	SD	50	4	1	0	23.8	43.6	10.4
93	3	SD	25	5	5	5	71.4	58.2	41.6
97	2	SD	10	0	5	7	57.1	37.7	21.6
101	1	SD	0	6	6	5	81.0	63.7	51.6
109	4	SD	50	4	1	0	23.8	36.4	8.7
115	2	SD	10	1	5	4	47.6	45.7	21.8
122	2	SD	10	3	5	5	61.9	56.8	35.2
128	1	SD	0	5	4	5	66.7	50.5	33.6
136	3	SD	25	6	1	3	47.6	60.6	28.8
141	2	SD	10	4	6	6	76.2	58.4	44.5
149	3	SD	25	7	7	1	71.4	54.2	38.7
152	4	SD	50	4	0	0	19.0	19.8	3.8
153	1	SD	0	6	6	7	90.5	69.4	62.7
156	4	SD	50	5	1	0	28.6	35.2	10.0
5	18	SF	10	0	0	2	9.5	0.0	0.0
9	20	SF	50	4	0	0	19.0	21.8	4.2
10	19	SF	25	2	3	5	47.6	60.3	28.7
13	17	SF	0	7	5	7	90.5	63.1	57.1
18	20	SF	50	5	0	0	23.8	19.7	4.7
19	18	SF	10	0	0	0	0.0	0.0	0.0
24	17	SF	0	6	6	5	81.0	58.3	47.2
33	19	SF	25	6	7	3	76.2	61.2	46.7
46	17	SF	0	5	5	6	76.2	63.7	48.6
48	20	SF	50	5	1	0	28.6	37.3	10.7
55	19	SF	25	4	2	3	42.9	45.9	19.7
56	20	SF	50	5	0	0	23.8	19.9	4.7
62	18	SF	10	0	4	6	47.6	37.0	17.6
63	18	SF	10	0	0	4	19.0	18.9	3.6
67	17	SF	0	6	5	6	81.0	59.1	47.9

PEN	TREAT	DILUENT	LEVEL	FREQ7	FREQ8	FREQ9	ROL	AVE EW	AVE EO
78	19	SF	25	5	6	6	81.0	56.4	45.6
86	17	SF	0	5	5	5	71.4	64.1	45.8
87	20	SF	50	2	1	0	14.3	37.8	5.4
102	19	SF	25	5	5	3	61.9	62.6	38.7
105	20	SF	50	3	0	0	14.3	19.6	2.8
108	18	SF	10	1	5	5	52.4	44.3	23.2
112	17	SF	0	0	0	0	0.0	0.0	0.0
118	19	SF	25	4	4	6	66.7	59.3	39.5
120	18	SF	10	0	6	6	57.1	38.6	22.0
123	19	SF	25	5	1	4	47.6	57.6	27.4
124	17	SF	0	7	5	6	85.7	64.4	55.2
130	20	SF	50	5	0	0	23.8	21.2	5.0
132	20	SF	50	4	1	0	23.8	40.7	9.7
134	18	SF	10	0	0	5	23.8	17.6	4.2
143	18	SF	10	0	2	6	38.1	19.3	7.4
146	17	SF	0	6	5	6	81.0	67.0	54.2
157	19	SF	25	5	6	3	66.7	60.1	40.1
1	9	V	0	5	6	6	81.0	61.8	50.0
3	11	V	25	5	3	6	66.7	54.2	36.1
4	10	V	10	0	1	6	33.3	20.5	6.8
8	10	V	10	0	3	6	42.9	37.7	16.1
12	12	V	50	5	1	0	28.6	34.9	10.0
14	11	V	25	5	3	2	47.6	52.5	25.0
20	12	V	50	3	0	0	14.3	21.3	3.0
25	9	V	0	3	2	3	38.1	70.0	26.7
41	10	V	10	3	5	4	57.1	56.8	32.4
45	11	V	25	5	6	0	52.4	44.7	23.4
50	9	V	0	7	6	6	90.5	57.2	51.7
53	10	V	10	1	5	5	52.4	38.1	19.9
58	11	V	25	5	5	3	61.9	71.4	44.2
73	12	V	50	5	0	1	28.6	42.7	12.2
76	9	V	0	7	7	7	100.0	58.3	58.3
77	12	V	50	3	0	0	14.3	18.3	2.6
91	12	V	50	3	0	0	14.3	18.9	2.7
96	10	V	10	0	0	0	0.0	0.0	0.0
99	9	V	0	4	6	7	81.0	63.3	51.2
104	9	V	0	6	5	7	85.7	55.6	47.6
114	11	V	25	6	3	1	47.6	35.7	17.0
116	11	V	25	0	0	0	0.0	0.0	0.0
117	10	V	10	0	2	6	38.1	19.4	7.4
119	12	V	50	4	0	0	19.0	19.7	3.8
125	9	V	0	7	7	7	100.0	59.9	59.9
126	10	V	10	3	5	5	61.9	57.6	35.6
127	11	V	25	4	5	3	57.1	58.8	33.6
131	11	V	25	4	5	4	61.9	66.1	40.9
138	12	V	50	5	0	0	23.8	19.1	4.6
142	9	V	0	6	5	6	81.0	56.9	46.1
148	12	V	50	4	1	0	23.8	39.7	9.5
160	10	V	10	0		2	14.3	19.5	2.8

APPENDIX D: TRIAL 2 FEED INTAKE AND BODY WEIGHT DATA

Date			20-Apr			27-Apr			04-May			11-May			18-May			25-May			01-Jun			Total	BW			
Hen	Feed		in	out	FI/day A	in	out	FI/day1	in	out	FI/day2	in	out	FI/day3	in	out	FI/day4	in	out	FI/day5	in	out	FI/day6	FI/day	start	end	BW change	SFI
1	Clay	0	1408	827	83	3065	2272	113	3777	2961	116	3435	2682	108	3133	2360	111	3078	2486	85	3240	2434	115	108	1736	1953	217	62.18672
2	Clay	0	1457	793	95	3493	2686	115	4157	3296	123	3490	2731	108	3231	2466	109	3171	2443	104	3130	2529	86	108	1693	1663	-30	63.57832
3	Clay	0	1264	433	119	3694	2862	119	3589	2742	121	3082	2299	112	3280	2467	116	3271	2508	109	3346	2573	110	115	1839	1964	125	62.30094
4	Clay	0	1324	584	106	3111	2278	119	3168	2328	120	2946	2186	109	3284	2500	113	3199	2430	110	3102	2308	113	114	1789	1863	74	63.73207
5	Clay	0	1318	802	74	3077	2293	112	3135	2229	129	2484	1720	109	3241	2405	119	3376	2577	114	3457	2700	108	115	1933	1936	3	59.69379
6	Sand	5	1413	863	79	3853	2960	128	3366	2423	135	2755	1908	121	3120	2208	130	3257	2513	106	3277	2441	119	123	1638	2125	487	75.22821
7	Sand	5	1404	776	90	3834	3097	105	4116	3316	114	3316	2604	102	3217	2496	103	3177	2568	87	3272	2550	103	102	1640	1719	79	62.45064
8	Sand	5	1427	826	86	3699	2860	120	3489	2612	125	2934	2151	112	3274	2453	117	3168	2484	98	3492	2678	116	115	1787	1875	88	64.20311
9	Sand	5	1568	868	100	3412	2525	127	3399	2496	129	3156	2333	117	3242	2436	115	3160	2381	111	3541	2758	112	119	1736	1884	148	68.30289
10	Sand	5	1495	684	116	3782	2830	136	3865	2902	138	3204	2377	118	3048	2276	110	3158	2278	126	3441	2585	122	125	1749	1896	147	71.48575
11	Sand	15	1484	904	83	3388	2677	102	3269	2507	109	3214	2421	113	3466	2692	111	3378	2544	119	2881	2087	113	111	2056	1903	-153	54.05318
12	Sand	15	1486	667	117	3603	2510	156	3184	2088	156	3385	2219	167	3646	2409	177	3077	2147	133	2998	2021	140	155	1642	2214	572	94.23612
13	Sand	15	1441	729	102	3551	2539	145	3271	2140	162	3213	2225	141	3529	2551	140	3256	2404	122	2722	1895	118	138	1820	1804	-16	75.73522
14	Sand	15	1573	830	106	3205	2258	135	2930	1969	137	3103	2143	137	3284	2351	133	3045	2167	125	3044	2076	138	134	1901	2034	133	70.7347
15	Sand	15	1391	705	98	3455	2459	142	3059	2148	130	3342	2373	138	3298	2477	117	3292	2339	136	3032	2041	142	134	1649	2012	363	81.45341
16	Clay	10	1425	806	88	3451	2669	112	3344	2543	115	3297	2604	99	3295	2572	103	3239	2671	81	3348	2834	73	97	1796	1482	-314	54.06194
17	Clay	10	1468	764	101	3043	2190	122	2764	1907	122	3342	2546	114	3236	2471	109	3360	2436	132	2938	2082	122	120	1798	1543	-255	66.87192
18	Clay	10	1497	1027	67	3329	2500	118	3161	2280	126	3074	2198	125	3076	2293	112	3191	2401	113	3446	2794	93	115	1881	1902	21	60.90732
19	Clay	10	1514	910	86	3467	2591	125	3272	2371	129	3061	2199	123	3140	2291	121	3206	2448	109	3509	2696	116	121	1791	1957	166	67.2875
20	Clay	10	1467	789	97	3204	2418	112	3138	2317	117	2951	2102	121	3208	2386	117	3508	2655	122	3713	2872	120	118	1746	1870	124	67.81487
21	Polystyrene	15	1383	614	110	3382	2468	131	3131	2209	132	3432	2579	122	3199	2344	122	3160	2471	98	2795	2168	90	116	1732	1659	-73	66.79589
22	Polystyrene	15	1531	814	102	3481	2557	132	3309	2421	127	3212	2195	145	3370	2586	112	3398	2609	113	2776	2142	91	120	1634	1616	-18	73.35198
23	Polystyrene	15	1519	834	98	3561	2644	131	3425	2424	143	3020	2202	117	3203	2378	118	3009	2107	129	2497	1584	130	128	1937	2050	113	66.10247
24	Polystyrene	15	1500	539	137	3473	2436	148	3011	1970	149	3211	2308	129	3090	2109	140	3028	2091	134	2665	1736	133	139	1886	1944	58	73.57092
25	Polystyrene	15	1541	639	129	3435	2485	136	3116	2112	143	3169	2218	136	3077	2203	125	3410	2579	119	2905	2014	127	131	1798	1936	138	72.84019
26	Sand	10	1492	753	106	3446	2471	139	3405	2371	148	3425	2476	136	3482	2678	115	3502	2696	115	3290	2300	141	132	1998	2102	104	66.23052
27	Sand	10	1537	798	106	3725	2846	154	3579	2510	153	3587	2614	139	3170	2232	134	3280	2317	138	2887	1916	139	143	1944	2119	175	73.37228
28	Sand	10	1492	726	109	3573	3082	70	3997	3097	129	3369	2424	135	3008	2095	130	3076	2238	120	3174	2414	109	115	1647	1766	119	70.07691
29	Sand	10	1450	878	82	3276	2495	112	3245	2439	115	3042	2415	90	3166	2391	114	3438	2753	98	3453	2813	91	103	1629	1666	37	63.36929
30	Sand	10	1553	888	95	3714	2958	108	3839	3166	96	3166	2568	85	3532	2879	93	3866	3186	97	3186	2704	69	91	1427	1293	-134	64.10718
31	Bran	15	1433	669	109	2997	2192	115	3798	2857	134	3327	2652	96	3297	2456	120	3177	2276	129	2706	1960	107	117	1899	1891	-8	61.51985
32	Bran	15	1458	743	102	3287	2477	116	2845	1934	130	3023	2360	95	3160	2381	111	3048	2306	106	2591	1887	101	110	1531	1481	-50	71.68673
33	Bran	15	1472	854	88	3585	2807	111	3294	2530	109	3046	2158	127	3043	2183	123	3078	2270	115	2860	1898	137	120	1915	1959	44	62.89444
34	Bran	15	1481	744	105	3346	2587	109	3600	3082	74	3588	2632	137	3184	2345	120	3229	2403	118	2938	2065	125	114	1785	1832	47	63.64279
35	Bran	15	1475	746	104	3231	2434	114	3377	2555	117	3380	2469	130	2917	2277	91	3072	2415	94	2750	2074	97	107	1776	1553	-223	60.38047
36	Sawdust	15	1403	702	100	3601	2731	124	3011	2177	119	3090	2254	119	3132	2355	111	2948	2024	132	2757	1895	123	122	1776	1742	-34	68.42959
37	Sawdust	15	1500	770	104	3545	2783	109	3133	2212	132	3188	2257	133	3037	2412	89	2944	2030	131	2706	1737	138	122	1893	1869	-24	64.42658
38	Sawdust	15	1507	892	88	3347	2565	112	2814	2043	110	3200	2255	135	3042	2231	116	2850	2141	101	2823	2101	103	113	1704	1592	-112	66.22094
39	Sawdust	15	1615	710	129	3261	2479	112	2704	1739	138	3025	2105	131	3034	2271	109	2797	2023	111	3061	2313	107	118	1774	1729	-45	66.45327
40	Sawdust	15	1569	817	107	3465	2615	121	2879	2185	99	3011	2150	123	3010	2273	105	2986	2178	115	2935	2034	129	116	1740	1749	9	66.38478
41	Clay	15	1492	789	100	3807	2968	120	3449	2580	124	3101	2231	124	3180	2343	120	3263	2478	112	3237	2065	167	128	1670	1774	104	76.58683
42	Clay	15	1553	948	86	3757	2818	134	3041	2089	136	3031	2221	116	3010	2200	116	3279	2484	114	2887	2263	89	117	1725	1779	54	68.06211
43	Clay	15	1513	707	115	3712	2770	135	3050	1938	159	3183	2197	141	3023	2071	136	3170	2371	114	3354	2374	140	137	1783	1916	133	77.05179
44	Clay	15	1638	911	104	3641	2753	127	2911	2001	130	3078	2217	123	3035	2253	112	3196	2396	114	3197	2490	101	118	1721	1743	22	68.44166
45	Clay	15	1569	810	108	3876	3075	114	3313	2438	125	3223	2467	108	3323	2301	146	3585	2791	113	3186	2627	80	114	1632	1506	-126	70.10971
46	Sawdust	0	1353	673	97	3899	3097	114	3606	2745	123	3515	2695	117	3798	3026	110	3878	3098	111	3773	3219	79	109	1910	1936	26	57.20893
47	Sawdust	0	1366	787	83	3723	2920	115	3663	2744	131	3167	2236	133	3053	2156	128	3129	2307	117	3231	2342	127	125	1929	2092	163	64.92261
48	Sawdust	0	1424	900	75	3656	2844	116	3428	2536	127	3348	2493	122	3105	2271	119	3586	2865	103	3674	2977	100	115	1932	1822	-110	59.29459
49	Sawdust	0	1436	755	97	3895	3042	122	3454	2594	123	3189	2379	116	3127	2580	78	3117	2456	94	3535	3113	60	99	1813	1723	-90	54.5334
50	Sawdust	0	1476	673	115	3833	2907	132	3349	2519	119	3094	2273	117	3166	2291	125	3278	2355	132	3297	2417	126	125	1948	2097	149	64.23927
51	Clay	5	1421	671	107	3799	2966	119	3382	2543	120	3014	2246	110	3135	2367	110	3479	2613	124	3303	2754	78	110	1613	1551	-62	68.24757
52	Clay	5	1541	898	92	3876	2954	132	3488	2590	128	3207	2371	119	3034	2198	120	3044	2263	109	2890	2460	76	114	1774	1743	-31	64.18774
53	Clay	5	1495	680	116	3810	2874	134	3517	2713	115	3148	2224	132	2959	2054	129	3164	2580	83	3352	2656	99	115	1864	1844	-20	61.95713
54	Clay	5	1523	770	108	3913	3050	123	3516	2631	126	3230	2376	122	3235	2391	121	3285	2434	122	3141	2244	128	124	1880	2107	227	65.78521
55	Clay	5	1492	896	85	3437	2614	117	3184	2282	129	3112	2288	118	3125	2469	94	3624	2825	114	3265	2609	94	111	1832	1827	-5	60.55313
56	Bran	10	1480	860	89	3617	2812	115	3244	2402	120	3415	2567	121	3032	2238	113	3528	2790	105	3070	2350	103	113	1886	1858	-28	59.9442
57	Bran	10	1562	994	81	3415	2746	96	3175	2365	116	3124	2347	111	3506	2775	104	3447	2733	102	3006	2465	77	101	1579	1675	96	63.97358
58	Bran	10	1451	798	93	3672	2926	107	3364	2499	124	3059	2306	108	3071	2370	100	3427	2714	102	3158	2594	81	103	1648	1582	-66	62.73838
59	Bran	10	1467	808	94	3535	2782	108	3117	2227	127	3041	2093	135	3189	2263	132	3202	2458	106	3185	2268	131	123	1824	1985	141	67.59868
60	Bran	10	1361	779	83	3446	2892	79	3192	2477	102	3134	2359	111	3027	2300	104	3376	2632	106	3475	2724	107	102	1647	1769	122	61.65611
61	Polystyrene	5	1444	866	82	3593	2697	128	3509	2682	118	3262	2327	134	3171	2373	114	3168	2404	109	2904	2080	118	120	1711	1884	173	70.1706
62	Polystyrene	5	1462	845	88	3453	2646	115	3249	2360	127	3152	2290	123	3145	2295	121	3284	2530	108	3261	2458	115	118	1676	1932	256	70.53074
63	Polystyrene	5	1418	758	94	3530	2689	120	3411	2542	124	3062	2254	115	2985	2196	113	3547	2774	110	3331	2631	100	114	1741	1793	52	65.39345
64	Polystyrene	5	1447	800	92	3743	3081	95	4006	3277	104	3277	2440	120	3094	2298	114	3044	2345	100	3509	2826	98	105	1852	1812	-40	56.62733
65	Polystyrene	5	1420	704	102	3813	2986	118	3574	2690	126	3190	2326	123	3023	2159	123	2848	2029	117	3353	2766	84	115	1814	1743	-71	63.58219
66	Bran	5	1422	624	114	3648	2972	97	3565	2664	129	3218	2587	90	2990	2220	110	3474	2762	102	3565	2782	112	107	1759	1770	11	60.56742
67	Bran	5	1469	809	94	3015	2398	88	3029	2189	120	3193	2479	102	3049	2296	108	3514	2783	104	3624	2791	119	107	1874	2001	127	58.99802
68	Bran	5	1489	788	100	3451	2775	97	3520	2713	115	3142	2367	111	3013	2261	107	3606	2930	97	3691	2907	112	106	1614	1753	139	65.93497
69	Bran	5	1444	749	99	3616	2981	91	3590	2837	108	3085	2388	100	3042	2322	103	3273	2581	99	3561	2788	110	102	1668	1779	111	60.9598
70	Bran	5	1373	500	125	3521	2659	123	3388	2530	122	3051	2219	119	3071	2181	127	3253	2481	110	3209	2378	119	120	1867	2051	184	64.338
71	Bran	0	1405	682	103	3554	2732	117	3575	2575	143	3322	2408	131	3070	2235	119	3596	2891	101	3714	2849	124	122	1575	1842	267	77.73545
72	Bran	0	1464	751	102	3590	2779	116	3610	2739	124	3245	2458	113	3091	2303	113	3539	2852	98	3738	2938	114	113	1773	1948	175	63.71633
73	Bran	0	1465	929	77	4121	3360	109	4426	3625	115	3625	2885	108	3643	2889	108	3781	3053	104	3833	3036	114	109	1628	1817	189	66.99573

Hen	Feed		in	out	FI/day A	in	out	FI/day1	in	out	FI/day2	in	out	FI/day3	in	out	FI/day4	in	out	FI/day5	in	out	FI/day6	FI/day	start	end	BW change	SFI
74	Bran	0	1466	865	86	3975	3298	97	4112	3333	111	3333	2598	105	3229	2470	108	3729	3007	103	3812	2981	119	107	1531	1776	245	70.02426
75	Bran	0	1603	908	100	3888	3376	73	4482	3595	127	3595	2725	124	3061	2238	118	3323	2582	106	3387	2567	117	111	1828	1937	109	60.61399
76	Sawdust	5	1590	963	90	3374	2845	76	3861	3112	107	3112	2568	78	3030	2320	101	3150	2548	86	3307	2557	107	92	1482	1413	-69	62.39638
77	Sawdust	5	1549	841	101	3710	2984	104	3953	3382	82	3382	2564	117	3026	2294	104	3205	2545	94	3272	2418	122	104	1662	1796	134	62.47063
78	Sawdust	5	1460	746	102	3471	2727	106	3514	2755	108	3061	2302	109	3126	2345	112	3561	2869	99	3543	2752	113	108	1742	1843	101	61.85966
79	Sawdust	5	1540	812	90	4100	3301	114	4284	3476	113	3476	2478	143	3018	2182	119	3112	2319	113	3421	2589	119	120	1638	1816	178	73.36618
80	Sawdust	5	1401	852	78	3524	2773	107	3435	2569	124	3041	2222	117	3064	2328	105	3331	2633	100	3418	2576	120	112	1542	1740	198	72.74721
81	Sawdust	10	1520	800	103	3700	2946	108	3970	3073	128	3073	2241	119	3038	2228	116	3257	2606	93	3246	2428	117	113	1936	2010	74	58.55839
82	Sawdust	10	1524	825	100	3358	2430	133	3218	2234	141	3124	2188	134	3023	2108	131	3003	2138	124	2608	1755	122	131	1935	2052	117	67.4554
83	Sawdust	10	1466	715	107	3240	2498	106	3703	2759	135	3147	2274	125	3020	2172	121	3255	2424	119	3262	2421	120	121	2001	2035	34	60.43407
84	Sawdust	10	1404	846	80	3529	2761	110	4164	3273	127	3273	2445	118	3106	2294	116	3163	2573	84	3919	3047	125	113	1863	1928	65	60.84273
85	Sawdust	10	1488	779	101	3589	2704	126	3946	3032	131	3032	2102	133	3020	2158	123	3038	2231	115	3957	3110	121	125	1882	1940	58	66.3643
86	Sand	0	1357	644	102	4143	3363	111	4492	3697	114	3696	2847	121	3189	2536	93	3376	2622	108	3567	2739	118	111	1740	1932	192	63.75342
87	Sand	0	1387	890	71	3682	2976	101	3605	2833	110	3274	2555	103	3052	2331	103	3395	2783	87	3679	2949	104	101	1665	1754	89	60.87516
88	Sand	0	1383	691	99	3850	3082	110	4179	3420	108	3420	2707	102	3066	2398	96	3364	2732	90	3477	2663	116	104	1555	1622	67	66.71413
89	Sand	0	1438	939	71	3688	2918	110	4118	3308	116	3308	2592	102	3047	2478	81	3667	2957	101	4212	3469	106	103	1635	1785	150	62.91685
90	Sand	0	1421	571	121	3792	3012	111	3798	2899	128	3094	2328	109	3081	2215	124	3275	2585	99	3301	2434	124	116	1781	1869	88	65.08115
91	Polystyrene	0	1350	594	108	3995	3217	111	3659	2840	117	3019	2265	108	3056	2271	112	3581	2826	108	3666	2867	114	112	1858	2029	171	60.10047
92	Polystyrene	0	1393	592	114	3836	3095	106	4000	3208	114	3206	2454	107	3054	2327	104	3301	2549	107	3736	2929	115	109	1658	1812	154	65.65282
93	Polystyrene	0	1459	779	97	3766	2963	115	3715	2943	110	3193	2514	97	3089	2378	102	3531	2709	117	3601	2777	118	110	2084	2060	-24	52.65515
94	Polystyrene	0	1378	472	129	3765	2875	127	3590	2716	125	3033	2106	132	3149	2204	135	3379	2484	128	3408	2481	132	130	1978	2110	132	65.72536
95	Polystyrene	0	1488	764	103	3818	3213	86	3996	3184	116	3184	2452	105	3107	2392	102	3422	2677	106	3734	2907	118	106	1793	1843	50	58.8811
96	Polystyrene	10	1349	777	82	3676	2844	119	4065	3167	128	3167	2242	132	3092	2208	126	3371	2599	110	3384	2451	133	125	1690	1718	28	73.88278
97	Polystyrene	10	1421	587	119	3633	2883	107	3427	2597	119	3024	2227	114	3168	2430	105	3479	2667	116	3247	2401	121	114	1625	1677	52	69.94432
98	Polystyrene	10	1538	772	109	3611	2829	112	3840	2987	122	3240	2444	114	2966	2319	92	3499	2819	97	3419	2546	125	110	1527	1594	67	72.18948
99	Polystyrene	10	1481	960	74	3833	2897	134	4057	2949	158	3168	2215	136	3133	2447	98	3287	2373	131	3395	2589	115	128	1964	1898	-66	65.50771
100	Polystyrene	10	1452	424	147	3658	2642	145	3529	2497	147	3013	2018	143	3055	2278	111	3298	2311	141	3265	2326	134	137	1908	2113	205	71.71309
101	Sawdust	5	1440	772	95	3504	2785	103	3358	2533	118	3056	2265	113	3068	2291	111	3298	2558	106	3332	2537	114	111	1757	1949	192	62.95092
102	Sawdust	5	1530	819	102	3913	3043	124	3820	2894	132	3269	2447	118	3191	2369	118	3538	2634	129	3072	2122	136	126	1760	1890	130	71.6342
103	Sawdust	5	1402	589	116	3603	2722	126	3545	2813	105	3051	2211	120	3040	2204	119	3260	2430	119	3326	2495	118	118	1757	1889	132	67.07049
104	Sawdust	5	1492	664	118	3939	3020	131	3777	2887	126	3407	2591	117	3002	2209	113	3291	2479	116	3043	2105	134	123	1930	2017	87	63.61831
105	Sawdust	5	1423	758	95	3754	2964	113	3550	2659	127	3048	2242	115	3087	2346	106	3354	2722	90	3804	3085	103	109	1885	1870	-15	57.84767
106	Clay	5	1459	775	98	3555	2762	113	3627	2725	129	3122	2275	121	2943	2084	123	3320	2450	124	3573	2684	127	123	1840	2172	332	66.77795
107	Clay	5	1355	585	110	3876	3071	115	3900	2999	129	3060	2230	119	3000	2251	107	3213	2441	110	3601	2738	123	117	1811	1999	188	64.68276
108	Clay	5	1656	924	105	3544	2693	122	3250	2380	124	3043	2197	121	3248	2486	109	3466	2670	114	3486	2621	124	119	1726	1987	261	68.83932
109	Clay	5	1386	716	96	3759	2898	123	3548	2708	120	3206	2425	112	3181	2482	100	3408	2642	109	3323	2508	116	113	1669	1799	130	67.91207
110	Clay	5	1511	838	96	3960	3008	136	3612	2619	142	3051	2091	137	3270	2501	110	3043	2165	125	2971	2150	117	128	1703	1953	250	75.12653
111	Sand	0	1491	810	97	3849	2857	142	3833	2843	113	3456	2700	108	3790	3034	108	3757	3044	102	3521	2750	110	114	1721	1824	103	66.10636
112	Sand	0	1545	807	105	3774	3233	77	4010	3180	119	3180	2505	96	3047	2360	98	3375	2675	100	3751	3018	105	99	1621	1769	148	61.20707
113	Sand	0	1512	772	106	3741	2932	116	3550	2742	115	3060	2289	110	3053	2343	101	3686	2924	109	3620	2844	111	110	1689	1895	206	65.33452
114	Sand	0	1543	611	133	3973	2993	140	3734	2293	206	3144	2253	127	3075	2209	124	3342	2560	112	3562	2639	132	140	1702	1914	212	82.30513
115	Sand	0	1601	910	99	3749	2930	117	3489	2664	118	3140	2327	116	3202	2449	108	3734	2886	121	3695	2805	127	118	1961	2125	164	60.07261
116	Sawdust	0	1629	1007	89	3476	2583	128	3486	2559	132	3322	2440	126	3068	2230	120	3390	2566	118	3276	2396	126	125	1853	2072	219	67.37851
117	Sawdust	0	1660	995	95	3781	2979	115	3802	2960	120	3187	2494	99	3003	2303	100	3157	2482	96	3323	2461	123	109	1752	1903	151	62.16977
118	Sawdust	0	1542	903	91	3822	3012	116	3700	2768	133	3203	2324	126	3032	2243	113	3330	2533	114	3421	2591	119	120	1935	2119	184	61.99951
119	Sawdust	0	1609	667	135	3755	2898	122	3487	2598	127	3302	2380	132	3014	2327	88	3472	2635	120	3599	2687	133	122	1808	2003	195	67.48578
120	Sawdust	0	1557	843	102	4089	3298	113	4016	3133	126	3133	2374	109	3027	2263	109	3768	2438	190	3359	2601	108	126	1778	1896	118	70.76839
121	Polystyrene	10	1563	781	112	4133	3351	112	4451	3603	121	3603	2763	120	3260	2390	124	3450	2670	111	3606	2693	130	120	1652	1805	153	72.54554
122	Polystyrene	10	1587	977	87	3719	2935	112	3611	2666	135	3060	2140	131	3165	2272	128	3303	2404	128	3456	2378	154	131	1654	1835	181	79.4265
123	Polystyrene	10	1608	1022	84	3837	3065	110	3948	3101	121	3101	2280	117	3065	2256	118	3198	2406	113	3311	2438	125	117	1916	2018	102	61.07342
124	Polystyrene	10	1543	746	114	4367	3519	121	4176	3236	134	3236	2317	131	3081	2263	117	3298	2447	121	3351	2371	140	127	1787	1882	95	71.33664
125	Polystyrene	10	1647	645	143	3589	2677	130	3077	2154	132	3146	2240	129	3022	2157	124	3408	2513	128	3308	2359	136	130	1937	2114	177	66.97274
126	Sawdust	15	1655	841	102	3272	2494	111	3238	2406	119	3291	2523	110	3028	2128	129	2795	2059	105	3416	2679	105	113	1802	1769	-33	62.78738
127	Sawdust	15	1490	858	90	3298	2513	112	3143	2199	135	3066	2172	128	3078	2127	136	2979	2134	121	2984	2123	123	126	1844	1920	76	68.18898
128	Sawdust	15	1566	870	99	3196	2482	102	3082	2337	106	3075	2368	101	3035	2256	111	3038	2352	98	3727	2970	108	105	1438	1469	33	72.77159
129	Sawdust	15	1559	939	89	3144	2559	84	3299	2499	114	3110	2359	107	3031	2116	131	3004	2261	106	3830	2800	119	110	1963	1851	-112	56.10581
130	Sawdust	15	1560	871	98	3269	2635	91	3217	2298	132	3050	2325	104	3127	2299	118	3103	2309	113	4043	3145	128	114	1911	1803	-108	59.80663
131	Bran	15	1555	904	93	3660	2844	117	3711	2863	121	3222	2487	105	3035	2193	120	3171	2464	101	3728	2893	119	114	1863	1928	65	61.106
132	Bran	15	1522	566	136	3696	3031	95	3632	2852	112	3096	2422	96	3024	2334	99	3235	2503	105	3534	2728	115	104	1508	1612	104	68.63869
133	Bran	15	1584	806	108	4009	3220	113	3992	3064	133	3064	2207	122	3210	2299	130	3102	2230	125	3629	2810	117	123	1772	1866	94	69.55015
134	Bran	15	1495	662	119	4298	3489	116	4161	3178	140	3178	2302	125	3078	2208	124	3240	2470	110	3897	2980	131	124	1829	1963	134	68.02182
135	Bran	15	1527	719	115	3986	3060	132	3854	2926	133	3045	2173	124	3017	2156	123	3161	2566	85	3668	2744	132	122	1898	1944	46	64.04862
136	Sand	15	1594	698	128	3791	2879	130	3861	2849	144	3097	2155	135	3161	2198	138	3600	2697	129	3438	2460	139	136	2128	2264	136	63.85495
137	Sand	15	1437	674	109	3624	2658	138	3432	2404	147	3114	2094	146	3025	2137	127	3378	2358	145	3162	2198	138	140	1889	2083	194	73.75686
138	Sand	15	1574	812	109	3828	2855	139	3434	2429	144	3388	2399	141	3039	2084	136	3108	2149	137	2720	1781	134	139	1867	2112	245	74.22016
139	Sand	15	1505	478	147	3785	2958	118	4180	3280	129	3280	2467	116	3225	2373	122	3472	2696	111	3151	2331	117	119	1805	1976	171	65.82641
140	Sand	15	1504	735	110	3813	2849	109	4208	3290	131	3290	2460	119	3053	2197	122	3199	2403	114	3163	2294	124	120	1862	1891	29	64.37267
141	Clay	10	1446	782	95	3274	2474	114	3369	2549	117	3048	2292	108	3400	2604	114	3261	2534	104	3687	2858	118	113	1675	1793	118	67.20256
142	Clay	10	1478	609	124	3590	2715	125	3471	2555	131	3135	2306	118	3108	2271	120	3441	2647	113	3920	3072	121	121	1834	1896	62	66.18502
143	Clay	10	1519	785	105	3380	2642	105	3278	2491	112	3178	2447	105	3224	2484	109	3437	2667	110	4111	2916	171	119	1670	1787	117	71.01939
144	Clay	10	1559	715	121	3229	2401	118	3059	2024	148	3177	2182	142	3041	2021	146	3349	2387	137	3331	2370	137	138	2142	2334	192	64.47801
145	Clay	10	1648	691	137	3325	2480	121	3415	2380	148	3296	2364	133	3132	2117	145	3217	2391	118	3569	2583	141	134	1975	2058	83	67.96986
146	Polystyrene	5	1594	1001	85	3438	2724	102	3467	2580	127	3177	2353	118	3005	2182	118	3472	2605	124	2956	2087	124	119	1677	1869	192	70.76554
147	Polystyrene	5	1596	936	94	3468	2727	106	3466	2548	131	3494	2750	106	3004	2135	124	3220	2472	107	2898	2039	123	116	1610	1771	161	72.14877

Hen	Feed		in	out	FI/day A	in	out	FI/day1	in	out	FI/day2	in	out	FI/day3	in	out	FI/day4	in	out	FI/day5	in	out	FI/day6	FI/day	start	end	BW change	SFI
148	Polystyrene	5	1448	745	100	3453	2563	127	3293	2438	122	2926	2138	112	2906	2071	119	3472	2676	114	3038	2154	126	120	1881	2031	150	63.88826
149	Polystyrene	5	1535	780	108	3699	2902	114	3627	2708	131	3137	2322	116	3183	2377	115	3487	2702	112	3139	2293	121	118	1856	1964	108	63.74564
150	Polystyrene	5	1586	937	93	3533	2807	104	3779	2922	122	3065	2280	112	3042	2333	101	3470	2621	121	3017	2142	126	114	1806	1879	71	63.23351
151	Bran	10	1533	691	120	3417	2503	131	3529	2641	127	3256	2398	123	3002	2200	115	3212	2365	121	2812	1865	135	125	2124	2232	108	58.91288
152	Bran	10	1504	867	91	3370	2629	106	3579	2779	114	3047	2277	110	3042	2289	108	3170	2428	106	2735	1921	116	110	1751	1873	122	62.82804
153	Bran	10	1635	958	97	3526	2836	99	3505	2757	107	3109	2402	101	2996	2248	107	3293	2531	109	2807	2087	103	104	1609	1710	101	64.777
154	Bran	10	1561	734	118	3444	2714	104	3878	3003	125	3068	2235	119	3191	2364	118	3273	2347	132	2602	1722	126	121	1847	1939	92	65.36726
155	Bran	10	1641	893	107	3575	2870	101	3763	3029	105	3156	2447	101	3075	2338	105	3244	2522	103	2828	2068	109	104	1855	1850	-5	58.04287
156	Bran	0	1510	617	128	3972	3057	131	3971	3072	128	3072	2373	100	3244	2371	125	3494	2759	105	3599	2771	118	118	1629	1816	187	72.32746
157	Bran	0	1556	858	100	3752	3000	107	3740	2940	114	3089	2410	97	3044	2325	103	3583	2850	105	3485	2762	103	105	1752	1814	62	59.67307
158	Bran	0	1526	769	108	3248	2477	110	3955	3069	127	3069	2288	111	3177	2479	100	3756	2889	110	3704	2847	122	113	1843	1923	80	61.48877
159	Bran	0	1533	862	96	3345	2597	107	3717	2813	129	3056	2278	111	3313	2375	134	3603	2848	108	3403	2618	112	117	1880	2041	161	62.16185
160	Bran	0	1590	695	128	3616	2940	97	4041	3177	123	3177	2394	112	3054	2379	98	3659	2942	102	3652	2874	111	107	1661	1801	140	64.39322
161	Sawdust	10	1496	726	110	3417	2598	117	3227	2374	122	3124	2302	117	3034	2171	123	2970	2244	104	3605	2769	119	117	1722	1827	105	67.99956
162	Sawdust	10	1470	777	99	3327	2570	108	3439	2643	114	3121	2338	112	3232	2498	105	3353	2436	131	3446	2606	120	115	1668	1741	73	68.92058
163	Sawdust	10	1502	784	103	3346	2506	120	3365	2483	126	3186	2406	111	3043	2264	111	3267	2528	106	3600	2780	117	115	1823	1996	173	63.18862
164	Sawdust	10	1509	704	115	3400	2620	111	3244	2350	128	3049	2172	125	3053	2200	122	3169	2363	115	3089	2159	130	122	1924	1972	48	63.35883
165	Sawdust	10	1541	937	86	3301	2412	127	3311	2356	136	3083	2173	130	3138	2324	116	3205	2479	104	3052	2176	125	123	2007	2040	33	61.32939
166	Sand	5	1540	927	87	3671	2999	96	4041	3266	111	3266	2548	103	3630	2784	121	3793	2948	121	4239	3398	120	112	1757	1944	187	63.64745
167	Sand	5	1483	827	94	3707	2958	107	3835	3045	113	3045	2278	109	3227	2444	112	3699	3014	98	4486	3715	110	108	1784	1894	110	60.65556
168	Sand	5	1414	684	104	3539	2758	111	3883	3000	123	3196	2387	116	3313	2437	125	3507	2737	110	3683	2803	127	119	1769	1996	227	67.13909
169	Sand	5	1467	726	106	3777	2855	132	3771	2773	143	3167	2202	138	3086	2161	132	3166	2303	123	3774	2814	137	134	1847	2032	185	72.60422
170	Sand	5	1501	844	94	3613	2796	117	3855	2983	125	3376	2559	117	3154	2380	111	3147	2417	104	3569	2752	117	115	1726	1824	98	66.60597
171	Polystyrene	15	1577	952	89	3445	2756	98	3702	2634	153	3123	2353	110	3257	2239	145	3599	2849	107	2883	1989	128	123	1712	1827	115	72.11977
172	Polystyrene	15	1434	830	86	3687	2737	136	4007	3166	120	3166	2224	135	3037	2170	124	3348	2468	126	2808	1934	125	128	1841	1916	75	69.25584
173	Polystyrene	15	1426	903	75	3358	2531	118	3906	2890	145	3078	2114	138	3016	2087	133	3426	2555	124	2697	1962	134	132	1819	2020	201	72.53331
174	Polystyrene	15	1591	944	92	3482	2736	107	3646	2828	117	3045	2268	111	3093	2322	110	3531	2812	103	2681	2043	120	111	1645	1683	38	67.61471
175	Polystyrene	15	1530	760	110	3434	2482	136	3545	2564	140	3284	2308	137	3280	2432	121	3761	2845	131	2914	1923	142	134	1770	1885	115	75.93624
176	Clay	15	1454	729	104	3714	2840	125	3564	2708	122	3117	2321	114	3178	2344	119	3659	2934	104	4040	3162	125	118	1866	1892	26	63.33053
177	Clay	15	1564	760	115	3620	2744	125	3360	2430	136	3510	2517	142	3014	2073	134	3344	2710	91	4103	3111	142	128	1856	1918	62	69.08739
178	Clay	15	1536	680	122	3389	2597	113	3358	2520	120	3129	2265	123	3219	2478	106	3806	3017	113	3419	2508	130	117	1977	1995	18	59.42265
179	Clay	15	1569	820	107	3369	2561	115	3251	2407	121	3040	2338	100	3042	2323	103	3630	2967	95	4129	3204	132	111	1822	1827	5	60.89201
180	Clay	15	1489	927	80	3367	2567	114	3302	2447	122	3318	2468	121	3174	2473	100	3832	3180	93	3800	3050	107	110	1905	1883	-22	57.5928
181	Bran	5	1437	563	125	3496	2748	107	3856	3004	122	3110	2325	112	3005	2167	120	3356	2622	105	3302	2435	124	115	1762	1832	70	65.17215
182	Bran	5	1397	643	108	3476	2686	113	3535	2634	129	3072	2217	122	3026	2277	107	3233	2524	101	3329	2427	129	117	1863	1937	74	62.71375
183	Bran	5	1587	926	94	3550	2916	91	3583	2788	113	3103	2382	103	3007	2354	83	3364	2628	105	3579	2720	123	105	1765	1842	77	59.30123
184	Bran	5	1452	819	90	3776	2971	115	3916	3016	129	3090	2295	114	3101	2300	114	3240	2616	89	3787	2909	125	114	1710	1814	104	66.86578
185	Bran	5	1613	779	119	3529	2829	100	3690	2863	118	3484	2740	106	3002	2380	89	3982	2809	168	3639	2777	123	117	1812	1915	103	64.75481
186	Clay	0	1420	730	99	3497	2772	104	4138	3221	131	3221	2423	114	3335	2524	116	3772	2945	118	4075	3167	130	119	1589	1829	240	74.72055
187	Clay	0	1466	829	91	4110	3359	107	4289	3485	115	3485	2760	101	3076	2405	96	3678	2947	104	3898	3091	115	106	1728	1853	125	61.56718
188	Clay	0	1430	739	99	3555	2796	108	4294	3376	131	3376	2546	118	3056	2235	117	3990	2747	178	3513	2666	121	129	1566	1789	223	82.37548
189	Clay	0	1459	711	107	3838	3063	111	3904	3096	116	3096	2338	108	2983	2268	102	3607	2918	98	3733	2942	113	108	1886	1916	30	57.2792
190	Clay	0	1436	616	117	3683	2847	119	3912	3004	130	3151	2341	116	3008	2270	105	3400	2583	117	3213	2347	124	118	1822	1905	83	65.00706
191	Polystyrene	0	1538	1023	74	3415	2696	103	3755	2984	110	3120	2396	103	3010	2242	110	3356	2923	62	3584	2764	117	101	1669	1809	140	60.40829
192	Polystyrene	0	1621	869	104	3585	3218	52	4052	3272	111	3234	2506	104	3182	2493	99	3436	2790	92	3413	2636	111	95	1482	1632	150	64.04794
193	Polystyrene	0	1582	748	119	3368	2522	121	3630	2599	147	3338	2407	133	3242	2454	113	3803	3077	104	3510	2667	120	123	1858	1911	53	66.18099
194	Polystyrene	0	1505	896	87	3818	3128	99	4108	3394	102	3394	2754	91	3008	2359	93	3466	2816	93	3492	2826	95	95	1617	1694	77	59.04232
195	Polystyrene	0	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	#VALUE!
196	Sand	10	1570	728	120	3671	2701	139	3989	3031	137	3031	2042	141	3054	2020	148	3306	2311	142	3204	2088	159	144	2099	2281	182	68.76971
197	Sand	10	1462	685	111	3723	2654	153	3661	2644	145	3161	2189	139	3141	2459	97	3246	2384	123	3413	2479	133	132	2059	2087	28	64.01513
198	Sand	10	1514	764	107	3976	3115	123	4360	3477	128	3468	2650	117	3017	2208	116	3445	2714	104	3640	2818	117	117	1599	1723	124	73.31219
199	Sand	10	1543	768	111	3691	2832	123	3744	2913	119	3080	2262	117	3123	2261	123	3440	2643	114	3789	2891	128	121	1615	1762	147	74.66903
200	Sand	10	1462	930	76	3946	2930	145	3672	2625	150	3310	2338	139	3082	2164	131	3431	2549	126	3379	2398	140	138	1861	1991	130	74.41724

Appendix E: Trial 2 egg production data

Hen	Diluent	Level	EW1	EW2	EW3	EW4	EW5	EW6	ave EW	ave wk 1-3	ave wk 4-6	ROLA	ROL1	ROL2	ROL3	ROL4	ROL5	ROL6	ave ROL	ave wk 1-3	ave wk 4-6	ave egg prod
1	Clay	0	53.79	52.89	54.10	54.68	53.23	56.65	54.22	53.59	54.85	7	7	6	7	6	6	7	92.9	6.7	6.3	50
2	Clay	0	59.48	60.01	59.85	62.55	62.29	61.07	60.87	59.78	61.97	7	7	7	7	7	6	6	95.2	7.0	6.3	58
3	Clay	0	59.16	57.45	60.77	60.20	60.70	59.37	59.61	59.13	60.09	7	7	7	7	7	7	7	100.0	7.0	7.0	60
4	Clay	0	54.69	56.15	55.30	58.26	55.94	57.01	56.23	55.38	57.07	7	7	7	7	7	7	7	100.0	7.0	7.0	56
5	Clay	0	64.19	63.08	61.98	61.57	61.39	63.05	62.54	63.08	62.00	6	7	7	7	7	7	7	100.0	7.0	7.0	63
6	Sand	5	55.21	57.17	58.09	59.58	58.86	58.71	57.94	56.82	59.05	7	7	7	7	7	7	7	100.0	7.0	7.0	58
7	Sand	5	64.76	62.13	64.05	65.06	58.48	65.54	63.33	63.64	63.03	6	7	6	7	6	6	6	90.5	6.7	6.0	57
8	Sand	5	61.70	62.76	63.83	66.25	66.44	64.06	64.17	62.76	65.58	7	6	7	6	7	7	7	95.2	6.3	7.0	61
9	Sand	5	63.80	64.32	61.03	63.97	64.09	62.26	63.24	63.05	63.44	6	6	6	7	7	7	7	95.2	6.3	7.0	60
10	Sand	5	64.33	63.71	66.21	66.46	67.73	68.02	66.08	64.75	67.40	7	7	7	7	7	6	7	97.6	7.0	6.7	65
11	Sand	15	49.31	49.45	51.52	53.62	50.17	50.05	50.68	50.09	51.28	5	6	5	7	6	7	5	85.7	6.0	6.0	43
12	Sand	15	65.17	63.83	65.48	66.42	65.68	60.96	64.59	64.83	64.35	7	7	7	7	7	7	7	100.0	7.0	7.0	65
13	Sand	15	60.34	66.16	66.74	70.94	69.82	66.54	66.76	64.41	69.10	7	5	7	7	7	7	7	95.2	6.3	7.0	64
14	Sand	15	66.13	67.14	63.50	64.91	67.76	64.59	65.67	65.59	65.76	6	7	7	7	7	7	7	100.0	7.0	7.0	66
15	Sand	15	57.62	57.61	59.34	59.33	60.65	57.62	58.70	58.19	59.20	7	7	7	7	7	7	7	100.0	7.0	7.0	59
16	Clay	10	63.26	64.82	64.75	82.33	60.00	63.07	63.04	64.27	61.80	6	7	6	5	5	6	6	83.3	6.0	5.7	53
17	Clay	10	59.50	57.59	57.97	63.18	60.66	58.82	59.62	58.35	60.89	6	7	7	5	7	6	7	92.9	6.3	6.7	55
18	Clay	10	54.10	53.88	56.03	55.51	55.74	54.55	54.97	54.67	55.26	7	6	7	7	6	7	6	92.9	6.7	6.3	51
19	Clay	10	57.34	59.12	55.59	54.11	54.71	57.33	56.36	57.35	55.38	6	7	7	7	6	7	7	97.6	7.0	6.7	55
20	Clay	10	0.00	60.32	60.48	62.29	62.97	60.02	51.01	40.26	61.76	6	4	7	6	7	7	6	88.1	5.7	6.7	45
21	Polystyrene	15	58.75	58.14	57.64	60.59	55.10	52.70	57.15	58.17	56.13	7	7	7	7	7	7	6	97.6	7.0	6.7	56
22	Polystyrene	15	60.87	59.68	64.31	62.64	60.57	61.22	61.55	61.62	61.48	6	7	6	7	7	7	6	95.2	6.7	6.7	59
23	Polystyrene	15	62.33	63.16	64.94	64.55	63.73	63.32	63.67	63.47	63.87	6	7	7	7	7	7	7	100.0	7.0	7.0	64
24	Polystyrene	15	68.96	67.32	66.37	68.94	69.11	65.22	67.65	67.55	67.76	7	7	7	7	7	7	7	100.0	7.0	7.0	68
25	Polystyrene	15	57.15	58.33	58.84	57.53	56.84	58.07	57.79	58.11	57.48	7	7	7	7	7	7	7	100.0	7.0	7.0	58
26	Sand	10	67.30	69.04	69.69	69.42	66.49	66.65	68.10	68.68	67.52	7	7	7	7	7	6	7	97.6	7.0	6.7	66
27	Sand	10	64.07	62.83	59.52	60.84	62.79	67.68	62.96	62.14	63.77	6	7	7	7	7	7	7	100.0	7.0	7.0	63
28	Sand	10	47.78	55.85	61.36	57.93	59.31	57.06	56.55	55.00	58.10	4	3	6	7	7	7	7	88.1	5.3	7.0	50
29	Sand	10	51.24	50.27	53.04	52.17	52.95	50.65	51.72	51.52	51.92	7	6	7	7	5	7	6	90.5	6.7	6.0	47
30	Sand	10	57.58	56.18	57.44	58.12	58.70	56.31	57.39	57.06	57.71	6	7	6	5	7	6	6	88.1	6.0	6.3	51
31	Bran	15	59.97	59.57	59.49	64.13	59.29	61.68	60.69	59.68	61.70	7	7	7	7	7	7	7	100.0	7.0	7.0	61
32	Bran	15	57.19	60.30	63.37	58.64	57.54	57.72	59.13	60.29	57.97	7	6	7	6	7	6	6	90.5	6.3	6.3	53
33	Bran	15	64.33	64.86	59.17	64.79	64.07	63.15	63.39	62.78	64.00	6	7	7	7	7	7	7	100.0	7.0	7.0	63
34	Bran	15	62.15	69.20	62.45	71.85	65.46	65.56	66.11	64.60	67.62	5	4	6	5	7	6	7	83.3	5.0	6.7	55
35	Bran	15	59.34	56.53	56.78	56.91	56.68	53.48	56.62	57.55	55.69	7	7	7	7	7	7	3	90.5	7.0	5.7	51
36	Sawdust	15	55.39	55.15	57.87	57.23	59.27	59.34	57.38	56.14	58.61	7	7	7	7	7	7	7	100.0	7.0	7.0	57
37	Sawdust	15	55.09	55.32	57.48	57.87	57.69	57.18	56.77	55.97	57.58	7	5	7	7	6	7	7	92.9	6.3	6.7	53
38	Sawdust	15	55.53	56.32	0.00	48.93	59.56	55.28	45.94	37.28	54.59	6	7	5	0	4	7	5	66.7	4.0	5.3	31
39	Sawdust	15	58.16	54.79	57.30	55.50	57.55	56.02	56.55	56.75	56.36	6	7	6	7	7	7	7	97.6	6.7	7.0	55
40	Sawdust	15	58.67	56.83	59.57	59.69	57.85	58.80	58.57	58.36	58.78	6	7	4	4	7	7	7	85.7	5.0	7.0	50
41	Clay	15	69.33	66.88	71.18	67.27	66.87	67.15	68.11	69.13	67.10	7	7	7	7	7	7	7	100.0	7.0	7.0	68
42	Clay	15	60.44	61.33	58.24	63.13	65.60	61.31	61.67	60.00	63.34	5	7	7	6	6	7	7	95.2	6.7	6.7	59
43	Clay	15	60.31	61.02	62.17	65.02	66.93	65.50	63.49	61.17	65.82	4	7	7	7	7	6	7	97.6	7.0	6.7	62
44	Clay	15	58.63	61.80	60.80	60.90	59.87	58.82	60.14	60.41	59.86	6	7	7	7	7	7	7	100.0	7.0	7.0	60
45	Clay	15	61.61	59.85	57.22	55.56	58.49	55.96	58.11	59.56	56.67	7	6	7	7	7	7	7	97.6	6.7	7.0	57
46	Sawdust	0	56.56	58.61	59.84	59.98	61.77	55.51	58.71	58.34	59.09	7	6	7	7	7	7	7	97.6	6.7	7.0	57
47	Sawdust	0	61.56	58.76	58.07	59.69	59.07	60.79	59.66	59.46	59.85	4	6	7	7	7	7	7	97.6	6.7	7.0	58
48	Sawdust	0	64.31	61.16	64.23	68.53	67.55	67.17	65.49	63.23	67.75	3	7	7	7	7	7	6	97.6	7.0	6.7	64
49	Sawdust	0	58.04	58.73	60.72	57.26	58.82	56.37	58.33	59.16	57.49	7	7	6	7	6	7	7	95.2	6.7	6.7	56
50	Sawdust	0	60.32	57.01	59.38	63.03	60.19	62.11	60.34	58.90	61.78	7	6	6	7	7	7	7	95.2	6.3	7.0	57
51	Clay	5	59.61	58.55	59.77	65.01	65.88	61.56	61.73	59.31	64.15	7	7	7	6	7	7	7	97.6	6.7	7.0	60
52	Clay	5	56.91	57.74	57.95	58.81	57.59	52.59	56.93	57.53	56.33	7	7	7	7	7	7	7	100.0	7.0	7.0	57
53	Clay	5	62.95	65.82	64.76	66.59	67.60	64.75	65.41	64.51	66.31	6	7	7	7	6	7	6	95.2	7.0	6.3	62
54	Clay	5	66.86	64.23	62.37	68.05	65.92	65.75	65.53	64.49	66.57	6	7	7	6	7	7	7	97.6	6.7	7.0	64
55	Clay	5	56.58	55.71	57.09	60.59	58.06	61.82	58.31	56.46	60.16	6	6	6	7	7	6	7	92.9	6.3	6.7	54
56	Bran	10	60.35	58.21	58.73	59.39	63.44	61.92	60.34	59.10	61.58	7	6	6	6	7	7	6	90.5	6.0	6.7	55
57	Bran	10	56.87	58.04	59.83	58.44	58.96	58.86	58.50	58.24	58.75	6	6	6	6	7	7	6	90.5	6.0	6.7	53
58	Bran	10	63.00	64.85	65.67	66.67	65.34	66.62	65.36	64.51	66.21	5	6	7	7	7	7	7	97.6	6.7	7.0	64
59	Bran	10	59.33	59.70	58.28	56.88	58.63	59.90	58.78	59.10	58.47	7	7	7	6	7	7	6	95.2	6.7	6.7	56
60	Bran	10	53.64	54.39	57.46	57.22	55.12	58.94	56.13	55.16	57.09	5	5	6	6	6	7	7	88.1	5.7	6.7	49
61	Polystyrene	5	55.87	54.85	56.50	57.82	58.57	58.67	57.05	55.74	58.35	6	7	7	7	7	7	7	100.0	7.0	7.0	57
62	Polystyrene	5	59.08	59.01	61.03	60.14	61.46	61.39	60.35	59.71	60.99	6	6	6	7	7	7	6	92.9	6.3	6.7	56
63	Polystyrene	5	58.26	59.34	58.02	59.53	59.73	59.12	59.00	58.54	59.46	6	7	7	7	7	7	7	100.0	7.0	7.0	59
64	Polystyrene	5	62.47	63.58	63.59	66.41	66.71	63.89	64.44	63.22	65.67	7	6	6	7	7	7	7	95.2	6.3	7.0	61
65	Polystyrene	5	58.61	59.11	63.17	60.63	64.78	61.46	61.29	60.30	62.29	7	7	7	7	6	7	7	97.6	7.0	6.7	60
66	Bran	5	63.32	61.20	61.74	58.51	62.34	62.06	61.53	62.09	60.97	5	7	7	6	7	6	7	95.2	6.7	6.7	59
67	Bran	5	57.31	58.13	56.48	54.72	59.64	58.83	57.52	57.31	57.73	6	6	7	5	7	7	7	92.9	6.0	7.0	53
68	Bran	5	60.62	57.87	57.15	58.07	58.54	60.39	58.77	58.55	59.00	6	7	7	7	6	7	6	95.2	7.0	6.3	56

Hen	Diluent	Level	EW1	EW2	EW3	EW4	EW5	EW6	ave EW	ave wk 1-3	ave wk 4-6	ROLA	ROL1	ROL2	ROL3	ROL4	ROL5	ROL6	ave ROL	ave wk 1-3	ave wk 4-6	ave egg prod
69	Bran	5	58.66	56.95	59.06	57.35	59.03	56.84	57.98	58.23	57.74	6	7	5	7	6	7	6	90.5	6.3	6.3	52
70	Bran	5	63.44	60.50	63.53	63.66	62.82	63.45	62.90	62.49	63.31	7	6	7	7	6	7	7	95.2	6.7	6.7	60
71	Bran	0	0.00	70.03	69.04	72.61	67.62	71.24	58.42	46.36	70.49	7	6	7	7	7	7	7	97.6	6.7	7.0	57
72	Bran	0	59.39	62.13	60.69	64.93	62.07	62.44	61.94	60.74	63.15	6	5	7	6	7	7	6	90.5	6.0	6.7	56
73	Bran	0	62.25	63.73	63.10	62.23	61.75	61.45	62.42	63.03	61.81	5	6	7	7	7	7	7	97.6	6.7	7.0	61
74	Bran	0	48.80	51.96	53.55	53.56	53.14	54.03	52.51	51.44	53.58	7	6	7	7	7	7	7	97.6	6.7	7.0	51
75	Bran	0	63.20	63.17	62.36	67.12	63.68	62.75	63.71	62.91	64.52	7	5	6	7	7	7	7	92.9	6.0	7.0	59
76	Sawdust	5	52.76	53.21	54.91	56.79	49.69	54.08	53.57	53.62	53.52	6	7	6	6	7	7	6	92.9	6.3	6.7	50
77	Sawdust	5	58.41	58.76	58.26	52.78	55.99	60.28	57.41	58.48	56.35	7	7	6	6	6	7	6	90.5	6.3	6.3	52
78	Sawdust	5	56.38	58.37	58.00	58.51	57.48	59.68	58.07	57.58	58.56	7	7	7	7	7	7	6	97.6	7.0	6.7	57
79	Sawdust	5	60.27	58.83	55.98	66.37	67.47	64.44	62.22	58.36	66.09	6	7	7	7	7	7	7	100.0	7.0	7.0	62
80	Sawdust	5	52.90	55.97	61.23	61.60	59.20	57.97	58.14	56.70	59.59	7	6	7	7	7	6	7	95.2	6.7	6.7	55
81	Sawdust	10	65.97	66.80	66.05	66.93	66.43	68.08	66.71	66.27	67.15	7	7	7	7	7	6	6	95.2	7.0	6.3	64
82	Sawdust	10	59.13	59.28	62.38	63.88	64.57	61.14	61.73	60.26	63.19	7	7	7	7	7	7	7	100.0	7.0	7.0	62
83	Sawdust	10	59.30	58.44	58.31	62.76	62.11	58.70	59.94	58.68	61.19	7	7	7	7	7	7	5	95.2	7.0	6.3	57
84	Sawdust	10	60.18	56.52	57.38	60.23	57.53	61.12	58.82	58.02	59.63	5	6	6	5	7	5	6	83.3	5.7	6.0	49
85	Sawdust	10	58.18	56.13	57.77	59.07	60.87	63.04	59.18	57.36	60.99	5	7	7	7	7	7	7	100.0	7.0	7.0	59
86	Sand	0	56.72	54.31	59.12	58.55	54.58	55.18	56.41	56.72	56.10	7	7	6	7	5	7	7	92.9	6.7	6.3	52
87	Sand	0	55.31	56.62	57.83	60.65	55.66	59.11	57.53	56.59	58.47	4	7	6	6	7	6	6	90.5	6.3	6.3	52
88	Sand	0	59.40	59.73	58.35	60.96	57.13	59.53	59.18	59.16	59.20	6	7	7	7	7	7	6	97.6	7.0	6.7	58
89	Sand	0	57.22	56.94	56.25	59.58	58.77	57.90	57.77	56.80	58.75	5	6	6	7	6	7	5	88.1	6.3	6.0	51
90	Sand	0	59.73	59.78	60.04	64.78	61.93	60.98	61.21	59.85	62.56	7	6	7	7	7	7	7	97.6	6.7	7.0	60
91	Polystyrene	0	56.69	58.96	57.97	62.47	59.06	58.04	58.86	57.87	59.86	7	7	7	7	7	7	7	100.0	7.0	7.0	59
92	Polystyrene	0	63.17	59.89	61.67	59.53	60.81	60.82	60.98	61.58	60.39	7	7	7	7	7	7	7	100.0	7.0	7.0	61
93	Polystyrene	0	59.38	59.81	63.74	56.64	61.47	63.31	60.73	60.98	60.47	7	7	7	6	6	7	7	95.2	6.7	6.7	58
94	Polystyrene	0	58.86	60.71	61.26	66.24	62.16	62.00	61.70	60.28	63.13	7	7	7	7	7	7	7	100.0	7.0	7.0	62
95	Polystyrene	0	56.41	54.72	57.72	60.78	60.43	59.47	58.25	56.28	60.23	6	7	7	7	7	7	7	100.0	7.0	7.0	58
96	Polystyrene	10	57.08	57.70	59.94	59.33	58.23	61.96	59.04	58.24	59.84	7	7	7	7	7	6	7	97.6	7.0	6.7	58
97	Polystyrene	10	61.60	76.81	66.32	63.89	60.48	64.86	65.66	68.24	63.07	5	5	7	7	7	7	7	95.2	6.3	7.0	63
98	Polystyrene	10	52.95	53.57	55.07	54.63	54.37	55.08	54.28	53.86	54.69	7	7	7	6	7	6	7	95.2	6.7	6.7	52
99	Polystyrene	10	62.21	64.83	66.39	64.38	64.88	65.97	64.78	64.48	65.08	7	7	7	7	7	7	7	100.0	7.0	7.0	65
100	Polystyrene	10	61.91	61.96	62.56	64.87	62.65	60.41	62.39	62.14	62.64	6	6	7	7	7	7	7	97.6	6.7	7.0	61
101	Sawdust	5	60.02	62.41	58.69	58.19	63.55	62.45	60.88	60.37	61.40	7	7	7	6	7	7	7	97.6	6.7	7.0	59
102	Sawdust	5	62.51	63.68	64.28	66.75	68.85	64.31	65.06	63.49	66.63	7	7	7	7	7	7	7	100.0	7.0	7.0	65
103	Sawdust	5	57.08	56.75	59.28	62.87	62.67	61.59	60.04	57.70	62.38	7	7	7	6	7	7	7	97.6	6.7	7.0	59
104	Sawdust	5	64.08	63.10	65.35	65.56	64.79	67.27	65.02	64.18	65.87	7	7	7	7	7	6	7	97.6	7.0	6.7	63
105	Sawdust	5	55.31	56.59	59.23	58.91	57.21	55.11	57.06	57.04	57.08	7	7	7	7	7	7	6	97.6	7.0	6.7	56
106	Clay	5	58.74	61.61	57.67	60.47	61.33	58.52	59.72	59.34	60.11	4	6	7	6	7	7	7	95.2	6.3	7.0	57
107	Clay	5	58.89	59.22	58.55	61.07	61.68	60.93	60.05	58.88	61.22	7	7	7	7	7	7	7	100.0	7.0	7.0	60
108	Clay	5	61.13	64.52	65.11	63.23	60.53	63.51	63.00	63.58	62.42	7	7	7	7	6	7	7	97.6	7.0	6.7	62
109	Clay	5	54.18	53.50	56.12	57.30	58.11	56.60	55.97	54.60	57.34	7	7	7	7	7	7	7	100.0	7.0	7.0	56
110	Clay	5	56.31	59.20	61.52	60.85	60.09	57.76	59.29	59.01	59.57	7	7	7	7	7	7	7	100.0	7.0	7.0	59
111	Sand	0	59.06	61.33	63.00	62.38	58.89	59.06	60.62	61.13	60.11	7	6	7	7	7	7	7	97.6	6.7	7.0	59
112	Sand	0	59.33	58.80	59.45	59.15	59.90	55.91	58.72	59.13	58.32	7	6	7	5	7	7	7	92.9	6.0	7.0	55
113	Sand	0	54.84	57.49	57.28	59.75	58.82	58.60	57.80	56.54	59.05	7	7	6	7	7	7	7	97.6	6.7	7.0	56
114	Sand	0	63.64	63.67	62.21	66.91	65.60	60.84	63.81	63.18	64.45	7	6	7	7	7	7	7	97.6	6.7	7.0	62
115	Sand	0	60.09	61.48	63.44	61.78	62.06	63.23	62.01	61.67	62.36	7	7	7	7	7	7	7	100.0	7.0	7.0	62
116	Sawdust	0	52.71	56.63	59.91	62.37	59.42	61.54	58.76	56.42	61.11	5	7	7	7	7	6	7	97.6	7.0	6.7	57
117	Sawdust	0	61.35	59.32	58.72	63.21	62.39	62.97	61.33	59.80	62.86	7	7	6	7	7	6	7	95.2	6.7	6.7	58
118	Sawdust	0	58.32	57.79	60.80	58.58	58.02	57.80	58.55	58.97	58.13	7	5	7	7	7	7	7	95.2	6.3	7.0	56
119	Sawdust	0	64.69	62.81	64.31	65.69	66.60	65.49	64.93	63.93	65.93	7	6	7	7	7	7	7	97.6	6.7	7.0	63
120	Sawdust	0	56.87	58.65	62.21	61.16	61.65	61.59	60.36	59.24	61.47	7	6	7	7	7	7	7	97.6	6.7	7.0	59
121	Polystyrene	10	0.00	61.68	58.28	64.75	63.76	62.55	51.83	39.99	63.68	5	4	6	6	6	7	6	83.3	5.3	6.3	43
122	Polystyrene	10	56.68	56.50	55.81	57.39	57.11	55.93	56.57	56.33	56.81	6	6	6	7	7	7	7	95.2	6.3	7.0	54
123	Polystyrene	10	55.68	56.85	58.84	57.62	60.67	55.32	57.46	57.06	57.87	7	7	7	7	6	7	7	97.6	7.0	6.7	56
124	Polystyrene	10	59.71	60.83	62.23	63.07	66.31	63.84	62.66	60.92	64.41	7	7	7	7	7	7	7	100.0	7.0	7.0	63
125	Polystyrene	10	60.84	61.37	64.65	65.07	62.46	61.30	62.62	62.29	62.94	7	7	7	7	7	7	7	100.0	7.0	7.0	63
126	Sawdust	15	55.38	57.31	55.47	54.85	58.42	54.77	55.70	56.05	55.35	6	7	7	7	7	7	6	97.6	7.0	6.7	54
127	Sawdust	15	54.48	60.86	63.21	64.72	60.81	64.48	61.42	59.51	63.33	6	5	7	7	7	7	7	95.2	6.3	7.0	58
128	Sawdust	15	55.01	55.40	53.33	58.85	57.49	55.18	55.64	54.58	56.51	6	5	6	7	7	7	7	92.9	6.0	7.0	52
129	Sawdust	15	55.28	55.43	57.93	57.69	57.80	58.12	57.04	56.21	57.87	7	6	6	7	7	6	7	92.9	6.3	6.7	53
130	Sawdust	15	57.84	58.87	63.26	58.82	62.67	61.18	60.44	59.99	60.89	7	6	7	7	6	7	6	92.9	6.7	6.3	56
131	Bran	15	56.34	59.18	58.36	60.12	59.09	59.83	58.82	57.96	59.68	7	7	7	7	6	7	7	97.6	7.0	6.7	57

Hen	Diluent	Level	EW1	EW2	EW3	EW4	EW5	EW6	aveEW	ave wk 1-3	ave wk 4-6	ROLA	ROL1	ROL2	ROL3	ROL4	ROL5	ROL6	ave ROL	ave wk 1-3	ave wk 4-6	ave egg prod
132	Bran	15	54.46	58.44	58.02	58.08	59.31	57.41	57.62	56.97	58.27	7	5	7	7	7	7	6	92.9	6.3	6.7	54
133	Bran	15	63.60	65.69	66.50	68.25	66.25	65.81	66.02	65.26	66.77	6	7	7	7	7	7	7	100.0	7.0	7.0	66
134	Bran	15	62.21	62.86	64.52	58.64	59.13	65.96	62.22	63.20	61.24	7	7	7	7	6	7	7	97.6	7.0	6.7	61
135	Bran	15	61.83	60.63	63.31	66.28	61.84	62.38	62.71	61.92	63.50	6	6	7	7	7	7	7	97.6	6.7	7.0	61
136	Sand	15	59.30	56.28	59.97	63.29	60.42	60.56	59.97	58.52	61.42	7	6	7	7	7	7	7	97.6	6.7	7.0	59
137	Sand	15	64.72	64.62	69.65	66.28	63.67	67.66	66.10	66.33	65.87	7	7	6	7	6	7	7	95.2	6.7	6.7	63
138	Sand	15	64.12	63.18	65.32	65.64	66.93	61.73	64.49	64.21	64.77	7	7	6	7	7	7	7	97.6	6.7	7.0	63
139	Sand	15	54.12	54.57	55.91	55.41	56.14	55.70	55.31	54.87	55.75	6	6	6	7	6	7	6	90.5	6.3	6.3	50
140	Sand	15	62.52	63.90	64.32	65.47	65.32	67.74	64.88	63.58	66.18	5	7	7	6	7	7	7	97.6	6.7	7.0	63
141	Clay	10	56.82	56.66	56.69	57.53	55.63	58.90	57.04	56.72	57.35	6	7	6	7	7	7	6	95.2	6.7	6.7	54
142	Clay	10	61.33	63.21	64.44	66.25	61.98	61.28	63.08	62.99	63.17	6	7	7	7	7	7	7	100.0	7.0	7.0	63
143	Clay	10	52.15	53.83	52.97	58.46	55.58	53.92	54.48	52.98	55.99	7	7	7	7	7	7	6	97.6	7.0	6.7	53
144	Clay	10	62.79	61.67	63.71	64.70	65.38	61.97	63.37	62.72	64.02	7	6	7	7	6	7	6	92.9	6.7	6.3	59
145	Clay	10	60.65	63.64	67.07	66.14	68.84	69.47	65.97	63.79	68.15	7	6	7	6	6	6	7	90.5	6.3	6.3	60
146	Polystyrene	5	60.70	62.04	66.60	62.85	61.82	61.70	62.62	63.11	62.12	6	6	7	7	7	7	7	97.6	6.7	7.0	61
147	Polystyrene	5	60.37	62.07	61.35	61.31	60.25	59.54	60.82	61.26	60.37	5	7	7	7	7	7	7	100.0	7.0	7.0	61
148	Polystyrene	5	51.19	47.54	48.79	49.76	49.67	48.66	49.27	49.17	49.36	7	7	7	7	7	7	6	97.6	7.0	6.7	48
149	Polystyrene	5	59.96	61.07	62.99	64.75	62.21	62.50	62.25	61.34	63.15	7	7	7	7	5	7	7	95.2	7.0	6.3	59
150	Polystyrene	5	60.05	60.77	61.62	59.72	58.69	62.22	60.61	60.82	60.21	5	6	7	7	7	6	7	95.2	6.7	6.7	58
151	Bran	10	58.20	54.43	57.55	59.88	58.33	59.20	57.93	56.73	59.14	6	7	3	5	7	7	7	85.7	5.0	7.0	50
152	Bran	10	57.62	55.85	58.38	57.81	63.21	58.31	58.53	57.28	59.78	7	6	4	7	6	7	7	88.1	5.7	6.7	52
153	Bran	10	51.36	55.83	55.40	57.04	54.12	57.12	55.14	54.20	56.09	6	7	7	6	7	7	6	95.2	6.7	6.7	53
154	Bran	10	59.91	64.97	68.63	68.06	66.26	72.74	66.76	64.51	69.02	7	6	7	7	7	7	7	97.6	6.7	7.0	65
155	Bran	10	54.41	53.54	54.82	53.83	58.44	55.63	55.11	54.26	55.97	6	7	7	7	7	7	7	100.0	7.0	7.0	55
156	Bran	0	65.28	62.63	68.03	66.80	60.06	62.55	64.22	65.31	63.14	6	7	7	7	6	7	7	97.6	7.0	6.7	63
157	Bran	0	59.91	59.24	56.83	63.03	64.89	60.24	60.69	58.66	62.72	7	7	6	7	7	7	7	97.6	6.7	7.0	59
158	Bran	0	52.50	53.83	55.03	56.25	58.11	59.87	55.93	53.79	58.08	7	7	7	7	7	7	7	100.0	7.0	7.0	56
159	Bran	0	54.58	53.60	56.04	59.60	54.23	55.27	55.55	54.74	56.36	7	6	7	7	7	6	7	95.2	6.7	6.7	53
160	Bran	0	62.53	66.86	62.81	64.70	63.00	65.24	64.19	64.07	64.31	5	6	6	7	6	7	7	92.9	6.3	6.7	60
161	Sawdust	10	64.79	61.93	63.90	62.11	64.27	66.52	63.92	63.54	64.30	7	7	7	7	7	7	7	100.0	7.0	7.0	64
162	Sawdust	10	52.69	59.94	57.91	55.38	58.73	58.52	57.19	56.85	57.54	6	5	7	7	7	7	6	92.9	6.3	6.7	53
163	Sawdust	10	56.94	58.82	59.97	59.19	60.42	59.58	59.15	58.58	59.73	7	7	7	7	7	7	7	100.0	7.0	7.0	59
164	Sawdust	10	61.48	62.86	65.96	64.97	64.80	64.51	64.10	63.43	64.76	7	6	7	7	6	7	6	92.9	6.7	6.3	60
165	Sawdust	10	59.07	59.32	58.90	62.28	60.18	57.93	59.61	59.10	60.13	4	7	7	7	7	7	7	100.0	7.0	7.0	60
166	Sand	5	57.69	58.03	60.66	56.47	64.61	58.89	59.39	58.79	59.99	6	6	6	7	6	7	6	90.5	6.3	6.3	54
167	Sand	5	56.33	57.29	58.79	57.87	58.16	57.84	57.71	57.47	57.96	7	7	7	7	7	7	7	100.0	7.0	7.0	58
168	Sand	5	60.12	61.01	59.73	59.26	59.54	57.46	59.52	60.29	58.75	6	7	7	7	7	7	7	100.0	7.0	7.0	60
169	Sand	5	69.20	66.18	65.93	69.72	72.83	69.68	68.93	67.11	70.74	6	7	7	7	7	7	7	100.0	7.0	7.0	69
170	Sand	5	66.88	65.44	62.96	64.29	62.05	64.26	64.31	65.09	63.53	7	7	7	7	7	7	7	100.0	7.0	7.0	64
171	Polystyrene	15	64.73	61.77	63.18	66.73	67.96	65.28	64.94	63.23	66.66	6	7	7	7	6	7	6	95.2	7.0	6.3	62
172	Polystyrene	15	58.49	57.76	58.26	58.56	58.53	55.16	57.79	58.17	57.42	5	6	7	6	7	7	7	95.2	6.3	7.0	55
173	Polystyrene	15	55.19	55.42	58.72	59.09	59.15	58.30	57.65	56.44	58.85	6	6	7	7	7	7	7	97.6	6.7	7.0	56
174	Polystyrene	15	61.36	59.43	59.72	61.66	59.90	63.98	61.01	60.17	61.85	6	7	6	5	6	6	6	85.7	6.0	6.0	52
175	Polystyrene	15	63.74	64.23	66.60	68.59	69.39	65.17	66.29	64.86	67.72	7	7	7	7	5	7	7	95.2	7.0	6.3	63
176	Clay	15	54.87	55.77	55.53	57.20	56.10	58.64	56.35	55.39	57.31	7	7	6	7	6	7	6	92.9	6.7	6.3	52
177	Clay	15	63.01	61.91	60.00	59.37	61.54	58.78	60.77	61.64	59.90	6	7	7	6	7	7	7	97.6	6.7	7.0	59
178	Clay	15	57.62	56.62	60.37	58.21	61.28	63.25	59.56	58.20	60.91	6	7	6	7	7	7	7	97.6	6.7	7.0	58
179	Clay	15	60.01	59.37	57.60	54.46	56.42	58.99	57.81	58.99	56.62	7	7	7	6	5	7	6	90.5	6.7	6.0	52
180	Clay	15	59.65	61.82	57.86	57.58	58.15	60.99	59.34	59.78	58.90	5	7	7	7	7	7	5	95.2	7.0	6.3	57
181	Bran	5	61.28	60.66	58.95	59.53	59.30	59.47	59.87	60.30	59.43	6	7	7	7	7	7	6	97.6	7.0	6.7	58
182	Bran	5	63.54	61.32	63.99	65.80	64.87	63.53	63.84	62.95	64.73	7	7	7	7	6	7	7	97.6	7.0	6.7	62
183	Bran	5	61.53	56.73	59.31	59.33	57.84	59.20	58.99	59.19	58.79	6	6	5	5	7	6	6	83.3	5.3	6.3	49
184	Bran	5	56.47	57.83	59.87	60.30	58.29	58.01	58.46	58.06	58.87	7	7	7	7	7	7	7	100.0	7.0	7.0	58
185	Bran	5	57.71	56.79	59.47	61.83	59.93	59.48	59.20	57.99	60.41	7	7	7	7	7	7	7	100.0	7.0	7.0	59
186	Clay	0	56.93	62.54	64.43	64.03	63.22	65.32	62.75	61.30	64.19	6	6	7	6	7	7	6	92.9	6.3	6.7	58
187	Clay	0	55.14	55.92	59.55	57.49	59.90	55.43	57.24	56.87	57.61	5	7	6	7	7	6	7	95.2	6.7	6.7	55
188	Clay	0	52.71	56.54	59.50	57.70	57.54	59.36	57.22	56.25	58.20	5	6	7	7	7	7	7	97.6	6.7	7.0	56
189	Clay	0	66.20	59.73	59.86	57.61	61.63	61.49	61.09	61.93	60.24	5	7	6	6	5	7	7	90.5	6.3	6.3	55
190	Clay	0	60.54	63.13	64.92	66.41	62.63	60.86	63.08	62.86	63.30	6	7	7	7	7	7	7	100.0	7.0	7.0	63
191	Polystyrene	0	56.56	57.74	55.06	53.91	56.14	58.59	56.00	56.46	55.55	5	7	6	7	7	7	6	95.2	6.7	6.7	53
192	Polystyrene	0	54.95	50.65	54.29	53.91	51.06	52.29	52.86	53.30	52.42	7	5	7	7	7	7	7	95.2	6.3	7.0	50
193	Polystyrene	0	61.25	61.38	63.66	64.23	62.77	66.14	63.24	62.10	64.38	7	7	6	7	7	7	7	97.6	6.7	7.0	62
194	Polystyrene	0	57.55	58.46	59.19	60.63	63.87	62.00	60.28	58.40	62.17	7	5	7	6	6	7	5	85.7	6.0	6.0	52
195	Polystyrene	0	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
196	Sand	10	60.91	62.53	60.37	62.23	66.84	65.38	63.04	61.27	64.82	7	7	7	6	7	6	7	95.2	6.7	6.7	60
197	Sand	10	64.65	63.57	66.40	67.65	62.07	63.18	64.59	64.87	64.30	5	7	7	7	7	7	7	100.0	7.0	7.0	65
198	Sand	10	58.11	61.30	60.88	64.13	60.11	58.77	60.55	60.10	61.00	6	7	7	7	7	6	7	97.6	7.0	6.7	59
199	Sand	10	53.65	54.08	52.68	52.77	51.27	52.82	52.88	53.47	52.29	6	7	7	7	7	7	7	100.0	7.0	7.0	53
200	Sand	10	59.37	58.60	65.99	64.31	62.71	61.77	62.11	61.29	62.93	5	7	7	7	7	7	7	100.0	7.0	7.0	62