The Effect of Dietary Alterations on Growth, Productivity, Behaviour and Preference of Broiler Breeder Females

by

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ABSTRACT

THE EFFECT OF DIETARY ALTERATIONS ON GROWTH, PRODUCTIVITY, BEHAVIOUR AND PREFERENCE OF BROILER BREEDER FEMALES

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This thesis is an investigation of dietary alterations, including the addition of fibre and an appetite suppressant (alternative diet) and the use of a skip-a-day (SAD) feeding regime, which may reduce hunger. Broiler breeders are severely feed restricted to limit growth, leading to symptoms of chronic hunger. We used behavioural indices, feather condition scoring and preference tests were used to compare satiating properties of the diets. Alternative diets reduced symptoms of hunger such as feather, object and aggressive pecking and resulted in better feather condition. Although SAD birds feather pecked more during feeding bouts, SAD birds still had better feather condition than daily birds. Preference testing revealed no differences in dietary preference, implying a lack of preference, or a methodological flaw. However, no aversion to the alternative diet was evident. Alternative diets, regardless of feeding frequency, may be the best option for bettering the welfare of growing broiler breeders.

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CHAPTER 1: GENERAL INTRODUCTION

Domestic livestock today face a number of welfare challenges, including incredible genetic changes as well as compromised opportunities for natural feeding behaviour. For some species, especially poultry raised for meat, genetic selection has been driven mainly by increased capacity for fast growth and high feed efficiency (Renema et al., 2007). In the past 50 years, broilers have changed dramatically, with current strains growing more than four times as fast as strains from the 1950's (Renema et al., 2007). Target weights for broilers at 6 wk of age are over 2.5 kg (Ross 708 Broiler Performance Objectives, 2011). The strain this body weight puts on a growing, juvenile skeleton and cardiovascular system has a negative impact on welfare, as indicated by increases in lameness, metabolic disorders and heart disease in broiler flocks (Mench, 2002). These welfare concerns affect a large number of animals, as more than 53 billion broilers are slaughtered every year around the world (Dawkins & Layton, 2012).

Although there are major welfare and health concerns occurring in broilers, the parent stock of these birds (broiler breeders) face different, yet still important welfare problems, mainly related to feeding. While broilers are allowed to eat to satiety to support their fast growth rates, this fast growth results in heavy juvenile body weights that are not conducive to a healthy adulthood. Therefore, birds that are destined for breeder flocks are severely feed restricted, being allocated only 25 – 35% of what they would eat if given the choice (de Jong et al., 2002). While this restriction is necessary to support optimal growth and health during rearing and into the lay period, it leads to a reduction in overall welfare as birds are often observed performing stereotypic behaviour indicative of chronic hunger (d'Eath et al., 2009; de Jong & Guémené, 2011).

A number of researchers (Zuidhof et al., 1995; Savory et al., 1996; Savory & Lariviere, 2000; Hocking et al., 2004; de Jong et al., 2005a; Sandilands et al., 2005; Sandilands et al., 2006) have experimented with different dietary diluents in an attempt to increase satiety, thereby alleviating the problems associated with restricted feeding. However, to the best of our knowledge, no previous study had examined the use of dietary diluents from North American sourced fibrous ingredients in combination with an appetite suppressant to replicate the positive benefits found by others (Sandilands et al., 2005; Sandilands et al., 2006). In addition, the effects of alternative feeding schedules that are common in North America, but prohibited in the United Kingdom have not been examined in combination with alternative diets. Therefore, this research was designed to investigate the effects of alternative diets and feeding regimes on the growth, productivity, behaviour and dietary preference of broiler breeder females. We hypothesized that diets providing a greater quantity of feed and including a chemical appetite suppressant would result in a reduction in hunger related behaviour. In addition, feeding regimes that do not provide feed on a daily basis were expected to cause an increase in hunger. We also expected birds to prefer diets that resulted in greater long-term satiety compared to quantitatively restrictive control diets.

CHAPTER 2: LITERATURE REVIEW

2.1 BROILER BREEDER PRODUCTION STANDARDS

The term "broiler breeders" is used to describe the parent and grandparent stocks that produce the lineage ("broiler" chickens) for the chicken meat industry. Breeding stocks are generally housed on the floor in large barns, with access to a litter area for scratching and foraging. This area also provides space for mating behaviour, as natural insemination occurs in almost all circumstances, with a recommended 11:1 female to male ratio during the laying period (Ross Breeder Management Manual, 2011). In a typical breeder barn, drinkers and feeders are located above raised slats so as to segregate manure and waste water from the birds and keep it off the litter. Nesting boxes are also used to encourage hens to lay eggs away from the floor and to ease egg collection for the stock personnel.

Broiler strains have been selected to become more feed efficient in order to reach market weight more quickly and at less cost, as modern broilers can grow at almost 5 times the rate of a meat bird from 1957 (Renema et al., 2007). Currently, a typical broiler chicken can reach a weight of 2.6 kg in 42 d (Ross 708 Broiler Performance Objectives, 2011). This rapid growth rate is accompanied by an extremely large appetite. In order to accommodate the metabolic demands of such fast growth rates, broilers are generally fed to satiety. *Ad libitum* feeding, however, is not a viable option for broiler breeders as it leads to excessive weight gain and poor reproductive performance (Savory & Maros, 1993; Mench, 2002). Therefore, breeders must be severely feed restricted for optimal health and productivity. Following *ad libitum* access to feed from 0 – 7 d, restriction usually begins at 1 wk of age, and can reach levels where birds are limited to 25% - 35% of what they would choose to consume (de Jong et al., 2002). Birds are generally fed on a daily basis, but alternative feeding regimes, such as "skip-a-day" (SAD) are common in North America (Mench, 2002). In contrast to daily feedings, SAD regimes allocate twice the daily ration every other day from 4 wk of age until the onset of lay (Ross Breeder Management Manual, 2007).

2.1.1 Benefits of Feed Restriction

As the parent stocks, broiler breeders have the same genetic potential for rapid growth as do their offspring. Genetic selection for fast growth is accompanied by an increase in appetite, supported by adaptive changes in both the central and peripheral mechanisms that control and are related to hunger and satiety (Denbow, 1989; Mench, 2002). Therefore, if fed on an *ad libitum* basis, broiler breeders will eat beyond an amount appropriate for healthy growth and development, leading to excessive weight gain and obesity during rearing (Savory & Maros, 1993). For example, *ad libitum* feeding resulted in birds that were almost 2.5 times heavier than restricted birds at 21 wk of age, leading to reduced ability to dissipate excess body heat (Savory & Maros, 1993). Increased body weight during rearing is associated with an increased risk of premature death, cardiovascular and musculoskeletal problems (Julian, 1998), as well as early onset of sexual maturity and multiple ovulations causing a decrease in reproductive performance (Pym & Dillon, 1974; Renema & Robinson, 2004). Savory & Maros (1993) reported *ad libitum*-fed birds reaching 10% egg production by 18 wk of age, much earlier than breeder recommendations of 5% production at 25 wk (Ross Breeder Management Manual, 2007). Early onset of lay, or high body weights at the onset of lay is associated with irregular oviposition, an increase in defective eggs and reduced hatchability (Renema & Robinson, 2004). Since obesity and the associated health problems are disadvantageous to the industry's productivity and profitability, broiler breeders are limit-fed to reduce the incidences of these problems (review by Mench, 2002).

2.1.2 Welfare Concerns for Feed Restriction

Even though restricting caloric intake supports the physical health and reproductive fitness of broiler breeders, it can have a detrimental effect on the birds' psychological welfare as chronic hunger is evident in restricted birds. However, by allowing broiler breeders to eat to full satiety, the future welfare of the broiler breeder may likely become compromised. As a result, there is a dilemma between rearing either a hungry and healthy or sated and obese bird.

By comparing broiler breeders' feed intake and body weights to those of their broiler counterparts of the same age, it is easy to see the severity of the imposed restriction. At 6 wk of age, a broiler chicken consumes 205 g/d and weighs just over 2 kg. Conversely, 6 wk old broiler breeders of the same genetic line are restricted to 41 g/d and weigh only 0.58 kg (Ross Breeder Management Manual, 2011). At this age, broiler breeders are more comparable to pullets of a laying strain in body weight and feed allocation (ISA White Product Performance, 2011). Broiler breeders can consume their entire daily ration in as little as 10 min from 4 wk of age onward (Kostal et al., 1992; Savory et al., 1993; Savory & Maros, 1993), and birds remain motivated to eat after consuming their daily ration. When compared to *ad libitum*-fed birds that had been fasted for 72 h, birds restricted to a commercial standard amount were calculated to be almost 4 times as motivated to eat in an operant conditioning test (Savory et al., 1993). In addition, using similar operant conditioning, Bokkers et al. (2004) found that broilers restricted to 50% *ad libitum* intake were willing to pay a higher price (ie. were more motivated) for a food reward than birds restricted to 75% *ad libitum* intake.

Behavioural indices of frustration and hunger are evident in much higher frequencies in feed-restricted broiler breeders compared to full-fed birds. Restriction that causes mild levels of hunger seems to elicit displacement behaviour, such as excessive preening, rather than stereotypic behaviour (Duncan & Wood-Gush, 1972). However, de Jong et al. (2002) reported a decrease in "comfort" behaviour (preening, dustbathing, wing flapping and stretching) with feed restriction in comparison to *ad libitum* feeding. With more severe restriction, stereotypic behaviour develops and can indicate a higher level of hunger and frustration (Duncan & Wood-Gush, 1972). In particular, spot or object pecking, pecking at an empty feeder and increased drinking or pecking at the nipple have all been identified as being more prevalent in restricted-fed birds when compared to *ad libitum*-fed birds (Savory et al., 1992; Savory & Maros, 1993; de Jong et al., 2002; Merlet et al., 2005). Increased activity and decreased resting have also been observed more often in restricted birds (Savory et al., 1992; de Jong et al., 2002; de Jong et al., 2003; Jones et al., 2004; Merlet et al., 2005) and may be a behavioural mechanism to support the need to find food (Baumeister et al., 1964). Increased aggression has been linked with food deprivation and frustration, but only in previously feed restricted birds that could see but could not access the feed (Duncan & Wood-Gush, 1971). Oral stereotypies and general activity appear to occur at the highest level immediately following a restricted feeding bout, indicating that the birds are still motivated to perform appetitive feeding behaviour and most likely still feel hungry (Savory & Mann, 1999; de Jong et al., 2003).

The link between feed restriction and some of the physiological indices of stress has been less clear. Hocking et al. (1996) and de Jong et al. (2003) found that plasma corticosterone increased as the level of restriction increased. However, some differences in corticosterone are inherently expected with different feeding methods due to its role in blood glucose regulation (Mench, 2002; Renema & Robinson, 2004). Heterophil:lymphocyte (H:L) ratio has also been identified as a indicator of stress in birds, and has been used as a welfare parameter with feed restriction in broiler breeders. However, these changes in the distribution of white blood cells are related to changes in circulating corticosteroids. Therefore the findings on the effect of restricted feeding are inconclusive and may be invalid, with some reporting elevated H:L levels (Hocking, 1993; Sunder et al., 2008) and others reporting no differences (Savory et al., 1992; Jones et al., 2004; Katanbaf et al., 1989).

2.1.3 Alternative Feeding Schedules

In North America, skip-a-day (SAD) and other alternative feeding regimes (such as "5-2", where birds are fed on 5 out of every 7 d) are quite commonly used to increase flock weight uniformity especially when feeder space is limited (Ross Breeder Management Manual, 2007; Richards et al., 2010). The age at which these regimes are initiated is generally a few wk after hatch (4 wk, as specified by Ross Breeder Management Manual, 2007), lasting until onset of lay. Because a large volume of feed is delivered at once, the opportunity for a larger proportion of the flock to access feed is greater than with daily feeding regimes, especially for birds ranked low in the hierarchy. Body weight uniformity is desirable as it makes managing the nutritional requirements of a large flock easier. It also leads to hens maturing at similar rates and coming into lay at the same time. This makes it more likely that the eggs from a flock will be closer in weight and size, resulting in broiler chicks that are more uniform at hatch weight, giving each chick an equal opportunity for growth and performance (Wolanski et al., 2007). Although there is widespread belief within the industry that SAD improves flock uniformity (Bramwell et al., 2008; Richards et al., 2010), the literature surrounding the performance and body weight variation does not support this notion. Bennett & Leeson (1989) found no differences in uniformity between daily and SAD fed birds from 5 – 20 wk of age. More recently, Ingram et al. (2001) observed no differences in uniformity among birds fed daily and birds on SAD regimes that were initiated at 2, 4 or 6 wk of age. Similarly, no differences in uniformity between daily-fed, SAD-fed or 5-2-fed birds were found from 4 – 40 wk of age (de Beer & Coon, 2007). Nonetheless, body weights of SAD birds were, more often than not, found to be lower than their daily fed counterparts (Powell & Gehle, 1976; Leeson & Summers, 1985) demonstrating that SAD can be used as an additional measure for effectively restricting growth rates. De Beer & Coon (2007) suggested that, although both feeding regimes offer the same caloric intake, SAD birds may be more inefficient in using this energy, as nutrients are deposited post-ingestion, and then remobilized over the next 2 d.

It is possible that the negative aspects of restriction may be intensified by alternative feeding regimes that do not provide at least some feed on a daily basis. On the other hand, there may be some positive aspects to allowing birds to eat to satiety on alternate days. For example, Douglas et al. (1998) found gestating sows to be less active and display less stereotypic behaviour when fed once every 3 d rather than on a daily basis. However, it is interesting to note that while SAD is quite common in North America, feeding schedules that do not provide feed on a daily basis are prohibited in the United Kingdom (DEFRA, 2007). Overall, there has been little scientific evidence that SAD regimes for broiler breeders negatively affect welfare in comparison to restricted daily feeding. Corticosterone concentrations were significantly higher in SAD-fed males compared to those fed *ad libitum*, with greater differences observed on "off-feed" days (Mench, 1991). However, when comparing to *ad libitum* fed birds, any type of feed restriction has the potential to elicit a physiological stress response or change in glucose metabolism, so attributing these results to SAD regimes may not be entirely valid. In addition, corticosterone concentrations may not accurately reflect the level of stress birds on different dietary treatments are experiencing. As previously discussed, corticosterone plays a role in glucose mobilization and higher blood concentrations may be a result of metabolic demands rather than mental stress (Mench, 2002).

Without increasing the daily feed allocation, de Jong et al. (2005b) tested the effects of supplying 1 or 2 meals/d, either in a trough or scattered on the ground. Although scattered feeding resulted in less frequent object pecking, regardless of number of daily feedings, the birds performed similarly in feed motivation tests as their trough-fed counterparts. The goal of scattered feeding was to increase the amount of time spent feeding and to stimulate foraging in a meaningful way, to help encourage and satisfy natural feeding behaviour. However, producers may be hesitant to adopt this type of feeding as it increases the risk of feed contamination. Birds fed twice a day were more active in the afternoon periods, which may indicate a high level of feeding motivation lasting through the day. It is important to note that all behavioural data was collected on 2 consecutive d and physiological samples were collected on 1 d at 7 wk of age. Feeding motivation testing was completed over 2 d at 8 wk of age. Therefore, it is possible that these data were not representative of the entire rearing period.

2.2 FEEDING BEHAVIOUR

Feeding behaviour involves both an appetitive and consummatory phase with the appetitive phase generally preceding the consummatory phase. The appetitive phase includes the initial searching for and locating food sources based on visual cues from the environment (Savory, 2010). This is also referred to as foraging, which includes scratching and pecking at the ground or substrate (Dawkins, 1989). The consummatory phase involves the ingestion of feedstuffs. For at least the first few d of life, these two phases seem to be performed independently of each other, controlled by different motivational systems (Savory, 2010; Hogan, 1971). Incorporation of the two phases into a sequence for normal feeding behaviour develops soon after hatch, in relation to substrates and early life experiences (Hogan, 1971; Savory, 2010).

Wild fowl may spend a large portion of their day performing foraging and feeding behaviour. Savory et al. (1978) observed a small population of domestic fowl in a natural outdoor environment, and while they only spent 30% of their time feeding in the morning, they spent up to 75% of their time feeding in the evening. The length of feeding bouts ranged from 10 min to over 1 h, depending on the weather. Similarly, Dawkins (1989) observed zoo-housed jungle fowl spending the majority of their day foraging, with birds scratching 60% and pecking 30% of the observed time. These birds preferred to engage in foraging behaviour even though feed was delivered in a trough on a regular basis. Therefore, this implies that birds prefer to spend large portions of the day in the appetitive phase when given the opportunity, even when feed is freely available (Dawkins, 1989; Inglis et al., 1997). Domestic chickens, in both cages and on litter, often display scratching behaviour while at the feeder (Glatz, 2002). While broilers display lower levels of foraging behaviour when compared to a commercial laying strain (White Leghorns) and wild jungle fowl (Lindqvist et al., 2006), this may be a direct consequence of the decreased mobility and not necessarily a reflection of their motivation to perform natural feeding behaviour (Bokkers et al., 2004). In addition, commercial birds selected for production traits spend less time and energy in feeding activity, reallocating energy resources to support rapid growth, or high egg production in the case of laying strains (Schütz & Jensen, 2001; Schütz et al., 2001; Lindqvist et al., 2006; Lindqvist & Jensen, 2009).

Because broiler breeders consume their daily rations in a very short period of time (Savory & Maros, 1993), searching and foraging behaviour as a part of feeding is virtually eliminated. In addition, the amount of time spent in both the appetitive and consummatory phases is significantly shortened. As a result, birds have more time to spend performing unwanted or harmful behaviour (ie. stereotypic object or feather pecking) and may be more inclined to act aggressively towards conspecifics (Mench, 2002).

2.2.1 Regulation of Feeding Behaviour

The regulation of feed intake is quite complex, consisting of a number of different levels of control, both within the brain as well as the periphery (Denbow, 1994). It has been suggested that satiety mechanisms in broilers (and, therefore, broiler breeders) have been impaired due to genetic selection for high growth rates (Burkhart et al., 1983, Bokkers & Koene, 2003). Instead of eating to meet metabolic demands for normal growth, fast growing strains will voluntarily eat to near full gastrointestinal capacity, whereas slower growing strains do not display this same behaviour, eating only a small percentage of total physical capacity (Bokkers & Koene, 2003).

Wild jungle fowl and laying hens have a diurnal pattern to their feeding behaviour, with high levels of feeding activity in the morning and the evening in comparison to the rest of the day (Savory, 1980; Dawkins, 1989). Evening feeding bouts may facilitate food storage in the crop to allow the nutrient release and absorption required throughout the night, as very little feeding behaviour occurs in the dark period (Savory, 1980). Therefore, single meal feeding in the morning alone may inhibit natural feeding behaviour, further implicating the negative effects of restricted feeding.

Feeding in mammalian species has been shown to be regulated in two manners which may be applicable to poultry: 1) via the “hunger mechanism” where the meal size determines the duration of the post-prandial interval (Thomas & Mayer, 1968) or 2) via the “satiety mechanism” where the duration of the pre-prandial interval determines the start and length of the succeeding meal (De Castro & Balagura, 1975). In most mammals and birds, the hunger mechanism affects feeding more strongly, where larger meals will predict a longer duration on non-feeding (Thomas & Mayer, 1968; Bokkers & Koene, 2003), although De Castro & Balagura (1975) showed that feeding behaviour of weanling rats up to 35 d of age was best described by the satiety mechanism before the hunger mechanism took over in adulthood. Savory (1981) found evidence to support the hunger mechanism in Japanese quail as meal size was the best predictor of the following inter-meal interval. Using brown Leghorn pullets as a model, Duncan et al. (1970) also found evidence for the hunger mechanism, with no indication that the satiety mechanism existed in chickens. In contrast, Clifton (1979) showed that domestic chicks were influenced by both mechanisms, depending on average inter-meal interval. In this study, they found that feeding patterns of chicks with longer than average intervals were dominated by the hunger mechanism, whereas the opposite was true for chicks with shorter than average intervals. However, more recently, Bokkers & Koene (2003) showed that feed intake in broilers is controlled mainly by satiety mechanisms, and both satiety and hunger mechanisms controlled feeding behaviour in laying strain pullets. This indicates that feeding behaviour has been altered in modern broiler chickens, as only upper set points control feeding patterns (ie. broilers eat to physical capacity). However, there is research suggesting that the normal structure of feeding behaviour is conserved in broiler chickens, except that feeding bouts are fewer, yet longer in duration in comparison to birds less heavily selected for high body weights (Howie et al., 2009).

2.2.2 Learned Behaviour, Nutritional Wisdom and Food Preference

In the wild, chicks learn about appropriate food sources via visual and auditory cues from the mother hen. Food calls, in the form of short staccato pulses, made while pecking at food, elicit responses from conspecifics, bringing them toward the food source (Collias, 1952; Sherry, 1977). Using a model beak as a visual cue, Suboski (1987) demonstrated that chicks preferentially peck at objects if the beak-like model is "pecking" at them as well. Food calling by the hen is affected by the quality of the foodstuff and response to food calls is negatively correlated with age of the chicks (Wauters & Richard-Yris, 2002). Maternal bonds develop soon after hatch, as chicks reared without a hen have little to no reaction to food calls when placed with a broody hen at 10 d of age (Collias, 1952). Therefore, in commercial settings, visual cues among large groups of chicks may be the dominant factor in facilitating learned feeding behaviour. Johnston et al. (1998) showed that chicks learned to avoid aversive substances by observing the reaction of their conspecifics, with the avoidance response of the observer chick being retained for up to 24 h. In addition to socially facilitated learning, Kyriazakis et al. (1999) describe a framework for feeding behaviour that involves a self-learning component based on the effect of certain substances or foods on an animal's internal state (ie. satiety levels, malaise). Animals learn about their environment and differences between food and non-food objects as their internal states change with ingestion of appropriate feedstuffs.

In the case of domestic fowl, producers make the feed as readily available as possible for day-old chicks by scattering feed on chick paper (Ross Broiler Management Manual, 2011), so as to stimulate feeding behaviour and social facilitation. Throughout the life of a commercial chicken, only one type of feed is available and it is always easily accessible, thereby reducing the amount of learning about the environment that is needed for survival. However, animals are able to not only learn to distinguish food from non-food, but also to differentiate between diets that provide varying levels of specific nutrients (Forbes & Kyriazakis, 1995; Provenza, 1995).

Broiler chicks were able to differentiate between low-protein/high-energy (8.2% CP, 3.39 Mcal/kg ME) and high protein/low energy (33.0% CP, 2.63 Mcal/kg ME) diets (Siegel et al., 1997) and when given the choice, chose the low-protein/high-energy diets, resulting in lower body weights from 9 d of age and onwards (Yo et al., 1998). Yo et al. (1998) showed that chicks given access to the 2 diets ate enough of each diet to ingest a combined diet with approximately 23% CP which indicates that the chicks are able to distinguish nutritional differences between diets and can self-select so as to create an optimally combined diet.

2.2.3 Dietary Preference Testing

Preference testing involves presenting an animal with two or more options and asking them to choose between them. In order for preference testing to be successful with dietary choices, the animals must be able to distinguish sensory properties of the different types of foods and to associate the different feedstuffs with their respective post-ingestive effects (Forbes & Kyriazakis, 1995); otherwise random selection is likely. In determining feed preferences, two types of preference tests are generally used: 1) Closed economy and 2) Open economy tests. Open economy tests allow access to the resource (ie. food) outside as well as within the testing period (Cooper, 2004). Closed economy tests limit access to the resource to within the testing period only (Cooper, 2004). Y-maze tests are commonly used to determine preference, wherein animals must chose one arm or area associated with a certain resource (Kirkden & Pajor, 2006). Preference tests involve an initial conditioning or training period, where the animals are exposed to all of the options. The extent of training may differ depending on species, strain, age and intensity of the response to the stimulus (ie. how rewarding or aversive it is). Broiler chickens forgot mildly aversive properties associated with a specific feedstuff within a few days (Forbes & Kyriazakis, 1995), but this may reflect impairments in the mechanisms that regulate feeding behaviour since they have been selected for such rapid growth rates. In contrast, Harlander-Matauschek et al. (2008) found that hens learned to avoid pecking at and eating feathers for 8 d of observation, after being conditioned to bitter tasting feathers. Age and maturity at the time of testing may also contribute to the discrepancies between these two reports.

Preference testing is most effective if used in combination with motivation tests, as testing for motivation can help quantify how strongly, in favour or in opposition, an animal feels about a situation (Kirkden & Pajor, 2006). Animals can demonstrate a preference for one experience (ie. sand for dustbathing) in favour of another option (ie. recycled paper for dustbathing) (Shields et al., 2004), but this does not demonstrate absolute preference. Preferred substrate in one test may only be the best of the given options, or, in some cases, the lesser of two evils.

2.3 HUNGER AND ORAL STEREOTYPIES

Hunger in animals is not well defined throughout the literature (D'Eath et al., 2009). It is difficult to define and quantify even with human research with qualitative measurements like visual analogue scales commonly used to assess and compare subjective states between people (Sørensen et al., 2003). This may be attributed to the fact that hunger is a very subjective state, as only the individual experiencing it is aware of how they are feeling at any given moment in time (D'Eath et al., 2009). Even the term "satiety" can mean different things depending on how and where it is used. For instance, the termination of a meal may be regulated by an animal reaching "satiation" (short-term), but "satiety" can define the interval between meals (longer term) (Sørensen et al., 2003; D'Eath et al., 2009). However, mechanisms that regulate either short or long term satiety may be impaired in broilers and broiler breeders (Bokkers & Koene, 2003; Nielsen, 2004), even though Howie et al. (2009) reported a conservation of natural feeding patterns in broiler chickens.

For animal research, identifying and quantifying animal feelings, including levels of hunger or satiety, can prove to be even more difficult than with human research. However, understanding subjective states in animals is a key component to recognizing symptoms of poor welfare, and thereby increasing welfare (Duncan & Petherick, 1991). Nonetheless, there are ways to assess hunger using a number of different indirect parameters, such as behavioural or physiological changes, preferences and motivation (D'Eath et al., 2009).

Measuring hunger by using only one of the above indices, especially physiological ones, may result in a misinterpretation of the data. For example, blood sampling to measure corticosterone concentrations may produce significant differences when comparing levels from birds on different diets or dietary regimes. Because corticosterone is heavily involved in the regulation of blood glucose (Mench, 2002) during periods of fasting, different diets will inherently produce different levels of it in the blood. These differences are quite possibly independent of the animal's hunger or satiety status. Another example would be that elevated heart rate may indicate psychological stress (decreased welfare), but it can also indicate level of excitement (increased welfare) (Dawkins, 1998).

2.3.1 Oral Stereotypic Behaviour

Stereotypic behaviour has been historically hard to define and understand, but Mason et al. (2007) describes it as a "repetitive behaviour induced by frustration, repeated attempts to cope and/or brain dysfunction". Oral stereotypic behaviour consists of repetitive movements involving the mouth of an animal, such as feather pecking in chickens (Dixon, 2008) or bar biting in sows (Mason & Mendl. 1997; Bergeron et al., 2000). These stereotypies in particular may largely stem from a lack of oral stimulation or satiation, such as severe feed restriction. Savory et al. (1978) observed a flock of wild fowl pecking on average 14,000 – 15,000 times per day during foraging bouts. The reduced amount of foraging or pecking needed for optimal nutrient intake, as well as the lack of environmental complexity, as seen with domestic poultry may lead to redirected pecking at non-food objects, in turn developing into oral stereotypies. Feed restriction in other agricultural species has been implicated in causing increased oral stereotypies. Terlouw et al. (1991) found that regardless of whether sows were loose-housed or crated, restricted-fed sows always displayed a high frequency of oral stereotypies. Similarly, Bergeron et al. (2000) showed that restricted-fed sows increased their oral stereotypic behaviour by more than 8-fold when compared to *ad libitum*-fed sows.

2.3.1.1 Feather Pecking

Feather pecking is considered to be the most widespread form of stereotypic behaviour affecting most sectors of the poultry industry (Dixon et al., 2008). Stereotypic behaviours are commonly associated with barren or behaviourally unfulfilling environments (Dixon, 2008). Therefore, the actual performance of feather pecking, and not just the damage incurred by the victims, most likely reflects a state of negative welfare. Feather pecking involves feathers on any part of the body being targeted and pecked at, with or without their actual removal or any associated tissue damage (Bilcik & Keeling, 1999; Van Krimpen et al., 2005; Dixon, 2008). Two types of feather pecking have been commonly discussed throughout the literature: 1) Gentle and 2) Severe. Gentle feather pecking usually does not result in feather loss, whereas severe pecking frequently leads to tissue damage and cannibalism (Dixon et al., 2008). In the case of domestic fowl, aggression and severe feather pecking are not synonymous, as they are believed to be driven by different motivational systems (Blicik & Keeling, 1999; Dixon et al., 2008). In comparison to feather pecking, aggressive pecks are usually directed at the head or comb of the victim (Van Krimpen et al., 2005), without becoming repetitive, resulting in submission to or avoidance of the aggressor.

Feather pecking is a multi-factorial problem present in almost every sector of the poultry industry. Diet composition and form, lighting, housing type, substrate availability, genetics, stage of production and other environmental factors all play a role in the development of this destructive behaviour (Dixon, 2008). Victims may experience pain during the actual removal of their feathers or resulting tissue damage and loss of feathers from a large region of the body can lead to an increase in metabolic demand, as heat maintenance costs increase (Leeson & Morrison, 1978). For broiler breeders, this can compound the problem of being feed restricted, as increases in feed allowance generally do not occur.

The majority of research concerning feather pecking has been done in table-egg laying pullets and hens (Van Krimpen et al., 2005; Dixon, 2008), with markedly fewer studies specifically identifying or discussing this behaviour in turkeys (Martrenchar, 1999), broiler chickens (Kristensen et al., 2007) and broiler breeders (Hocking et al., 1997; see reviews: Rosales, 1994; Leeson & Walsh, 2004; Hocking et al., 2004). Leeson & Walsh (2004) suggested that feather pecking is rare and less severe in broiler breeders than in laying strains, but may be caused by protein deficiency or an overall restriction of feed intake. Similarly, Hocking et al. (1997) found that broiler breeder males feather pecked much less than laying strains, but it is important to note that in this study, both strains of birds were fed *ad libitum*, essentially eliminating one of the main causes of feather pecking in broiler breeders (Rosales, 1994). However, more recently, Hocking et al. (2004) has suggested that feather pecking outbreaks among broiler breeder flocks have become increasingly more prevalent.

2.3.1.1.1 Feather Condition Assessments

Objective scoring systems have been developed and used by several researchers as an indirect measure of feather pecking (Bilcik & Keeling, 1999; LaBrash & Scheideler, 2005; Bright et al., 2006). Although behavioural observations directly indicate the frequency of feather pecking behaviour, it may be hard to quantify the severity of pecking. On the other hand, feather condition scoring may inadvertently include feather damage caused by other factors, such as mating, rubbing on fixtures in the environment or age. Feather condition assessments are varied across the literature, with some authors assessing the bird as a whole (Hughes & Duncan, 1972) while others score up to 11 body regions separately (Bilcik & Keeling, 1999).

2.4 ALTERNATIVES TO QUANTITATIVE RESTRICTION

In order to alleviate the problems associated with severe feed restriction, numerous studies have examined ways to reduce symptoms of chronic hunger without allowing excessive increases in body weights. A number of different methods have been tested, including: 1) inclusion of a high level of dietary fibre or non-nutritive fillers (Zuidhof et al., 1995; Savory et al., 1996; Savory & Lariviere, 2000; Hocking et al., 2004; de Jong et al., 2005a; Nielsen et al., 2011), 2) addition of appetite suppressing chemicals to the diet (Oyawoye & Krueger, 1990; Savory et al., 1996; Savory & Lariviere, 2000; Tolkamp et al., 2005), 3) a combination of dietary fibre and appetite suppressing chemicals (Sandilands et al., 2005; Tolkamp et al., 2005; Sandilands et al., 2006), or 4) alteration of feeding schedule (de Jong et al., 2005b). The most commonly used experimental diets included a high fibre component or chemical appetite suppressant, with diets combining the two being the most effective at controlling growth rates while reducing hunger-related behaviour (Sandilands et al., 2005; Sandilands et al., 2006).

2.4.1 The Role of Dietary Fibre

Rate of passage, digestion and absorption depend on the quantity of intake and the composition of the diet. Fibre can generally be broken down into two types; 1) Soluble fibre, which attracts and binds water and 2) Insoluble fibre, which is non-water holding. Insoluble fibres are generally regarded as nutrient diluents, and have the capability to increase feed bulkiness (Hetland et al., 2004). While it is generally thought that insoluble fibre components do not affect nutrient digestion or absorption, there has been some evidence indicating otherwise, both in a negative and positive direction (review: Hetland et al., 2003; Hetland et al., 2004).

Although there is some indication that a certain level of fibre is necessary in poultry diet, levels are generally low in commercially produced feeds as it increases bulk of feed and does not add any nutritional value to the diet. Incorporation of insoluble fibres in feeds can lead to a reduction in feather pecking and cannibalism outbreaks, or can be used as a substrate for foraging (review: Hetland et al., 2004).

2.4.2 Effect of Alternative Diets on Broiler Breeder Welfare

Due to the increase in bulkiness, the use of high fibre diets has been identified as a possible means to increasing satiety in other feed-restricted agricultural species, such as gestating sows. When fed during gestation, high fibre diets have been effective at reducing stereotypic and other hunger related behaviours in sows by up to 50% (Robert et al., 1993; Brouns et al., 1994; Bergeron et al., 2000). These results suggest that these diets lead to an increase in satiety due to the bulkiness and the larger daily allocation of feed. Therefore, feeding high fibre diets to broiler breeders may also have the potential to alleviate chronic hunger and reduce stereotypic behaviour.

Different sources and inclusion levels of dietary fibre or diluting agents have been tested with broiler breeders, including unmolassed sugar-beet pulp, oat hulls, sawdust, palm kernel meal, wheat bran, alfalfa, wheat gluten feed, potato pulp and sunflower seed meal (Zuidhof et al., 1995; Savory et al., 1996; Savory & Lariviere, 2000; Hocking et al., 2004; de Jong et al., 2005a; Nielsen et al., 2011). The aim of dietary dilution or elevated dietary fibre content is to increase the bulkiness of the diet without increasing caloric intake. Ideally, this will result in birds spending a longer period of time engaged in normal feeding behaviour and increased crop or gut fill, leading to a greater feeling of satiety. Success, in terms of limiting growth rate and reducing hunger-related behaviour, has varied among sources and concentrations of fibre (Zuidhof et al., 1995; Savory et al., 1996; Savory & Lariviere, 2000; Hocking et al., 2004; de Jong et al., 2005a; Nielsen et al., 2011). However, the combination of fibre with appetite suppressants has had more consistent success rates.

Although a variety of sources of dietary fibre have been examined, oat hulls (OH) have been one of the most popular choices for diet dilution; however, soybean hulls are a more appropriate fibre source in North America as they are more commonly used in animal agriculture (FAOSTAT, 2010). Inclusion rates of OH have ranged from 150 – 700 g/kg, with success rates as widely varied. Zuidhof et al. (1995) demonstrated acceptable growth rates with both 150 and 300 g/kg OH inclusion when fed on an *ad libitum* basis. However, others (Savory et al., 1996; Savory & Lariviere, 2000) could not effectively control excessive weight gain beyond 6 wk of age with 300 – 700 g/kg OH, with OH-fed birds weighing close to double the target at 15 wk. Nonetheless, diets with OH inclusion consistently demonstrated an increase in the satiating properties. Diets with OH inclusion took longer to eat from 4 – 18 wk (Zuidhof et al., 1995), increased the amount of time spent resting (Savory et al., 1996), and reduced the occurrence of spot pecking (Savory et al., 1996; Hocking et al., 2004) and drinking (Savory et al., 1996). However, Savory & Lariviere (2000) suggested that behavioural differences were more affected by body weight than treatment diet, and therefore they could not conclude that OH inclusion was beneficial. Although, by restricting intake to match the caloric intake of control-fed birds, Hocking et al. (2004) were able to attain growth curves following breeder recommendations as well as behavioural benefits.

Other dietary fibre sources that have been tested include unmolassed sugar-beet pulp, sawdust (Savory et al., 1996), palm kernel meal, wheat bran, alfalfa, wheat gluten feed, potato pulp and sunflower seed meal (de Jong et al., 2005a; Nielsen et al., 2011). Savory et al. (1996) tested 400 g/kg sugar beet pulp and 500 g/kg sawdust with little success. Birds fed the sawdust diet weighed approximately 40% less than the target body weight at 10 wk of age; whereas birds fed the sugar beet pulp grew according to breeder guidelines. However, both of these diets resulted in a reduction in resting behaviour compared to restricted-fed control birds. De Jong et al. (2005a) and Nielsen et al. (2011) tested the effects of diets including up to 5 different fibre sources, at up to 50% dilution. By restricting the daily allocation of diluted diets to match caloric intake of birds fed an undiluted diet on a restricted basis, body weights were controlled and positive welfare indices were observed including less object pecking (de Jong et al., 2005a), less feather and vent pecking (Nielsen et al., 2011), lower feeding motivation during a compensatory feed intake test (de Jong et al., 2005a; Nielsen et al., 2011) and more time spent sitting in comparison to birds fed undiluted diets on a restricted basis (de Jong et al., 2005a).

The use of chemical appetite suppressants, such as calcium propionate (CaP), phenylpropanolamine hydrochloride or monesin sodium has been another way researchers have attempted to reduce behavioural symptoms of hunger (Oyawoye & Krueger, 1990; Savory et al., 1996; Savory & Lariviere, 2000; Tolkamp et al., 2005; Sandilands et al., 2006). There has been little success with inclusion of phenylpropanolamine hydrochloride at 50 – 800 g/kg (Oyawoye & Krueger, 1990) or inclusion of monesin sodium at 200 – 300 g/kg (Oyawoye & Krueger, 1990; Savory et al., 1996), as they both resulted in bird weights close to double the target weight between 6 and 8 wk of age. CaP has shown much more promise. However, when used alone, the ability of CaP to effectively control weight when included in an *ad libitum* diet depends greatly on the source and purity of the chemical. Savory et al. (1996) showed on-target growth up to 6 wk of age with birds fed 50 g/kg of a purified version, with slightly overweight body weights at 10 wk of age, indicating a level of adaptation to the chemical. However, industrial or feed-grade versions of CaP were less successful at limiting weight gains at inclusion levels of 25 – 60 g/kg (Savory & Lariviere, 2000) and even up to 110 g/kg (Tolkamp et al., 2005). Nonetheless, birds on these diets dustbathed more often, were less motivated to eat and object pecked less than birds fed undiluted diets. However, birds were able to eat to satiety and were significantly heavier, which is the primary reason for the reduced symptoms of hunger.

Combining both a fibre source and appetite suppressant appears to be more effective than using only one or the other. Birds fed diets with added fibre still object pecked up to 40% of the time (de Jong et al., 2005a), whereas this behaviour was virtually eliminated with diets including OH and increasing levels of CaP (Sandilands et al., 2005; Sandilands et al., 2006). Although time spent performing all types of oral behaviour combined did not differ between OH+CaP diets and controls, control birds spent more time performing oral stereotypic behaviour and less time feeding and foraging (Sandilands et al., 2005; Sandilands et al., 2006). Feeding motivation was also significantly reduced with all of the alternative diets, indicating a reduction in hunger (Sandilands et al., 2005: Sandilands et al., 2006). Although the OH+CaP birds were fed on an *ad libitum* basis, growth was successfully restricted, and treatment birds were either lighter, or not different from controls through to 14 wk of age (Sandilands et al., 2006) and even up to lay (Tolkamp et al., 2005).

Overall, inclusion of an increased proportion of dietary fibre, regardless of source can reduce symptoms of chronic hunger. Nonetheless, the extent to which high fibre diets are successful appears to depend of source, inclusion level and feeding rate. Successful weight gain restriction was inconsistent with *ad libitum* feeding, but much more predictable with restricted caloric intake or in combination with appetite suppressing agents.

2.4.5 Do Birds Prefer Alternative Diets?

Although the alternative diets described previously resulted in a reduction in hunger-related behaviour, it is important to ensure that one welfare problem (hunger) isn't being replaced with another (aversive feed type). In general, diets that result in a greater level of satiety are expected to be preferentially chosen over restricted diets. However, animals do not always choose as expected. Because broiler breeders are chronically hungry, it would be assumed that a diet resulting in higher levels of satiety would be preferred, even if complete satiation is not met (Buckley et al., 2011b). However, only two groups have tested the preferences of broiler breeders for alternative versus control diets (Savory et al., 1996; Buckley et al., 2011b). Savory et al. (1996) offered a choice between a diet with 5% purified calcium propionate (CaP) and a control grower mash to birds that had been reared on the 5% CaP diet and to *ad libitum*-fed control birds. Birds had free access to both diets over a 24 h period, as this comparison appeared to focus on taste differences rather than the satiating properties. The amount of control grower mash that the CaP-reared birds consumed contributed approximately 65% of the total intake over the 24 h period, whereas the *ad libitum*-fed birds ate a higher proportion of control mash at 81% (Savory et al., 1996). It appears that the control diet was preferred, but not exclusively so, over the diet containing 5% CaP. More recently, Buckley et al. (2011b) examined birds' preferences between a diet including 3% CaP and a control or a diet including 30% oat hulls (OH) and a control in a closed economy test, where birds had access to limited amounts of both diets (larger amounts for alternative diets). Birds given a choice between control and CaP diets had a slight preference for the control diet (57% of total intake was for control diet). No preference for or against the OH diet was identified. It is important to note, however, that all feed offered to the birds (both control and alternative) was consumed almost entirely within 10 minutes of testing, with true aversions or preferences most likely being masked. In addition, these two studies may have only identified preferences in taste between the two diets. However, Buckley et al. (2011b) also conducted closed economy Y-maze choice tests to determine if the birds were willing to trade high quality feed (control diet) for a larger portion of poor quality feed (alternate diet). At a group level, no preference for either diet was revealed. Although this may indicate a lack of preference, it could also imply a lack of learning or ability to discriminate between the satiating properties of the diets. It may be that severely feed restricted broiler breeders are too hungry to learn the subtle differences between alternative and control diets. Buckley et al. (2011a) attempted a validation study to identify broiler breeders' abilities to distinguish differences in the volume available of the same food type. Birds fed undiluted diets at varying levels of restriction (recommended, 40%, 80% and *ad-libitum*) were given the choice between large and small quantities of the undiluted diet. Birds that had been reared with a lesser degree of feed restriction appeared to be more successful at learning to choose the larger quantity of food. As none of the birds fed to the recommended restriction level were successful in learning the task over the duration of the study, it appears that severe feed restriction impairs the birds' ability to learn, at least in relation to food-related tasks. It has been suggested that severe and chronic food-restriction may confound the results of preference tests that involve two food rewards as choices (Buckley et al., 2011a).

CHAPTER 3: THE EFFECT OF DIETARY ALTERATIONS DURING REARING ON GROWTH, PRODUCTIVITY AND BEHAVIOUR IN BROILER BREEDER HENS [1]

3.1 ABSTRACT

Parent stocks of meat birds are severely feed restricted, especially during the rearing period, as a means to avoid obesity-related health and fertility problems. This restriction often leads to chronic hunger, accompanied by stereotypic behaviour, indicative of a poor state of welfare. Research based in the UK has shown that using alternative diets, including fibre and appetite suppressants, may relieve some of the symptoms associated with chronic hunger. However, no data were available regarding North American-sourced ingredients or non-daily feeding regimes. Therefore, in this study we investigated the effects of two alternative diets, in combination with two feeding frequencies, on growth, productivity and behaviour in broiler breeders. It was hypothesized that daily-fed diets offering the largest volume of feed, with the most purified form of the appetite suppressing chemical, calcium propionate (CaP), would result in the greatest reduction in stereotypic behaviour indicative of chronic hunger. Six dietary treatments were tested, each with 5 replicate pens of 9-12 birds. Control diets (C) consisted of a commercial crumble, fed on a daily or skip-a-day (SAD) basis. Alternative diets included soybean hulls as a bulking ingredient and CaP of either a feed grade (F) or purified (P) quality, fed on either a daily or SAD basis. Birds were weighed weekly and egg production was recorded daily, with 2 d worth of eggs weighed per wk. Video cameras were used to record behaviour during and immediately following the morning feeding bout for 3 hr every 2 wk. Body weights, egg production and frequency of behaviours were analyzed with a mixed model

[1] A paper based on this chapter will be submitted to *Poultry Science* for publication.

ANOVA, with repeated measures. Diet, Frequency and Time all affected body weights (3-way interaction, *P* = 0.0063), with P birds being the lightest and closest to target during rearing and heaviest during the laying period. Egg production was affected by a Diet x Time interaction (*P* = 0.0277), as P birds came into lay later than both the C and F birds. Diet, Frequency, Time or an interaction of the 3 had significant effects on all reported behaviour during rearing. These differences tended to disappear during lay, with most stereotypic behaviour no longer present. Very little object pecking and aggression was observed both during and immediately following feeding bouts, however C birds still displayed this behaviour more often, especially during rearing (3.1% vs. 0.3% vs. 0.3%; C, F and P respectively). During feeding bouts, SAD birds feather pecked (*P* = 0.0026) and rested more (*P* = 0.0002) than daily-fed birds. Feather pecking after feeding bouts were affected by Diet x Time (*P* = 0.0331), with C birds feather pecking most often. Overall, the F diet appeared most effective at reducing behaviours associated with hunger, with the C diet being the least effective. There was little evidence to support the hypothesis that daily feeding was more effective at reducing hunger.

3.2 INTRODUCTION

Broiler chickens that are raised for meat production have been heavily selected for fast growth rates and voracious appetites (Mench, 2002). Broilers are currently able to reach market weight in less than 6 wk (Ross Broiler Performance Objectives, 2011). This fast growth is correlated with increased susceptibility to lameness, cardiovascular disease and premature death (Dawkins & Layton, 2012). However, welfare problems associated with chicken meat production are not exclusively found in broiler flocks. Broiler parent stocks (broiler breeders) face similar genetic selection pressure for fast growth and huge appetite, but are routinely feed restricted to avoid obesity-related health problems and to increase reproductive success (Hocking, 1993; Mench, 2002; de Beer & Coon, 2007). This restriction is quite severe, resulting in daily feed allocations of only 25-50% of *ad-libitum* intake (Savory et al., 1993; Mench, 2002) that can often be entirely consumed in less than 10 min (Savory et al., 1993). Feed is generally delivered as one small daily meal, but alternative feeding schedules, such as "skip-a-day" (SAD), are commonly used in North American production to increase flock weight uniformity (Mench, 2002; de Beer & Coon, 2007), though little scientific evidence can support this. While on a SAD regime, birds are fed twice their daily allocation, once every other day. Even though each meal is larger, the total caloric intake per wk remains the same compared to daily feeding. Regimes that do not provide feed on a daily basis are not allowed in the UK (DEFRA, 2007) as they are perceived to negatively affect welfare.

Because broiler breeders have such large appetites, these severe dietary restrictions result in symptoms of chronic hunger. These symptoms usually present as an increase in stereotypic behaviour and behaviour thought to be indicative of frustration such as pecking at non-food objects (including the walls, empty feeders, nipple drinkers, etc.), increased general activity and aggression, excessive drinking and increased feather pecking (Mench, 2002; Sandilands et al., 2006). In addition, chronically restricted birds are significantly more motivated to eat than *ad libitum*-fed birds that have been fasted for 72 h (Savory et al., 1993).

Researchers have examined ways to reduce hunger in broiler breeders through dietary manipulations (Zuidhof et al., 1995; Savory et al., 1996; Savory & Lariviere, 2000; Hocking et al., 2004; de Jong et al., 2005a; Sandilands et al., 2005; Sandilands et al., 2006). The most commonly tested dietary alterations have involved the inclusion of non-nutritive fillers, such as oat hulls, or appetite suppressants, such as calcium propionate (CaP). However, *ad libitum* feeding of these diets ingredients can still lead to problems of excessive weight gain (Savory et al., 1996; Savory & Lariviere, 2000). In addition, there appear to be differences in the ability to suppress appetite depending on the source and purity of CaP (Savory & Lariviere, 2000). Sandilands et al. (2006) found that when combined, oat hulls and industrial grade CaP had a positive interaction and were the most successful at reducing behavioural indicators of chronic hunger as well as controlling weight gain.

To be applicable to the North American industry, the effects of high fibre diets that include an appetite suppressant, in combination with alternative feeding schedules should be investigated. In addition, the effect of more locally available fibre sources needs to be identified. Therefore, the objective of this study was to determine the effect of two qualitatively restrictive diets in combination with a SAD feeding regime on growth, productivity and behaviour in broiler breeder females. We predicted that daily-fed diets offering the largest volume of feed, with the most purified form of CaP would result in the greatest reduction in stereotypic behaviour indicative of chronic hunger.

3.3 MATERIALS AND METHODS

All of the procedures used in this experiment were approved by the University of Guelph's Animal Care Committee and were in accordance with the guidelines outlined by the Canadian Council for Animal Care.

3.3.1 Birds

Day-old Ross 708 broiler breeder females (n=383) and males (n=51) were donated (courtesy of Aviagen, via Horizon Poultry, Alabama, USA) for this experiment and reared at the

OMAFRA Arkell Poultry Research Station (Guelph, ON, Canada). Males and females were reared separately. All of the birds were vaccinated against local diseases in accordance with the research farm's vaccination protocol. All birds were beak trimmed at 1 d of age at the hatchery using an infrared beam in order to minimize damage caused by feather pecking. All birds were reared according to the programs outlined by the breeding company (Aviagen, 2007). For the first 3 d of life birds were housed with a lighting regime of 23L:1D at 20 lux. From then on the lighting schedule was as follows: 12L:12D (20 lux) from d 4-21 and 8L:16D (4-7 lux) from 22 d to 22 wk of age. Chicks were provided with a heated mat until 7 d of age.

Upon arrival at the research farm, the female chicks were randomly allocated to 1 of 30 identical pens (1.83 x 2.36 m, Figure 3.1) that were already assigned 1 of 6 treatments (see *Dietary Treatments* section). All of the pens had wood shavings (approximately 3 cm depth) covering the entire floor. Each pen was furnished with a wooden perch (0.05 x 0.05 x 1.52 m, with top edges bevelled) at a height of 20 cm. Nest boxes (0.91 x 0.46 m, with three nest sites each measuring 0.30 m in width) were added at 20 wk to allow the birds to become accustomed prior to the onset of lay. Water was provided on an *ad-libitum* basis from a nipple drinker (7 nipples per pen). Round pan feeders (diameter = 38.1 cm) were used until the birds were 10 wk old. Hanging trough-style feeders (0.13 x 1.52 m) with exclusion grills were then installed to allow for more space per bird during feeding. At 22 wk, 1 rooster was added per pen of hens to simulate commercial farm settings. Rooster feeders were installed prior to combining sexes and roosters were fed separately from the hens, following breeder guidelines.

Pens were cleaned out as needed; however, whenever dirty pens were cleaned out, all other pens received at least a top layer of fresh wood shavings to avoid inducing behaviour, such as dust bathing, in only some pens.

3.3.2 Experimental Protocol

Prior to starting the experimental diets, birds were redistributed and pens were standardized to an average weight as close to the overall mean as possible (308.72 ± 1.00 g/bird) by removing 1 – 2 birds per pen. This left 18 pens with 11 birds and 12 pens with 12 birds. At 20 wk, 22 (0 – 2 per pen) of the smallest and least thrifty birds were culled. During the rearing period, 2 birds (0.58%) were found dead and 7 more (2.05%) were euthanized due to injury, infection, sexing error or beak deformities. During the laying period, 2 birds (0.64%) were found dead and 15 more (4.81%) were euthanized due to lameness and injury.

3.3.2.1 Dietary Treatments

This experiment was a 3x2 factorial design, with 3 different diets and 2 feeding regimes. The 2 feeding regimes tested were daily feeding and skip-a-day (SAD) feeding, where birds received twice the daily allocation every other day. Alternate feeding regmies commenced once the birds reached 4 wk of age and ended at 22 wk, as per breeder guidelines. The 3 experimental diets tested were a commercial (C) diet, and 2 diets containing soybean hulls (SBH) and either a feed-grade quality (F) or purified (P) appetite suppressant (calcium propionate, CaP). Therefore, there were 2 treatment groups that were fed the same diet, with 1 fed daily and the other fed on a SAD basis, for all 3 diet types. A total of 4 rooms were used to house the birds (12 pens total per room), with 2 rooms for daily birds and 2 rooms for SAD birds. To avoid disruption to birds not being fed while others were, daily and SAD birds were not housed in the same rooms, thereby confounding Room with Feeding Frequency. One of the rooms housing the daily fed birds was also used to house the males used for this experiment (4 pens) and other females used for preference testing (4 pens, see Chapter 5). Therefore, 1 pen of each daily-fed diet types was housed in 3 of the last remaining 4 pens. In the other room housing daily-fed birds, 4 pens of each diet type were randomly distributed within the room. Two rooms were used to house the SAD birds; diet types as evenly distributed across rooms as possible, with 4 or 5 pens left empty in each of the 2 rooms.

Diets that contained SBH and CaP were composed of a basal amount of the commercial crumble with the SBH and CaP being additional ingredients (Table 3.1). Alternative Starter diets comprised of a basal amount of the commercial control diet (59%), diluted with SBH (40%) and CaP (1%). As the birds matured, the inclusion rate of CaP increased; Grower 1 included 3% CaP and Grower 2 included 5%. Therefore, the basal amount of the commercial component decreased accordingly; 57% and 55% for Grower 1 and Grower 2, respectively. However, for the first 18 d, all birds were fed a commercial chick starter (2.86 Mcal/kg, Crude Protein = 18%). All birds were fed daily following lights-on at 08:00. Following breeder recommendations, all birds were fed on an *ad-libitum* basis from d 1-7 and were subsequently feed-restricted from d 8 onwards. Both experimental diets were formulated according to age of the bird: Starter crumble from 0-6 wk, Grower 1 crumble from 6-12 wk, Grower 2 crumble from 12-22 wk and Layer crumble from 22 wk onwards. All diets were analyzed at Agri-Food Laboratories in Guelph, ON (Table 3.2). The Layer diet was not analyzed; however, all birds were fed the same commercial crumble during the laying period.

At d 19, birds in the F and P treatments were switched from the commercial starter crumble to the alternative Starter diet. Birds in these treatments were allocated a larger volume of feed per d due to the fibrous dilution and inclusion of CaP in the F and P diets (Table 3.2). This increase depended on the age of the bird; 41%, 43% and 45% more feed for Starter, Grower 1 and Grower 2, respectively. At 22 wk of age, just prior to coming into lay, all birds were fed the commercial layer diet and SAD birds were switched back to daily feeding (Figure 3.2).

3.3.2.2 Growth and Productivity

Birds were weighed regularly to track growth and identify unthrifty birds. From d 1 to wk 8, birds were weighed on a per pen basis. After this, birds were all weighed individually. However, pen averages were used for growth analyses. Body weight uniformity (% CV as expressed by the standard deviation divided by the mean multiplied by 100%, Savory et al., 1996) analysis was performed using the individual weights from 8 wk onward. Birds were always weighed on days when all treatment groups had been fed. At wk 7, birds on the commercial and F diets were significantly heavier than the target weight. In order to slow their growth, the wk 7 feeding rate (43 g/bird/d) was fed until the average weights were closer to the target (wk 12). After this, the feeding rate was increased incrementally until wk 24, when the feeding rate matched the birds' age. To avoid the confounding factor of differences in caloric intake, the feeding rate for the P treatment was also held back, even though these birds were not significantly heavier than the target.

Productivity was measured by recording number of eggs laid/d/pen. Additionally, eggs were weighed individually for 2 consecutive d/wk.

3.3.2.3 Behavioural Data Collection

Security style video cameras (Panasonic WV-CP504 and Panasonic WV-CP480 CCTV colour cameras) were mounted overhead each pen prior to the start of the experiment. Due to a limited number of cameras available, only half of the pens (n=15) were recorded in a given session. Cameras were rotated between 2 pens during the time between the morning and afternoon recording period. Videos were recorded onto a digital recording unit (i3international, SRX Pro 1201SC) and transferred to external hard drives each wk. At 11 wk of age, video recording commenced. Pens were recorded for 4 consecutive d every other wk. Each day, a morning and an afternoon period was recorded. The morning period was from 08:00 – 11:00, and from wk 11 – wk 22, the afternoon period ran from 14:00 – 16:00. From wk 22 onwards, the afternoon period was extended until 18:00. In addition, live observations were performed at 8 and 16 wk of age to determine the length of time for each daily-fed treatment to consume their ration.

3.3.3 Data Analysis

The statistical analyses for this experiment were performed using the SAS statistical analysis package (SAS 9.2, 2007). Body weight, egg production (counts and weights) and behavioural data were analyzed using a mixed model ANOVA with repeated measures. Feeding Frequency was used as the main plot factor, with Diet Type as the subplot factor within Feeding Frequency. Room and Room*Feeding Frequency were used as random effects. Room*Feeding Frequency was included as a random effect because Feeding Frequency was not randomized or evenly distributed across the 4 rooms and therefore was confounded with Room. The analysis used for handling repeated measures over time was modelled after the method given by Wang & Goonewardene (2004), using a first order auto-correlation covariance structure.

3.3.3.1 Growth and Productivity

No transformations were used to analyze the body weight data, as data were normally distributed. Data points used for analysis began at 19 d and included body weights collected every 2 wk until 256 d (~37 wk). Because birds were not individually weighed until 60 d, initial body weight uniformity was not available. However, starting at 60 d, change in uniformity (coefficient of variance in percent, CV) was analyzed, after taking the square roots of the CVs.

Egg production was calculated by taking the mean number of eggs laid per wk as a percentage of hens housed. Egg production percentages are shown, but frequencies were used for analysis. Frequencies were transformed by taking the arcsine of the square root to normalize the data and stabilize the variances. Egg data exceeding 100% production were capped at 1 prior to transformation. Egg weights were averaged per pen over the 2 recording d per wk. Data were normally distributed and no transformation was applied.

3.3.3.2 Behaviour Data

In total, 40 d of video recordings were collected, each with a morning and afternoon period. For the purpose of this paper, only the morning periods for 14 of these days were analyzed. Because only half the pens were recorded each d, data from 2 consecutive d were compiled and analyzed as 7 "Time Periods" for both daily and SAD treatment groups; the first 5 recorded during the rearing phase (11, 13, 14, 16, 19 wk of age) and the last 2 during the laying phase (25 and 28 wk of age). However, at each Time Period during rearing, the full data set (5 pens) for the SAD treatments comprised 2 or 3 pens during "on-feed days" and the remaining 2 or 3 pens during the "off-feed days". Therefore, each Time Period was treated as the average for behaviour performed on "on- and off-feed days". Each video was split into 2 time periods; the first being the Feeding Bout and the second being the Post-Feeding Period. Videos were scan sampled every 2 min during the Feeding Bout and every 3 min during the Post-Feeding Period. The Feeding Bout began as soon as the person feeding the pen walked out and closed the pen door behind them (this time ranged from 08:00 – 08:38). As it was difficult to determine from the video footage at what point there was no more feed left, the end of the feeding bout was defined as the point when at least half the birds were away from the feeder for 5 consecutive observations. Live observations were performed at 8 and 16 wk to verify length of feeding bouts for each treatment. The Post-Feeding Period began immediately following the end of the Feeding Bout and ended 1.5 h later. For SAD-fed birds, off-feed days were also broken down into 2 periods, with the "Feeding Bout" spanning 8:20 – 9:30 and the "Post-Feeding Period" from 09:30 – 11:00.

Frequencies of specific behavioural activities (feeding, drinking, foraging, feather pecking, comfort, object pecking, aggression, perching, standing and walking) were recorded and analyzed (Table 3.3). Data were transformed by taking the arcsine of the square roots for all behavioural activities except Feeding, which was normalized with a cosine transformation. Aggression and stereotypic Object Pecking happened so infrequently that it was not possible to normalize the data for separate analyses. Therefore, the sum of these 2 activities was analyzed after being normalized with a +0.001 log transformation. In addition, perching and standing/sitting were combined for analysis and the combination was called "resting".

3.4 RESULTS

3.4.1 Growth and Productivity

Even though growth rates were artificially manipulated by holding all treatments back at a wk 7 feeding rate from wk 8 – 12 (in the Grower 1 period), there were differences in body weights among treatments. There was an interaction between Diet, Frequency and Time on body weights (P = 0.0063, Figure 3.3a – 3.3d). During the Starter period, the P birds followed the target weight guidelines (Figure 3.3a). The C and F birds started to gain more weight and were up to 25% heavier than the target and the P birds at 46 d of age. In the Grower 1 period (Figure 3.3b), the P birds remained the lightest of the treatments, but were below target weights, and SAD-P birds were the lightest. By Grower 2, all treatments had slowed their growth and were lighter than target, with the daily-F and daily-P birds being the heaviest groups (Figure 3.3c). Once in the Laying period, all treatment weights approached target, with daily-C and daily-F now being the lightest of the treatments (Figure 3.3d). There was a Diet by Time effect on change in body weight CV (P = 0.0033, Figure 3.4). All 3 diet types resulted in an increase in uniformity over time, with F and P being most uniform.

Percentage of egg production differed among Diets over time (P = 0.0277). Hens reared on the P diet came into lay later than the C and F reared hens (Figure 3.5). However, they all reached peak production at the same time and exceeded target production rates at 31 wk of age. In comparison to the breeder guidelines, all treatment groups were 1 wk behind production standards. There were no differences due to Feeding Frequency on egg production (P = 0.29, data not shown) or mean egg weights (P = 0.2087; data not shown). There was a trend for Diet to affect egg weights, as P birds' eggs tended to be lightest at 26 wk, and C birds' eggs tended to be the lightest from 34 – 36 wk (P = 0.0713, Figure 3.6).

3.4.2 Behaviour

We determined, via live observations at 8 and 16 wk of age, that daily-C birds consumed their entire ration in less than 28 min, the daily-F birds in less than 44 min, while the daily-P birds still had feed after 2 h at 8 wk of age, and close to 1 h at 16 wk. From data gathered during video observations, the feeding bout durations averaged 37.5, 48.6 and 47.5 min for the C, F and P diet types, respectively. The daily-fed mean was 42.1 min, compared to 51.3 min for the SAD-fed birds. All behaviour analyzed from the video footage was affected in some way by Diet type, Feeding Frequency, Time or an interaction of 2 or 3 of the factors (Table 3.4).

During feeding bouts, Feeding Frequency had an effect over time on feeding behaviour (P = 0.0023), with the daily-fed birds at the feeder more frequently than SAD-fed birds, up until point of lay when all birds were fed the same layer diet on a daily basis (Figure 3.7). Drinking behaviour was affected by Diet (C: 3.04 ± 0.39% of time drinking; F: 4.42 ± 0.51%; P: 3.43 ± 0.33%, *P* = 0.0382), with F birds at the drinker most often overall. Drinking was also affected by Frequency x Time (*P* = 0.0022); SAD-fed birds (Figure 3.8)a were at the drinkers most frequently. There was a significant interaction between Diet and Frequency (*P* = 0.0076) on the frequency of foraging, where daily-P and SAD-F birds foraged less often than the other treatments (data not shown). Resting (a combination of standing/sitting and perching) was also influenced by Diet (*P* = 0.0032, C: 22.6 ± 1.4% of time resting; F 23.7 ± 1.6%; P: 27.5 ± 1.3%), as P birds rested most often. Frequency x Time also affected resting (*P* = 0.0002, Figure 3.9), as SAD birds rested more often during the rearing period. Walking was affected by Diet x Time (*P* = 0.0085), as F birds walked the least and C birds walked the most during the rearing period (Figure 3.10). Feeding Frequency x Time affected comfort behaviour (*P* = 0.0066), with the SAD birds dustbathing and preening more often than daily-fed birds during rearing (data not shown). Feather pecking was not affected by Diet (*P* = 0.1341), but was influenced by Frequency (*P* = 0.0026, Daily: 0.22 ± 0.07% of time feather pecking; SAD: 2.46 ± 0.61%). SAD birds performed more feather pecking during rearing but the behaviour virtually disappeared across all treatment groups once the birds reached lay. Very little object pecking and aggression occurred around feeding time (combined mean = 0.19% of the time).

After feeding bouts, there was a trend for F birds to be at the feeder more often than C and P birds (*P* = 0.0556, C: 22.8 ± 1.2% of time at the feeder; F: 28.5 ± 1.3%; P: 24.3 ± 1.4%). There was an effect of Diet x Time (*P* = 0.0045) as well as Frequency x Time (*P* = 0.0034) on drinking behaviour, as the F birds were at the drinker more often than the P birds at 11 wk and more often than the C birds at 19 wk (Figure 3.11). The SAD birds were at the drinkers less often than daily birds at 16 and 19 wk (Figure 3.12). Diet x Time significantly affected foraging (*P* = 0.0455), as P birds foraged more often than C birds at 25 and 28 wk, but less often at 13 wk and more often than F birds at 11 and 25 wk (data not shown). Resting was influenced by a Diet x Frequency x Time interaction (*P* = 0.0003), as P and SAD-F rested more often from 11 – 19 wk (Figure 3.13). Analysis of walking behaviour agreed with resting data, as C birds walked more often than both F and P birds (C: 9.2 ± 0.3% of time walking; F: 7.8 ± 0.4%; P: 7.4 ± 0.3%, *P* = 0.0008). Object pecking and aggression combined was significantly affected by the 3-way interaction of Diet, Frequency and Time (*P* = 0.0150; Figure 3.14), with the daily-C birds performing this behaviour most frequently. Diet by Time affected feather pecking behaviour (*P* = 0.0331; Figure 3.15), with C birds feather pecking the most during rearing.

3.5 DISCUSSION

3.5.1 Growth and Productivity

The differences in body weight developed fairly soon after treatment diets started, and were accentuated by the manipulation in ration allowances (ie. being held back at wk 7 feeding rate). Although the C and F birds grew more quickly than recommended by wk 8, the P birds' mean body weights matched the target quite closely. However, the P birds were also restricted to wk 7 feeding rate to avoid confounds of increased calorie and energy consumption in comparison to C and F birds. Upon analysis, the crude protein (CP) content of the F diet was higher (when fed at 140% of the C diet's allocation) than both the C and P diets during Starter and Grower 1 periods (19d – 12 wk), even though all 3 diets were formulated to have the same CP content. Savory et al. (1996) had low growth rates with 10.4% CP compared to birds fed diets containing 19.6% CP; therefore the increased CP content in the F diet may explain the heavier body weights during the Starter and Grower 1 periods. However, the feed component analysis for both the C and the P diets revealed that these 2 diets had similar CP and energy content, yet the C birds grew faster than the P birds. It may be that the increased fibre and CaP act in a way that prevented or limited nutrient uptake and deposition into body tissues. However in a review, Hetland et al. (2004) suggested that although some have indicated otherwise, there is a wide belief that insoluble fibres act solely as nutrient diluents and do not affect nutrient digestibility. Previous research has demonstrated better results in terms of controlling body weights, as Tolkamp et al. (2005) and Sandilands et al. (2006) were able to match control treatments' body weights with *ad libitum*-fed diets containing a fibre and CaP.

Although the differences were small, SAD birds were lighter than daily birds by up to 7.5% at 21 wk. Similarly, Bennett & Leeson (1989) and Katanbaf et al. (1989) found that daily-fed birds were significantly heavier than SAD-fed counterparts at 22 and 21 wk of age, respectively. De Beer & Coon (2007) suggested that, although both feeding regimes offer the same caloric intake, SAD birds may be more inefficient in using this energy, as nutrients are deposited post-ingestion, and then remobilized for the rest of the next 2 d. In North America, SAD feeding regimes are generally used to increase flock body weight uniformity, so that birds come into lay at the same time and lay eggs of the same relative size (Richards et al., 2010). However, little scientific data, including that from this study can support this theory. Bennett & Leeson (1989) reported numerical, but not statistically significant increases in uniformity with SAD feeding. SAD may only be beneficial when feeder space is limited, giving more birds access to larger amounts of feed, in comparison to daily-fed birds. In the current study, there was no effect of Feeding Frequency on body weight uniformity. Although all diet types resulted in a reduction in % CVs over time, F and P birds had the most uniform body weight. This may be due to culling some of the smallest birds per pen, but average cull rates were no different for the 3 most uniform and the 3 least uniform pens. Body weight CVs reported here are similar to those reported elsewhere, however there were no differences reported between a control diet and a diet containing CaP and oat hulls (Tolkamp et al., 2005).

Egg production started approximately 1 wk later than recommended by the Ross breeder guidelines. This could be due to the slightly lighter body weights, in comparison to target, prior to lay, as heavier body weights during rearing results in earlier onset of lay (Yuan et al., 1994). However, the production increased in parallel to the breeder standard, and peaked at slightly higher productivity levels across all treatment groups. Egg weights did not differ between treatments, and were similar to target weights for each specified wk of production. Even though the experimental birds were slightly lighter than industry standards at time of lay, there does not seem to be any long term negative effect of the alternative diets. In other words, these diluted diets should not impact egg production or egg weight.

3.5.2 Behaviour

Behaviour during the feeding bouts mostly consisted of feeding, with the birds' heads fully in the feeder. By definition, any time a bird removed its head from the feeder, even if it remained stationary at the feeder, it was not considered feeding at that point. On average, during feeding bouts, birds spent 48.5% of their time with their heads in the feeder, 24.6% of the time resting, 10% of the time foraging, 8.3% of the time walking and 8.6% of the time engaged in other behaviour.

Although there were no differences among Diet Types for the amount of time birds spent with their head in the feeder, it took the F and P birds longer to consume their daily rations. Therefore, C birds may have finished eating before the end of the defined feeding bout and may have been engaged in other behaviours, such as foraging and walking. This increase in general activity during feeding may indicate a lack of satiety, as birds may be looking for more food. The increased walking could also reflect a more frenzied feeding bout, with birds being displaced along the feeder, or trying to find a new spot with more food. After the feeding bout, it is most likely that daily-C birds had no food left in the feeder as live observations indicated these birds were finished eating even before the feeding bouts technically ended for video analysis. Therefore, any activity at the feeder may in fact be classified as object pecking, and could be considered as an indication of sustained hunger. However, this may also be the case for daily-F birds, as they were also finished feeding before the feeding bout technically ended.

During and after feeding bouts, F birds spent more time drinking compared to those on the other diets. Although increased drinking is sometimes linked to hunger (Savory & Maros, 1993; Hocking et al., 1996), it is probably motivated by other causes in this study. Because the F birds were consuming a larger volume of food in comparison to the C birds, finished their ration more quickly than the P birds, and consumed a higher protein content than both the C and P birds, the increased drinking may be reflective of an increased metabolic demand for water, as water intake and protein consumption are positively correlated (Alleman & LeClercq, 1997). Nielsen et al. (2011) found that birds fed high-fibre diets drank more than control birds, but still were less motivated to eat, indicating the increase in drinking may not be reflective of level of hunger. We found dietary effects on walking and foraging. It is unknown why SAD-P and daily-F birds foraged more often than their dietary counterparts (daily-P and SAD-F), but their decreased general activity during feeding may imply that the alternative diets resulted in a greater feeling of satiety. It is also possible that reduced activity during feeding is a sign of malaise, or aversion to the diets.

During the feeding bouts in rearing, SAD birds were observed feeding less often than daily-fed birds. Because half of the observations included days where no feed was available to the SAD birds, they spent more time performing other behaviour, such as drinking, dustbathing/preening, resting and feather pecking. Increased drinking and stereotypic pecking (including those directed at feathers) may indicate an elevated level of hunger (Savory & Maros, 1993; Mench, 2002; de Jong & Guemene, 2011), although feather pecking rates declined from 11 – 19 wk, possibly indicative of an adaptation to the SAD regime. Corroborated with anecdotal evidence, there appears to be a strong effect of feeding regime adaptation, as general activity was high immediately following the switch from daily to SAD (4 wk of age), and dramatically declined later in the rearing period.

We expected to observe more aggression in the C and SAD birds in comparison to F, P and daily fed birds. However, frequency of aggressive pecking during feeding bouts was very low across all treatment groups. This may reflect the methodology used for behaviour observations; aggressive acts happen so quickly, and may be easily missed during scan sampling. However, aggression was also reported at low frequencies elsewhere (Sandilands et al., 2006), although scan sampling was also used and behavioural observations took place after feeding, when aggression may already be lower than while food is present.

Although foraging is a natural behaviour, increased foraging after a meal may represent a lack of complete satiety, as foraging is characterized by the seeking of food sources (Dawkins, 1989). Overall, P birds foraged the most, which may reflect an aversion to the diet, as the birds could be searching for other sources of food. However, foraging is a complex behaviour and differences between diets may not only reflect levels of hunger. Because birds were hand-fed from a scoop, it is possible that the diets with larger volumes (F and P) were easier to spill while filling the feeding trough.

It has been suggested that inactivity is negatively correlated with feeding motivation (Hocking et al., 1996; Savory & Lariviere, 2000). As resting was observed more often in daily-P, SAD-P and/or SAD-F birds from 11 – 19 wk, this may reflect an increased level of satiety. In addition, walking was generally more frequent for C birds than F or P birds, which may provide support that the C diet was ineffective at sating these birds. However, daily-P birds only rested most often during wk 11 and 13 which may imply an adaptation to the CaP inclusion with age as suggested by Savory et al. (1996).

The presence or absence of stereotypic behaviour may be the most direct way of comparing the welfare of birds on different diets, as Mason et al. (2007) suggested that frustration can induce the development of repetitive, stereotypic behaviour, such as feather pecking and object pecking. Feather pecking was observed most often in C birds and object pecking and aggression was most frequent with daily-C birds. As object pecking and aggression was as equally infrequent in SAD-C birds as it was with the alternative diets, this may imply that having a larger volume of food every other day is more satiating than having a smaller volume of the same diet type every day. Because feather pecking was observed at higher frequencies in both the daily-C and SAD-C birds, this may not only reflect a lack of satiety, but also may indicate that alternative diets can reduce feather pecking. Harlander-Matauschek et al. (2006) indicated that a lack of access to fibrous components can stimulate foraging and possibly redirected foraging on the feathers of conspecifics.

SAD birds drank more during feeding bouts, but less after feeding bouts than daily-fed birds. Because half of the observations during rearing included “off-feed” days, the methodology may have directly impacted the levels of drinking observed. However, if drinking can be reflective of hunger, the decline in drinking with age observed for the SAD birds may indicate that these birds were adjusting to the feeding regime and were less likely to replace a lack of feeding with increased water intake.

3.6 CONCLUSIONS

As hypothesized, we found that high-fibre diets including an appetite suppressant reduced behavioural indices of hunger, such as increased time spent resting, and decreased time spent feather pecking and object pecking and aggression. However, even with the alternative diets, there were indicators that some level of hunger was still present. Chronic hunger may be unavoidable as Hocking (1993) found that *ad libitum*-fed birds still spent a significant amount of time feeding throughout the night, suggesting a level of hunger sufficient to cause feeding behaviour during the dark period. Nonetheless, the addition of soybean hulls and calcium propionate to the diet may moderately improve welfare without causing malaise or feed aversion.

The effects of feeding frequency are less clear, and there is not much evidence to support one feeding frequency over the other within diet type. Behaviour that may indicate increased satiety or reduced hunger, such as increased time spent dustbathing/preening and resting, were observed more frequently with SAD birds during feeding. On the other hand, other behaviour that may be indicative of hunger, such as increased time spent drinking and feather pecking, were also performed most often by the SAD birds during feeding. It appears that SAD-F and SAD-P diets were both more effective at reducing hunger than the daily and SAD-C diet, but possibly no more so than the daily-F and daily-P diets. Therefore, there is no strong evidence to support our hypothesis that daily feeding would suppress hunger more effectively than SAD or vice versa.

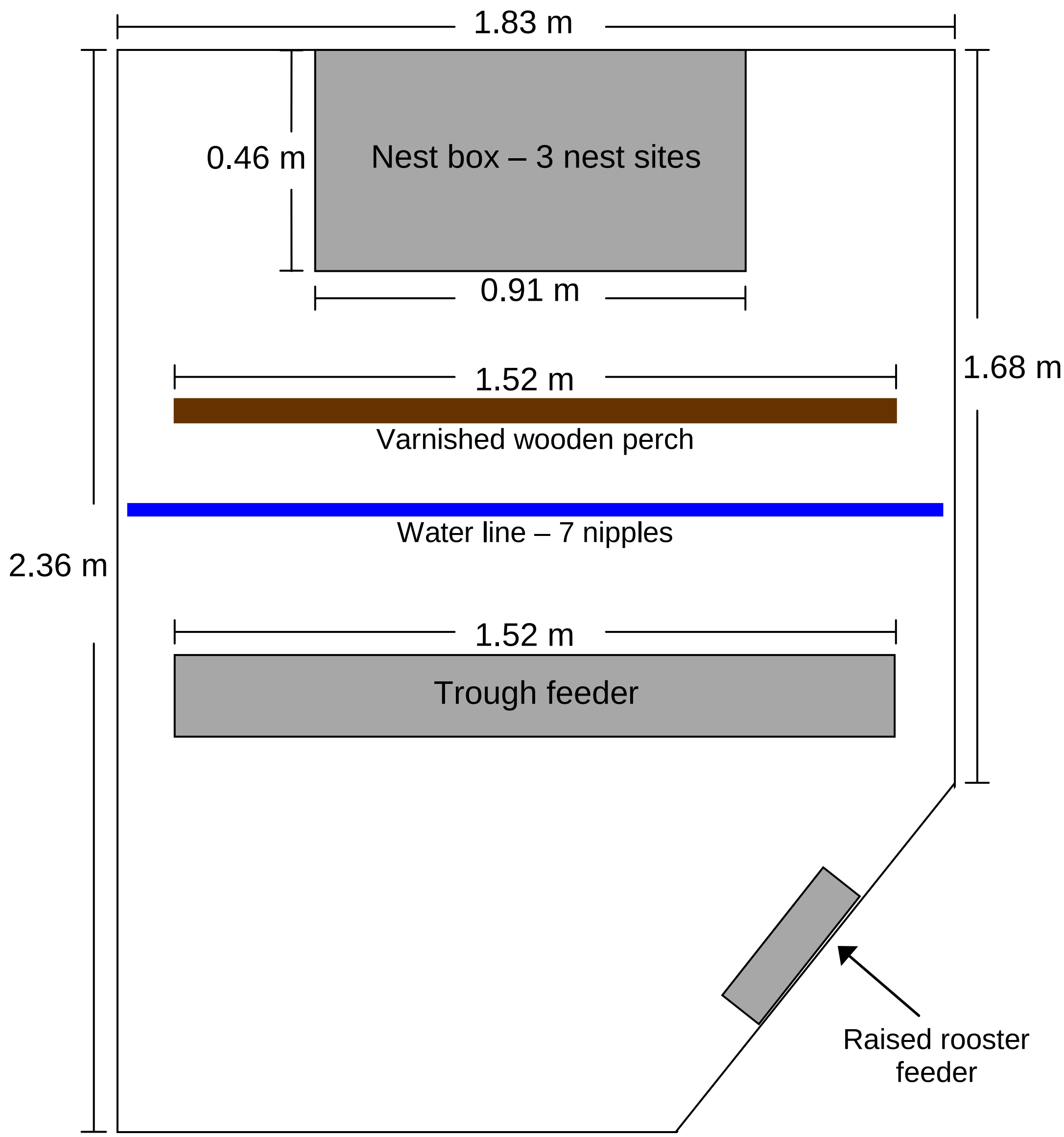

Figure 3. 1 Diagram of pen set-up (Arkell Poultry Research Station). Nest boxes were added at wk 20. Rooster feeders added at 22 wk, prior to introduction of roosters into female pens.

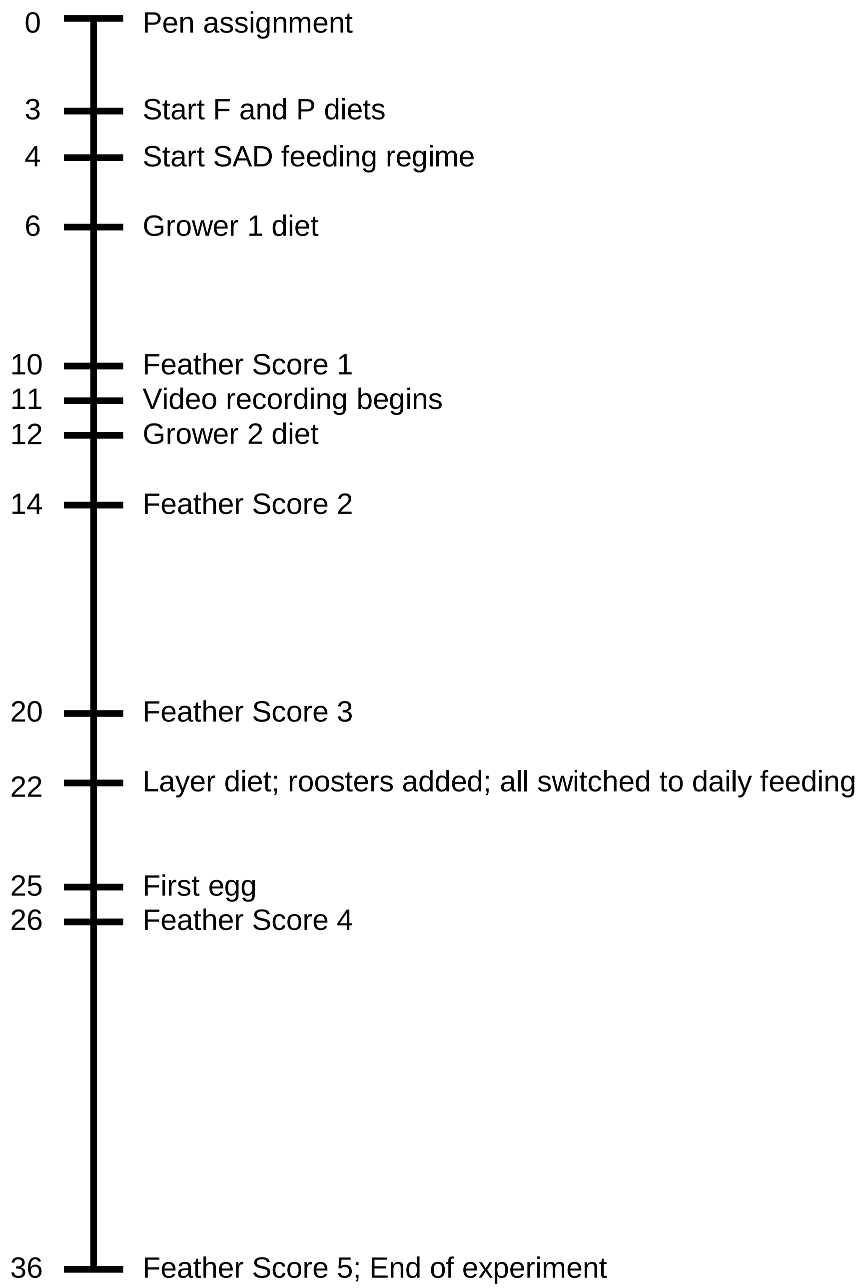

Figure 3. 2 Timeline for experimental protocol. Age of bird (rounded to the nearest wk) is along the left-hand side of the timeline. Switch to alternative diets (F (fibre + feed grade CaP) & P (fibre + purified CaP)) occurred at 19 d of age. SAD = skip-a-day.

Table 3. 1 Composition of C (Commercial), F (Fibre + feed grade CaP) & P (Fibre + purified CaP) diets used in Starter (0 – 6 wk), Grower 1 (6 – 12 wk) and Grower 2 (12 – 22 wk) phases.

	C	F & P
Corn (%)		
Starter	60.6	35.8
Grower 1	60.8	36.0
Grower 2	60.8	35.2
Wheat Shorts (%)		
Starter	8.8	5.2
Grower 1	16.0	8.8
Grower 2	16.0	8.1
Soybean Meal (%)		
Starter	24.0	14.2
Grower 1	16.5	9.8
Grower 2	16.5	9.6
Limestone (%)		
Starter	3.14	1.3
Grower 1	3.13	0.65
Grower 2	3.13	N/A
Dicalcium Phosphorus (%)		
Starter	2.0	1.2
Grower 1	2.1	1.2
Grower 2	2.1	1.2
Salt (%)		
Starter	0.34	0.20
Grower 1	0.36	0.21
Grower 2	0.36	0.21
Vitamin-Mineral Premix (%)		
Starter	1.0	0.59
Grower 1	1.0	0.59
Grower 2	1.0	0.58
Methionine (%)		
Starter	0.12	0.07
Grower 1	0.11	0.06
Grower 2	0.11	0.06
Calcium Propionate (%)		
Starter	N/A	1.44
Grower 1	N/A	3.19
Grower 2	N/A	5.05
Soybean Hulls (%)		
Starter	N/A	40.0
Grower 1	N/A	39.5
Grower 2	N/A	40.0

Table 3. 2 Percent inclusion (as analyzed) for Moisture, Protein, Calcium, NDF, Crude Fibre, Fat as well as M.E. (MCal/kg) and Calcium:Phosphorus Ratio in the C (Commercial), F (Fibre + feed grade calcium propionate) & P (Fibre + purified calcium propionate) diets.

	C	F	P
Moisture (%)			
Starter[1]	9.03	9.24	6.73
Grower 1[2]	9.98	11.25	9.55
Grower 2[3]	8.26	8.58	8.11
Protein (%)			
Starter	17.07	16.06	12.02
Grower 1	15.65	14.72	9.72
Grower 2	14.92	12.84	12.63
Ca:P[4] Ratio			
Starter	1.72	1.95	2.26
Grower 1	1.93	1.95	1.70
Grower 2	1.06	2.70	2.65
Calcium (%)			
Starter	1.31	1.09	1.22
Grower 1	1.62	1.06	0.87
Grower 2	0.87	1.51	1.36
NDF[5] (%)			
Starter	11.31	26.48	28.93
Grower 1	11.17	26.81	24.42
Grower 2	12.93	29.84	43.35
Crude Fibre (%)			
Starter	3.87	12.97	14.06
Grower 1	3.28	14.42	10.89
Grower 2	3.25	15.04	14.80
Fat (%)			
Starter	2.62	1.46	1.92
Grower 1	2.43	1.64	2.47
Grower 2	2.89	1.48	1.87
M.E.[6] (MCal/kg)			
Starter	2.48	1.89	1.81
Grower 1	2.48	1.68	2.03
Grower 2	2.68	1.78	1.76

[1] Starter fed from 0-6 wk of age
[2] Grower 1 fed from 6-12 wk of age
[3] Grower 2 fed from 12-22 wk of age
[4] Ca:P, Calcium to Phosphorus ratio
[5] NDF, neutral detergent fibre
[6] M.E., metabolizable energy

Table 3. 3 Ethogram of all possible behaviour.

Behaviour	**Description**
Feed	When any part of the head is in feeder
Drink	Any peck at nipple drinker
Walk	Walking (taking more than 2 steps, with head mid to upright), mutually exclusive of all other behaviour
Stand/Sit	Standing or sitting (with head mid to upright), mutually exclusive of all other behaviour
Roost/Perch	On perch, drinker line or feeder, mutually exclusive of all other behaviour
Forage	Scratch or peck at litter, head in downward position, looking at litter
Object Peck	Peck at wall, side of feeder, nest box, perch
Aggressive Peck	Any quick peck directed at penmate's head in a quick downward "aggressive" manner (usually with recipient moving away), can also be a quick movement with body in an aggressive manner towards another bird (usually resulting in other bird moving away)
Feather Peck	Any peck (usually repetitive) directed at penmate's body
Comfort	Dust bathe, stretch, shake, preen
Nest Box	In nest box, or standing on perch on nest box
Other	Wing flap, jump, mating with rooster, on rooster feeder, or any other behaviour not described here

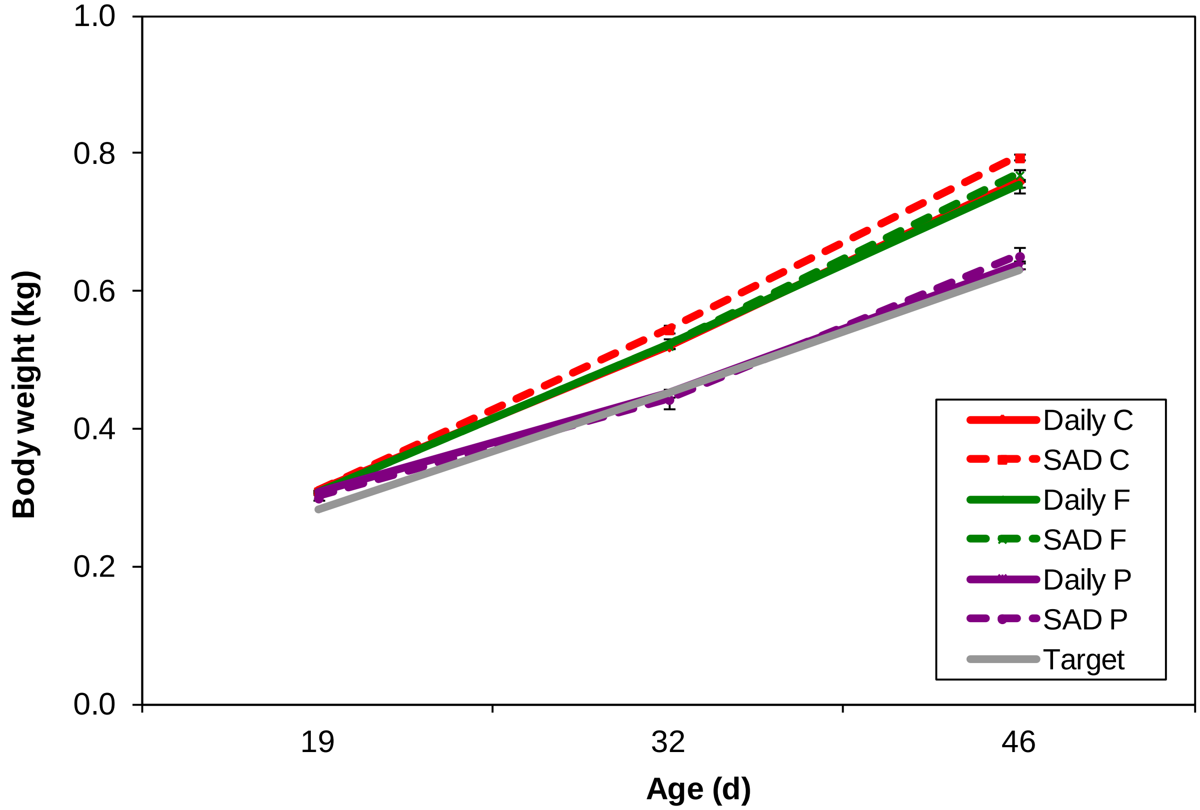

Figure 3. 3a Effect of Diet and Frequency on body weights (kg) during the Starter period (19 d to 6 wk). Daily vs. skip-a-day (SAD), control (C), feed grade calcium propionate + fibre (F) and purified calcium propionate + fibre (P) (Diet x Frequency x Time interaction, *P* = 0.0063).

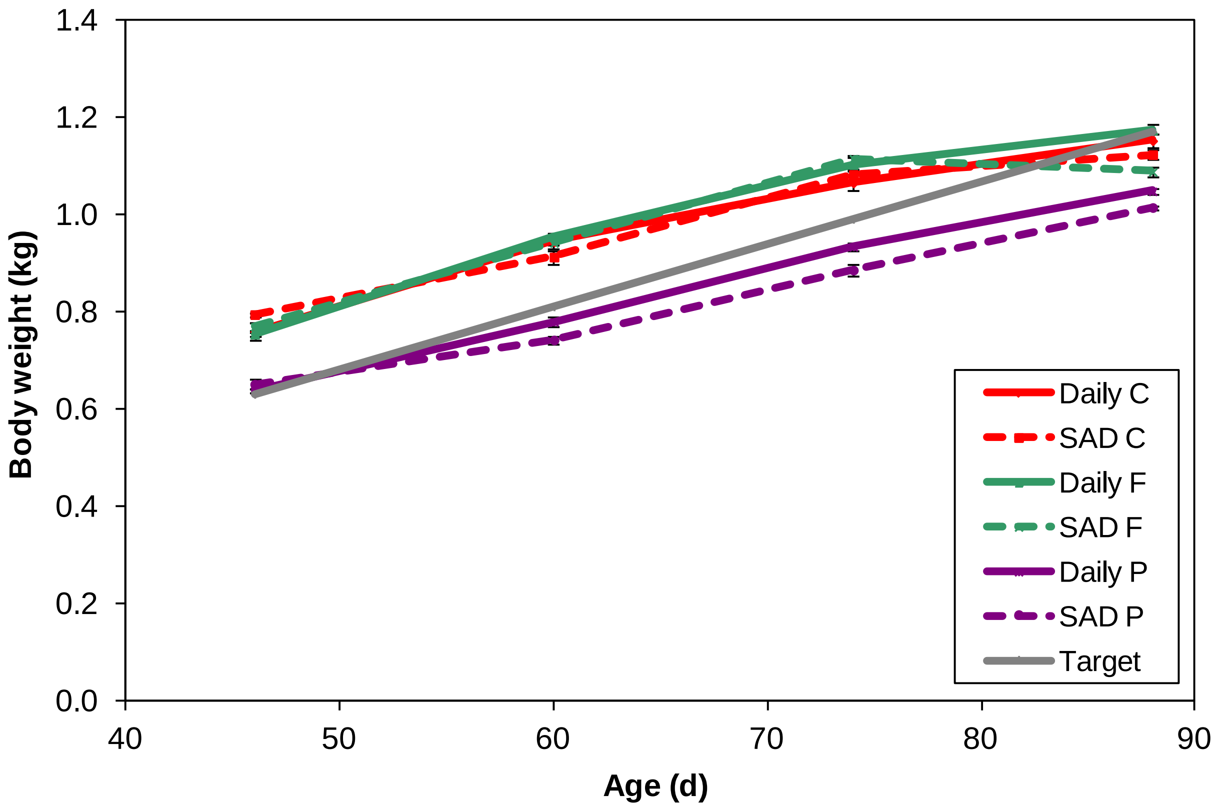

Figure 3. 3b Effect of Diet and Frequency on body weights (kg) during the Grower 1 period (6 to 12 wk). Daily vs. skip-a-day (SAD), control (C), feed grade calcium propionate + fibre (F) and purified calcium propionate + fibre (P) (Diet x Frequency x Time interaction, *P* = 0.0063).

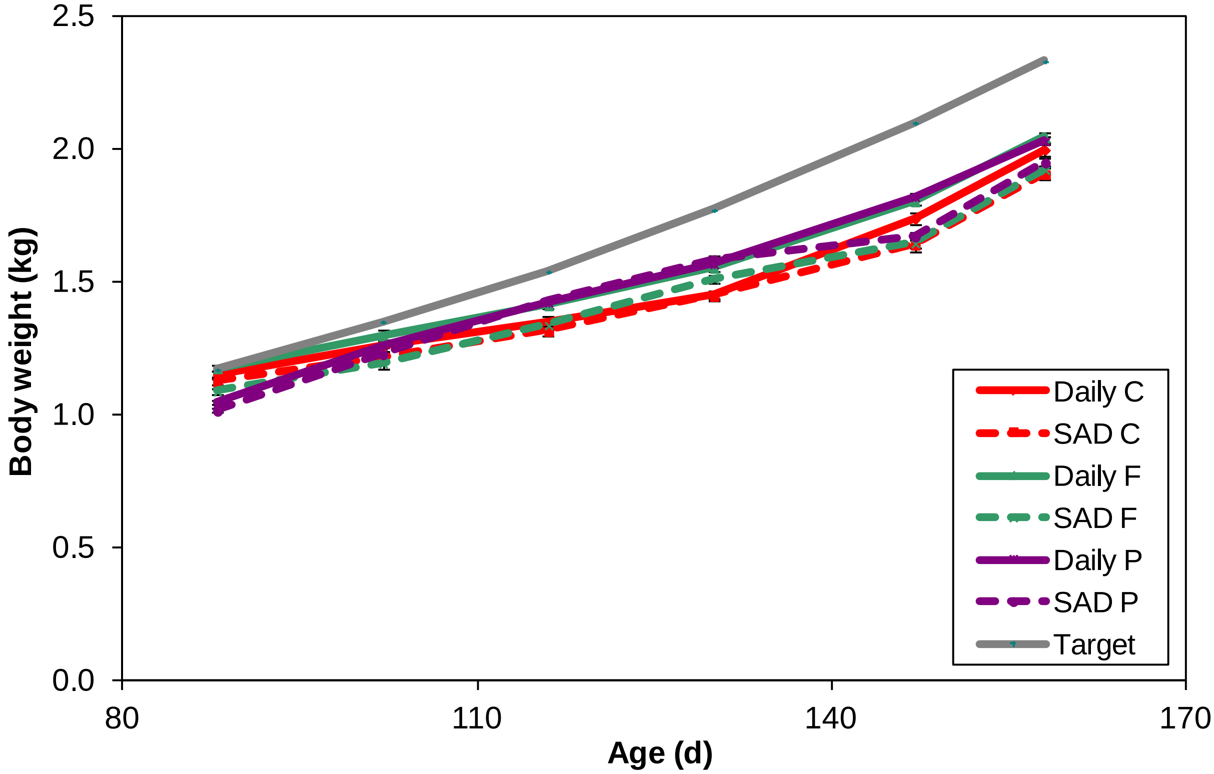

Figure 3. 3c Effect of Diet and Frequency on body weight (kg) during the Grower 2 period (12 to 22 wk). Daily vs. skip-a-day (SAD), control (C), feed grade calcium propionate + fibre (F) and purified calcium propionate + fibre (P) (Diet x Frequency x Time interaction, P = 0.0063).

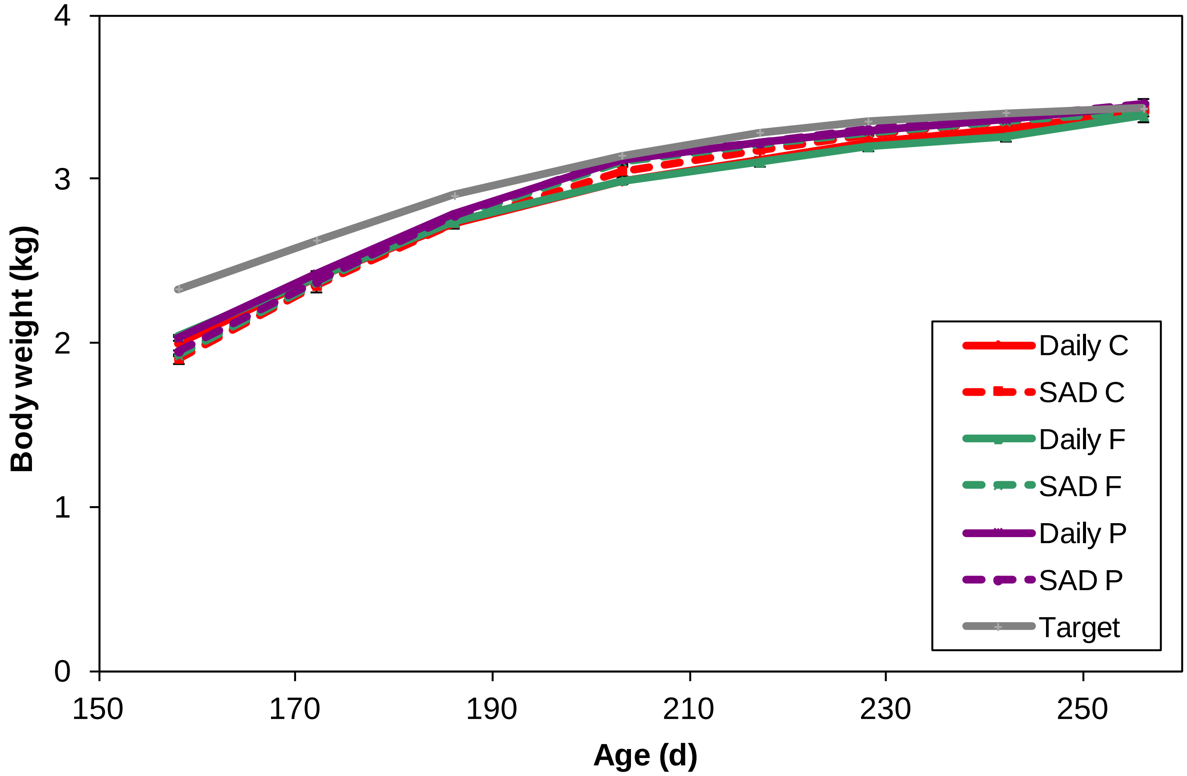

Figure 3. 3d Effect of Diet and Frequency on body weight (kg) during the Laying period (22 to 36 wk). Daily vs. skip-a-day (SAD), control (C), feed grade calcium propionate + fibre (F) and purified calcium propionate + fibre (P) (Diet x Frequency x Time interaction, *P* = 0.0063).

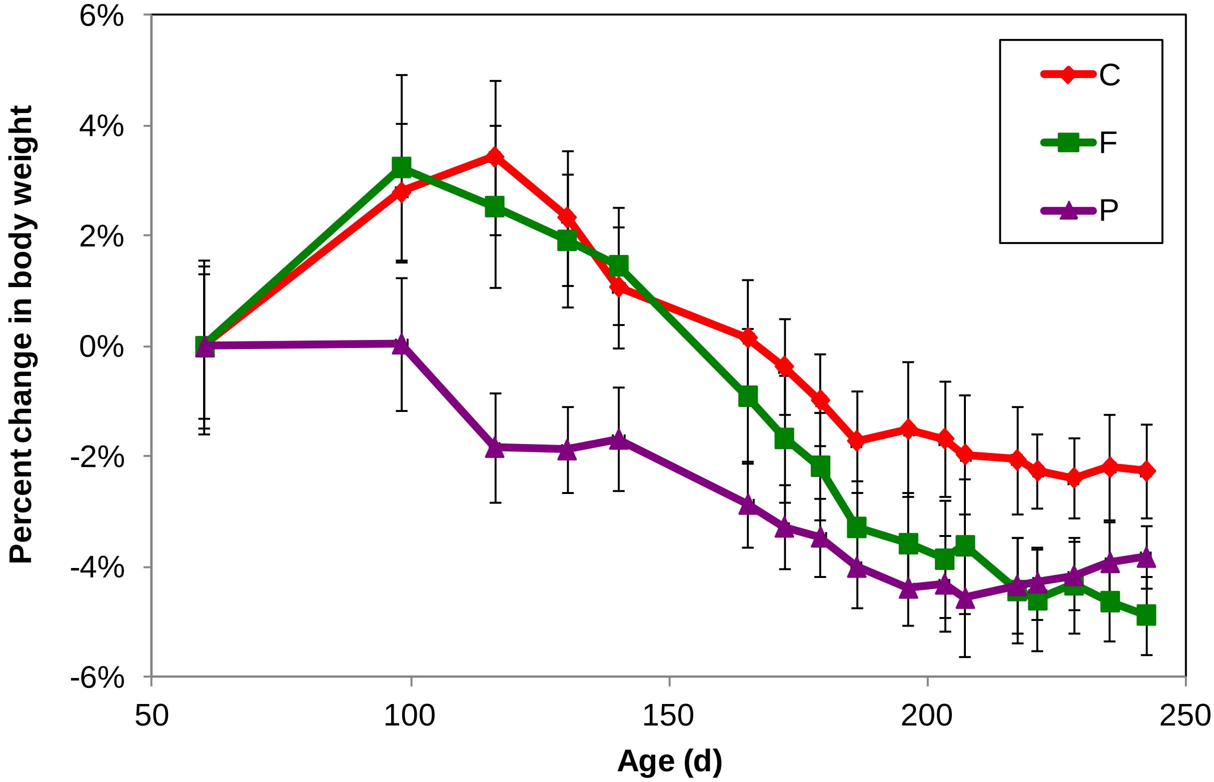

Figure 3. 4 Effect of Diet on the percent change in mean body weight (%CV) from 60d to end of experiment. Commercial (C), Fibre + Feed-grade Calcium propionate (F) and Fibre + purified Calcium propionate (P), Diet x Time interaction, *P* = 0.0033.

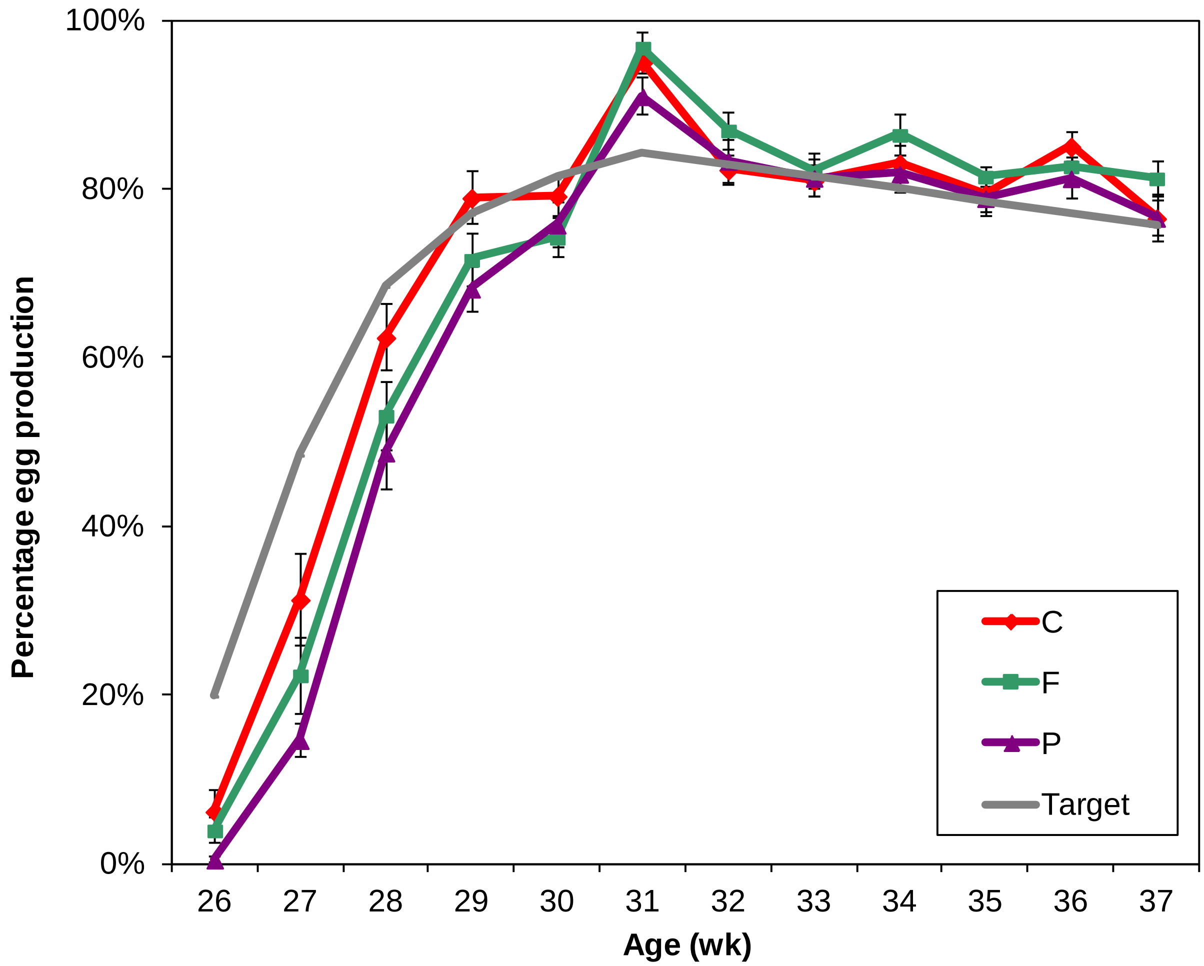

Figure 3. 5 Effect of Diet on percentage egg production (%) per hen per wk. Commercial (C), feed grade calcium propionate + fibre (F), purified calcium propionate + fibre (P), Diet x Time interaction, *P* = 0.0277.

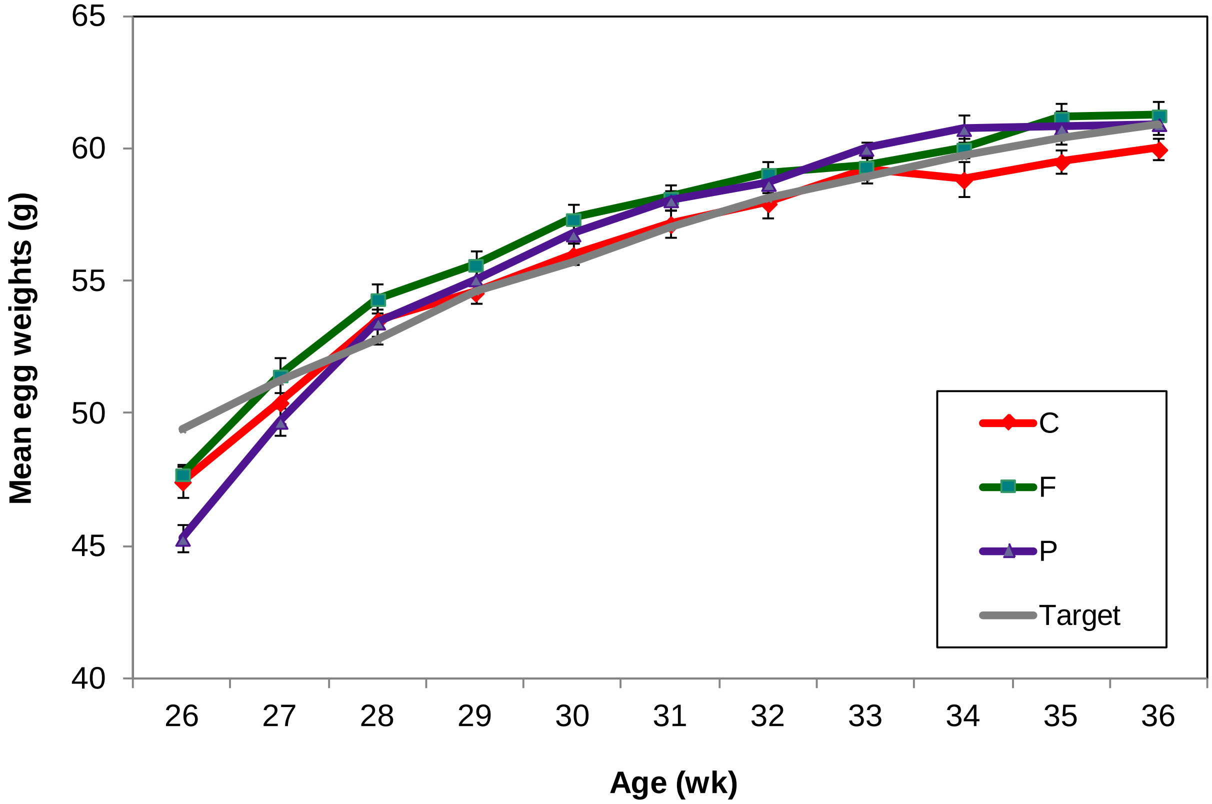

Figure 3. 6 Effect of Diet on mean egg weights (g). Commerical (C), fibre + feed grade calcium propionate (F) and fibre + purified calcium propionate (P), Diet x Time interaction, $P = 0.0713$.

Table 3. 4 Significant effect (*P* < 0.05) of Diet Type (D) and Feeding Frequency (FF) (and their interaction with Time (T)) for behaviour both during and after the feeding bout from 11 – 28 wk of age. Non-significant results not shown. Bolded *P* values presented in results section.

		Significance of Effects (*P* value)					
		D	FF	D x FF	D x T	FF x T	D x FF x T
Feeding	During					**0.0023**	
	After	**0.0556**					
Drinking	During	**0.0382**	<0.0001			**0.0022**	
	After	0.0188	<0.0001		**0.0045**	**0.0034**	
Foraging	During			**0.0076**			
	After				**0.0455**		
Resting	During	**0.0032**	0.0671			**0.0002**	
	After	0.0011			0.0003	0.0010	**0.0003**
Walking	During	0.0048			**0.0085**		
	After	**0.0008**					
Comfort	During					**0.0066**	
	After						
Object Pecking + Aggression	During						
	After	0.0001		0.0003			**0.0150**
Feather Pecking	During		**0.0026**				
	After	0.0112			**0.0331**		

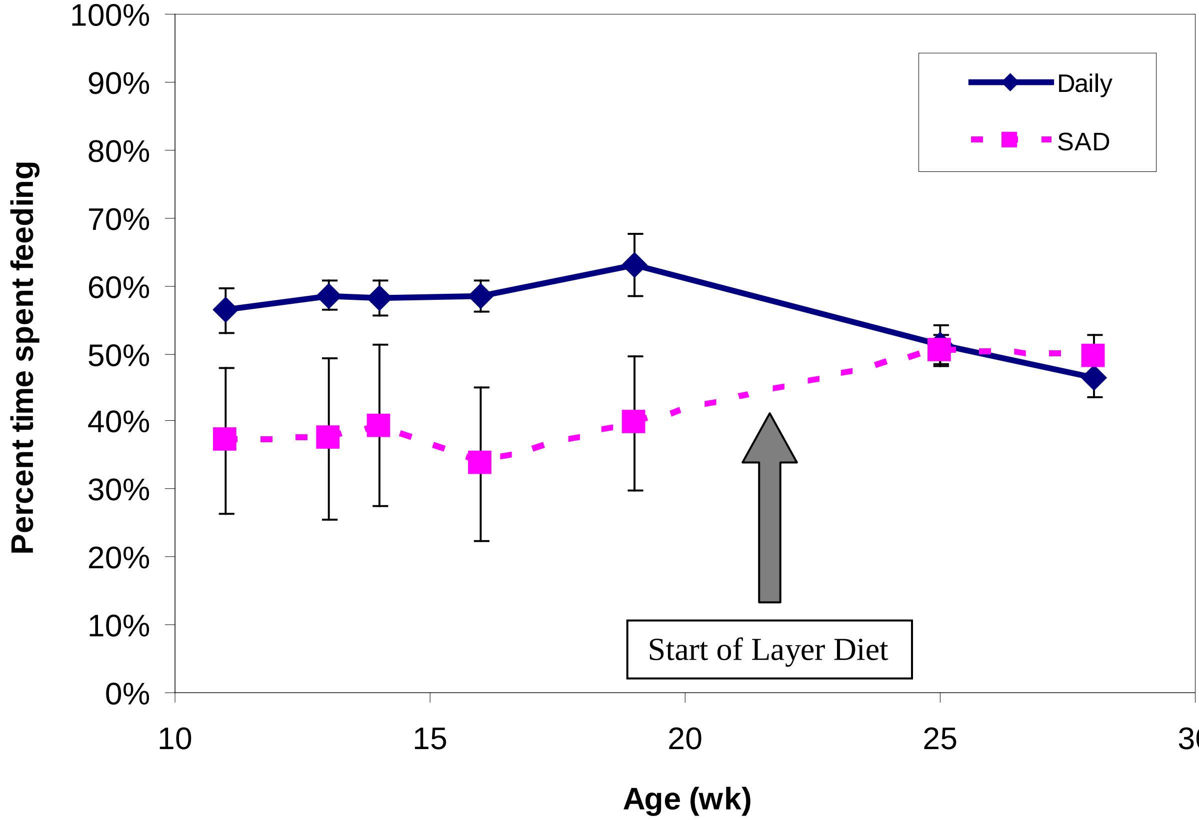

Figure 3. 7 Percentage of time spent feeding (head in feeder) during the feeding bout by feeding frequency (Daily vs skip-a-day (SAD), Frequency x Time interaction, *P* = 0.0023).

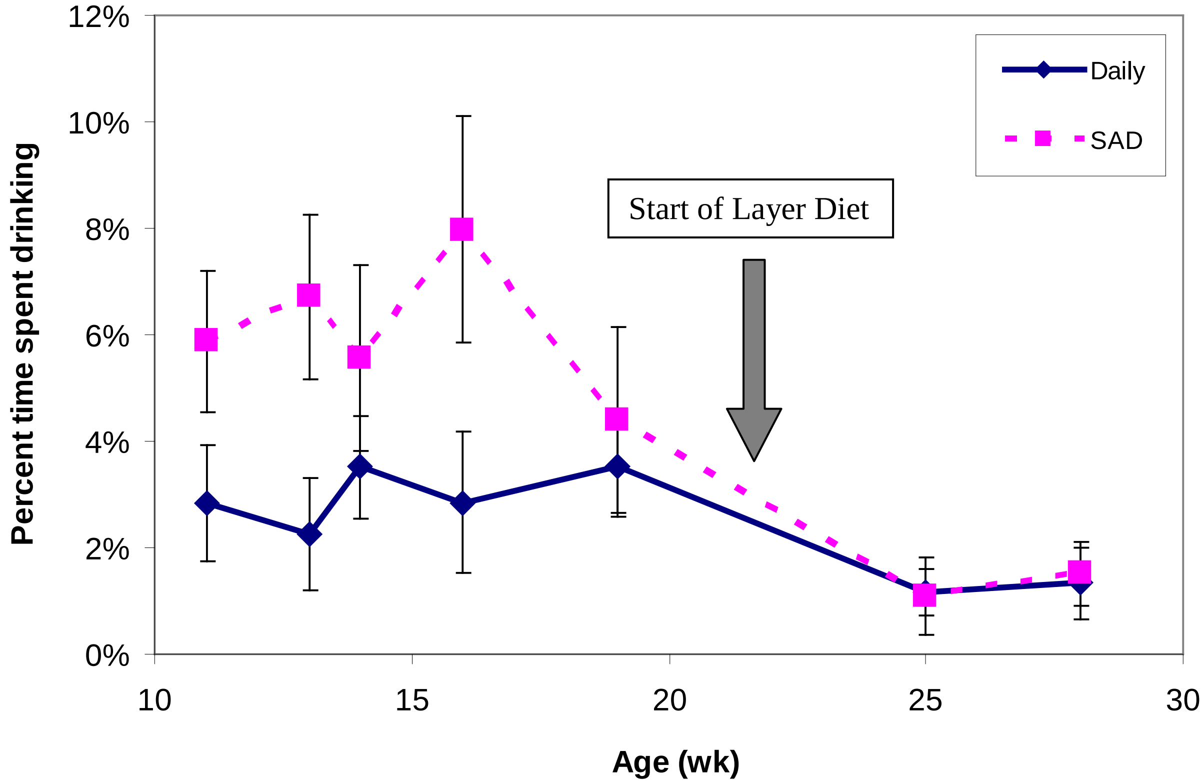

Figure 3. 8 Percentage of time spent drinking during the feeding bout by feeding frequency (Daily vs skip-a-day (SAD), Frequency x Time interaction, *P* = 0.0022).

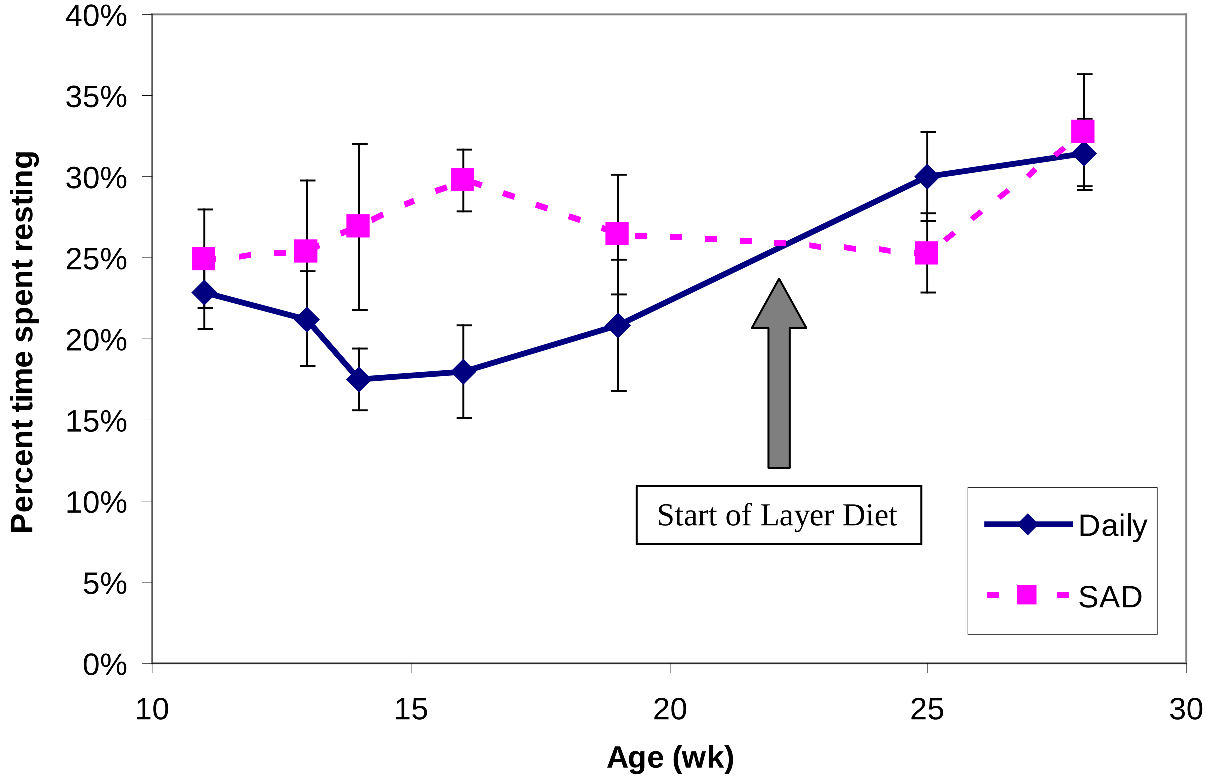

Figure 3. 9 Percentage of time spent resting (including standing/sitting and perching) during the feeding bout by feeding frequency (daily vs. skip-a-day (SAD), Frequency x Time interaction, *P* = 0.0002).

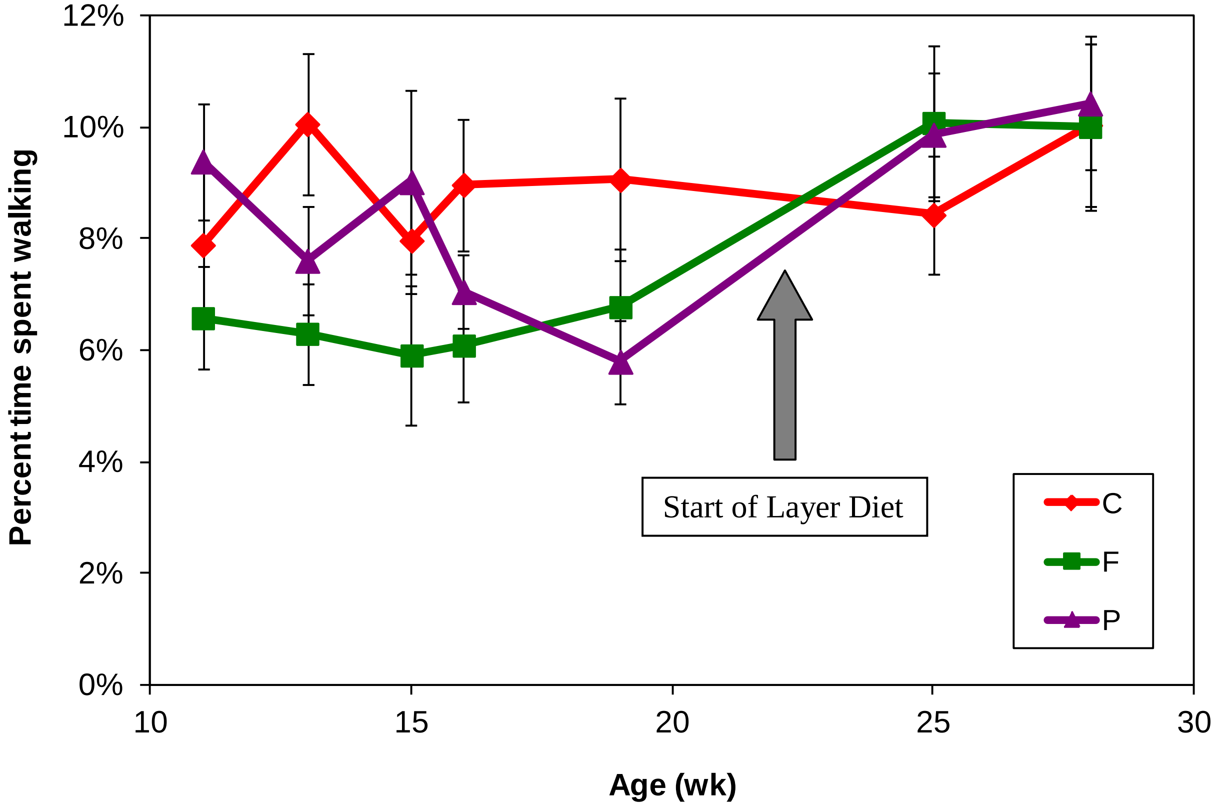

Figure 3. 10 Percentage of time spent walking during the feeding bout by diet type (control (C), feed grade calcium propionate + fibre (F) and purified calcium propionate + fibre (P), Diet x Time interaction, P = 0.0085).

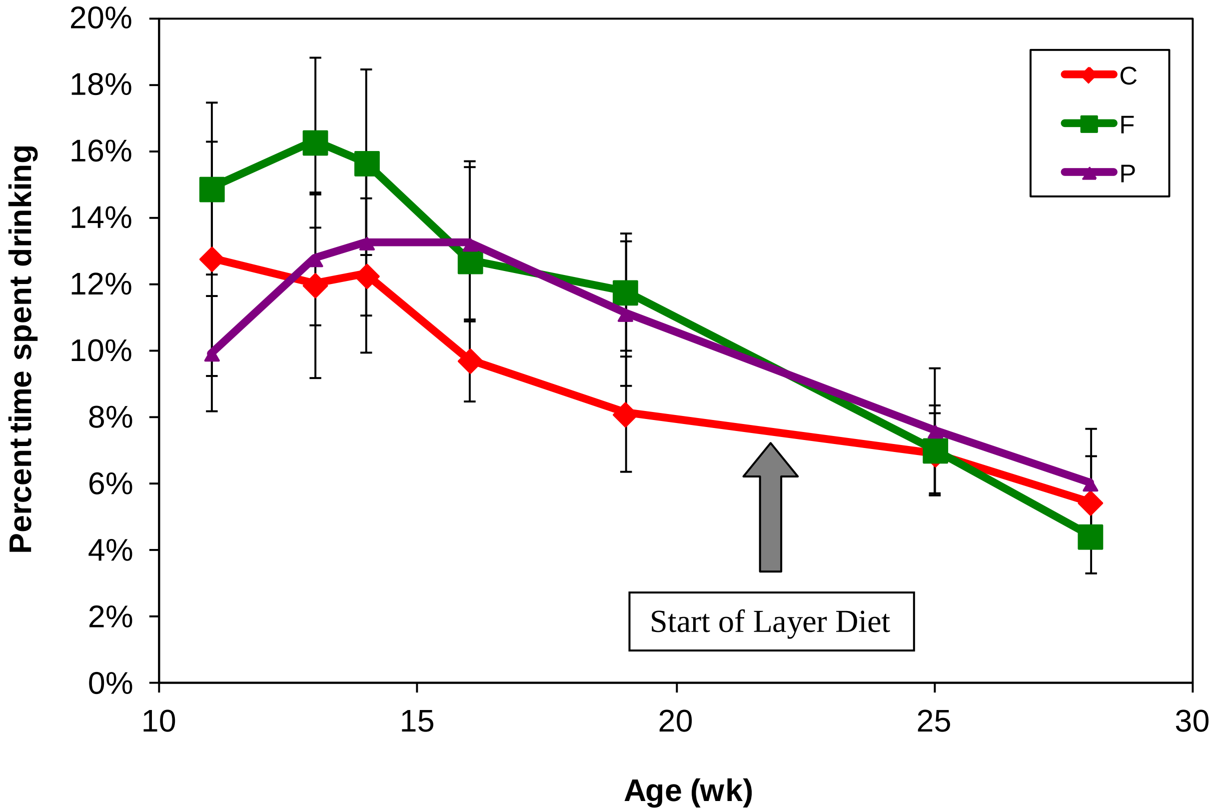

Figure 3. 11 Percentage of time spent drinking after the feeding bout by diet type (control (C), fibre + feed grade calcium propionate (F) and fibre + purified calcium propionate (P), Diet x Time interaction, $P = 0.0045$).

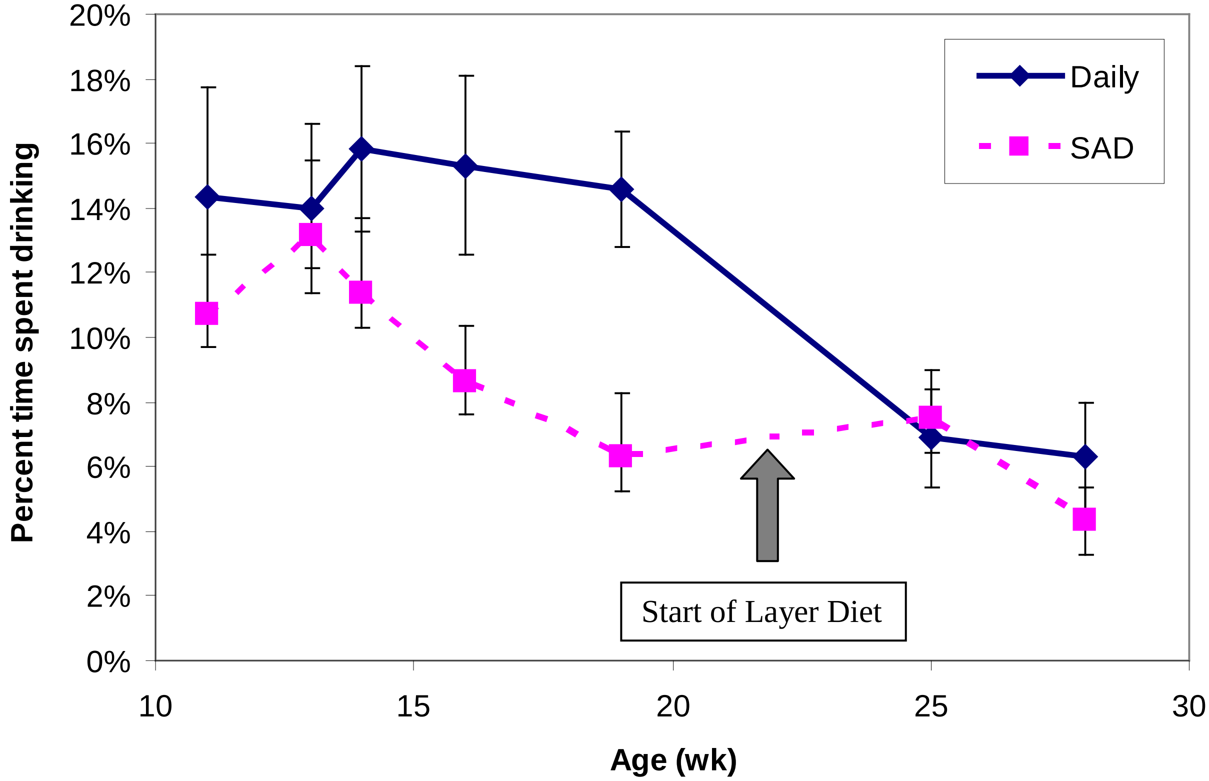

Figure 3. 12 Percentage of time spent drinking after the feeding bout by feeding frequency (daily, and skip-a-day (SAD), Frequency x Time interaction, $P = 0.0034$).

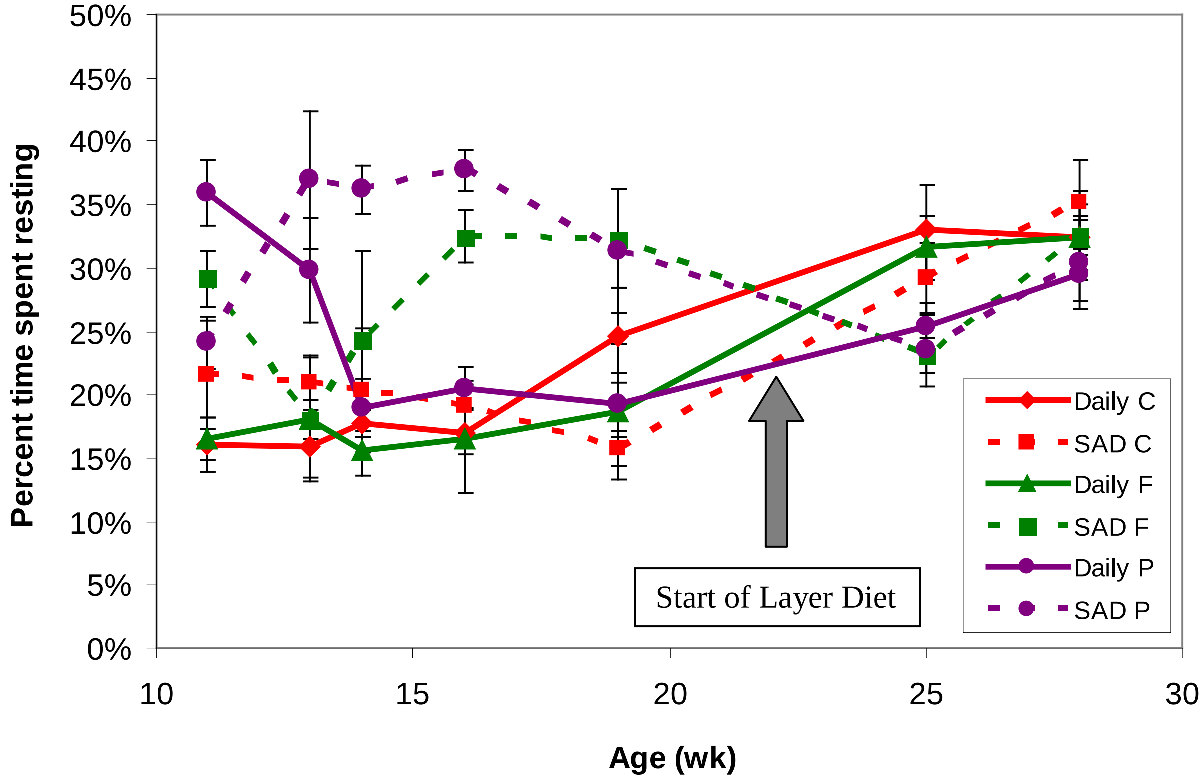

Figure 3. 13 Percentage of time spent resting (including standing/sitting and perching) after the feeding bout by Diet and Feeding Frequency, Daily and skip-a-day (SAD) control (C), feed grade calcium propionate + fibre (F) and purified calcium propionate + fibre (P), Diet x Frequency x Time interaction, *P* = 0.0003.

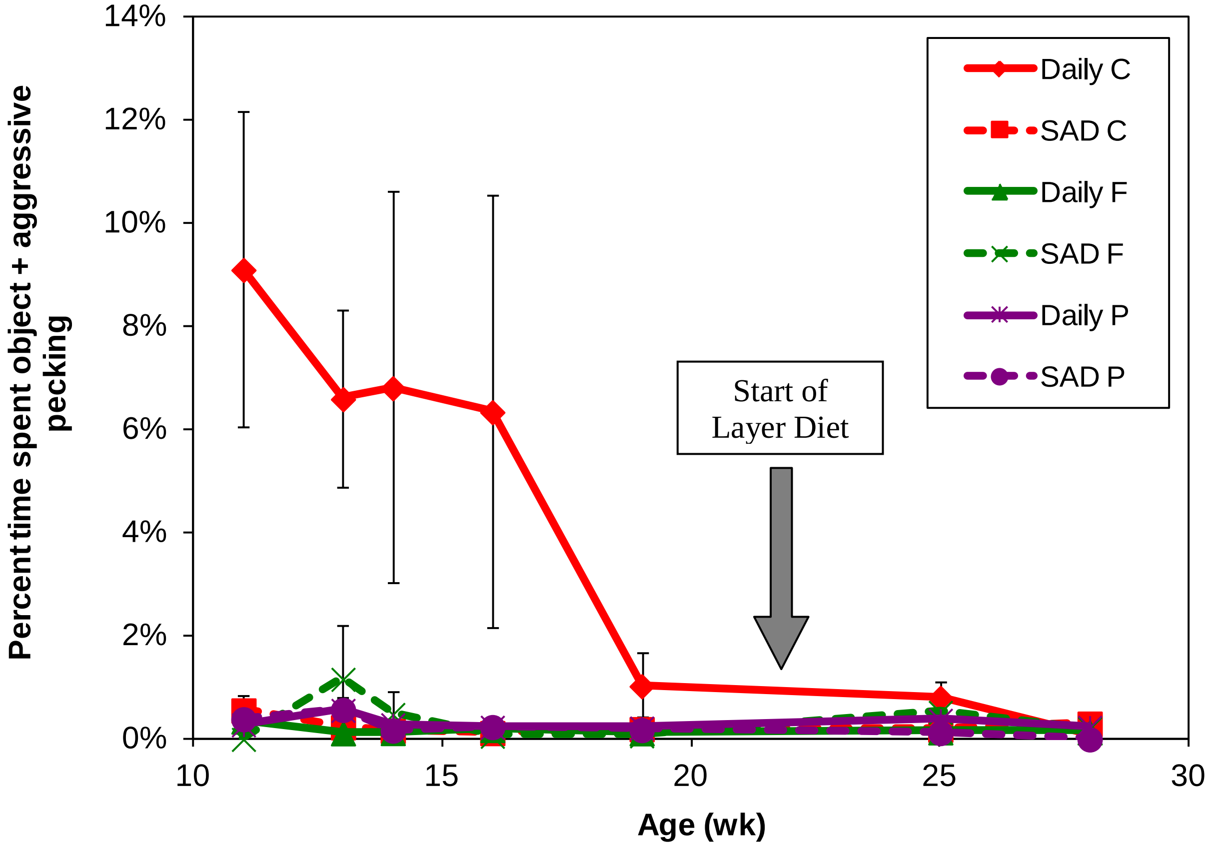

Figure 3. 14 Percentage of time spent object and aggressive pecking combined after the feeding bout by Diet and Feeding Frequency, Daily and skip-a-day (SAD) control (C), feed grade calcium propionate + fibre (F) and purified calcium propionate + fibre (P), Diet x Frequency x Time interaction, P = 0.0150.

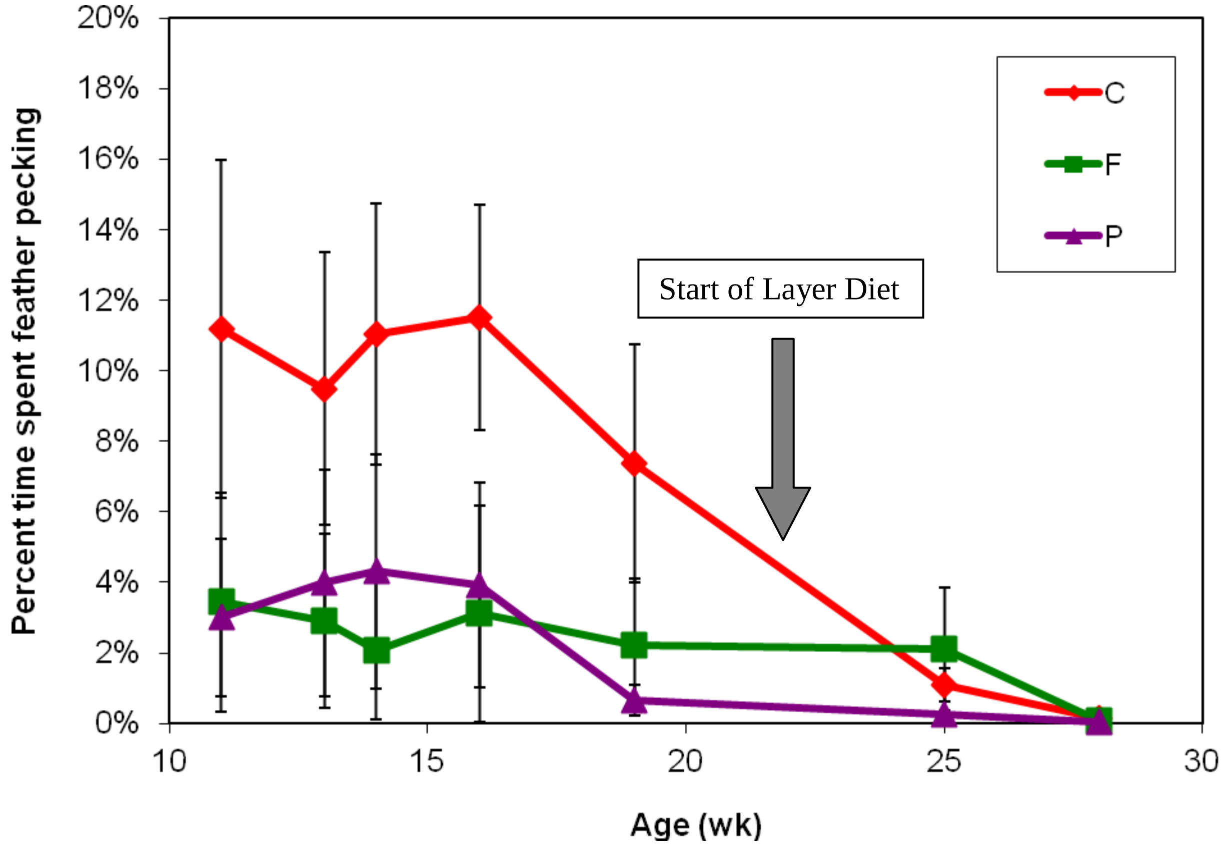

Figure 3. 15 Percentage of time spent feather pecking after the feeding bout by diet type (control (C), feed grade calcium propionate + fibre (F) and purified calcium propionate + fibre (P), Diet x Time interaction, *P* = 0.0331).

CHAPTER 4: EFFECTS OF DIETARY ALTERATIONS ON FEATHER PECKING: USING A FEATHER CONDITION SCORING SYSTEM [2]

4.1 ABSTRACT

Due to their capacity to grow quickly, broiler breeders are severely feed restricted to maintain healthy body weights. This restriction can induce stereotypic behaviour, including feather pecking, which has negative welfare implications for both the victim and performer. It has been suggested that the problem may be symptomatic of chronic hunger or a lack of dietary fibre or foraging substrate. In this study, we determined whether feather pecking could be reduced and welfare improved via dietary manipulation. Six dietary treatments were tested, each with 5 replicate pens of 9-12 birds. Control diets (C) consisted of a commercial crumble, fed on a daily or skip-a-day (SAD) basis. Alternative diets included soybean hulls as a bulking ingredient and calcium propionate (CaP) as an appetite suppressant of either a feed grade (F) or purified (P) quality. Both alternative diets were also fed on either a daily or SAD basis. Five or six of the birds were randomly chosen from each pen and feather scored at 10, 14, 20, 26 and 36 wk of age. Six body parts (neck, back, wings, legs, vent area, tail) were given a score from 0-5 (0 = no feather damage, and 5 ≥ 50% feather loss with tissue damage). Scores were summed for each bird, and averaged for each pen. Data were analyzed with Room and Feeding Frequency (daily, SAD) as main factors and Diet (C, F, P) as the sub-factor with repeated measures (SAS 9.2). There was an interaction between Diet and Time (*P* = 0.0007) with the C birds' feather condition worsening more quickly over time in comparison to both the F and P birds. There was an interaction between Feeding Frequency and Time (*P* = 0.015), with SAD-fed birds scoring

[2] A paper based on this chapter will be submitted to *Poultry Science* for publication.

better than daily-fed birds at 20, 26 and 36 wk of age. This interaction could indicate that the SAD regime increased satiety after the birds became accustomed to the schedule. Because feather condition was better with the alternative diets, this indicates a reduction in stereotyped feather pecking with these diets. This may demonstrate that the alternative diets increase satiety compared to the control diets.

4.2 INTRODUCTION

Broilers breeders are bred specifically to produce fast-growing progeny, the modern day broiler chickens. Because broiler breeders have the genetic potential to grow as quickly and efficiently as their broiler offspring, they must be severely feed restricted throughout the rearing period to ensure optimal health and avoid obesity. However, the severe quantitative feed restriction necessary for reproductive success results in chronic hunger and broiler breeders often display high levels of oral stereotypic behaviour associated with hunger, such as feather pecking.

Feather pecking is the most common stereotypic oral behaviour evident in most sectors of the poultry industry (Blokhuis & Arkes, 1984; Blokhuis, 1986; Bilcik & Keeling, 1999; Bright et al., 2006; Lambton et al., 2010). This behavioural problem can reflect a negative state of well-being for affected birds and can represent an economic loss to the industry (Lambton et al., 2010). Feather pecking is correlated with outbreaks of cannibalism (Leeson & Walsh, 2004; Dixon, 2008), decreased egg production and increased morbidity and mortality (Mench, 2002). In addition, feather pecking is painful for the recipients and increases heat loss if large parts of the body become denuded, in turn increasing the cost of metabolic maintenance (Bilcik & Keeling, 1999; LaBrash & Scheideler, 2005). Although feather pecking appears to be a multi-factorial problem caused by genetics, environment, age and/or diet (Leeson & Walsh, 2004; Van

Krimpen et al., 2005; Dixon, 2008), in broiler breeders, this behaviour may be most closely related to hunger.

Researchers have attempted to alleviate chronic hunger and the associated symptoms in broiler breeder pullets using alternative diets (Zuidhof et al., 1995; Savory et al., 1996; Savory & Lariviere, 2000; Hocking et al., 2004; de Jong et al., 2005a; Sandilands et al., 2005; Sandilands et al., 2006; Nielsen et al., 2011). To date, the most effective diets contain both a high-fibre component and a chemical compound acting as an appetite suppressant (calcium propionate) (Sandilands et al., 2005; Sandilands et al., 2006). There has been a wide range of behavioural benefits of these diets, such as reduced activity and stereotypic behaviour, and Sandilands et al. (2006) were able to almost completely abolish the performance of object pecking in broiler breeders fed a diet consisting of a high-fibre component as well as a chemical appetite suppressant (calcium propionate). However, most of the effective alternative diets have been fed on a daily and *ad-libitum* basis (Savory et al., 1996; Sandilands et al., 2005; Sandilands et al., 2006), which isn't common practice in North America.

It is common for North American broiler breeder producers to adopt alternative feeding schedules on which birds may not be fed every day (Bramwell et al., 2008). Skip-a-day (SAD) is the most commonly used alternative feeding schedule, where birds are fed twice their daily allocation every other day (Bramwell et al., 2008). Because the birds are not receiving feed on a daily basis, these alternative feeding regimes are considered to be detrimental to an animal's well-being, and are banned in the United Kingdom (DEFRA, 2007). There is some research describing feed efficiency and production in broiler breeders being fed using alternative feeding regimes (Bennett & Leeson, 1989; Ingram et al., 2001; de Beer & Coon, 2007). However, there is no research pertaining to the behavioural effects of SAD feeding alone or in combination with alternative diets.

The objectives of this experiment were to assess the differences in feather condition of broiler breeder hens fed a qualitatively restricted diet compared to those fed a commercial quantitatively restricted diet. Feather condition scoring was used for this experiment. Birds reared on diets associated with an increase in satiety (ie. qualitatively restrictive diets) were expected to feather peck less and therefore have better feather condition scores. Because SAD feeding is generally considered to reduce welfare, it was hypothesized that the birds fed on a daily basis would be less hungry and would have better feather condition scores compared to their SAD-fed counterparts.

4.3 MATERIALS AND METHODS

This experiment was carried out in conjunction with the Longitudinal Study previously outlined in Chapter 3. All of the procedures used in this experiment was approved by the University of Guelph's Animal Care Committee and were in accordance with the guidelines outlined by the Canadian Council for Animal Care.

4.3.1 Birds

Day-old Ross 708 broiler breeder females (n=383) and males (n=51) were donated (courtesy of Aviagen, via Horizon poultry, Alabama, USA) for this experiment and reared at the OMAFRA Arkell Poultry Research Station (Guelph, ON, Canada). Males and females were reared separately. All of the birds were vaccinated against local diseases in accordance with the research farm's vaccination protocol. All birds were beak trimmed at 1 d of age at the hatchery using an infrared beam in order to minimize damage caused by feather pecking. All birds were reared according to the programs outlined by the breeding company (Aviagen, 2007). For the first 3 d of life birds were housed with a lighting regime of 23L:1D at 20 lux. From then on the lighting schedule was as follows: 12L:12D (20 lux) from d 4-21 and 8L:16D (4-7 lux) from d 22 to wk 22. Producer recommendations for heating were followed with a gradual reduction in heating (from 32°C on d 1 to 21°C on d 42, Aviagen 2007). Chicks were provided with a heated mat up until 7 d of age.

Upon arrival to the research farm, the female chicks were randomly allocated to 1 of 30 identical pens (1.83 x 2.36 m, Figure 3.1) that had been assigned 1 of 6 treatments (see <u>*Dietary Treatments*</u> section). All of the pens had wood shavings (approximately 3 cm depth) covering the entire floor. Each pen was furnished with a wooden perch (0.05 x 0.05 x 1.52 m, with top edges bevelled) at a height of 20 cm. Nest boxes (0.91 x 0.46 m, with three nest sites each measuring 0.30 m in width) were added at wk 20 to allow the birds to become accustomed prior to the onset of lay. Water was provided on an *ad-libitum* basis from a nipple drinker (7 nipples/pen). Round pan feeders (38.1 cm in diameter) were used until the birds were 10 wk old. Hanging trough-style feeders (0.13 x 1.52 m) with exclusion grills were then installed to allow for more space per bird during feeding. At 22 wk, 1 rooster was added per pen of hens to simulate commercial farm settings. Rooster feeders were installed prior to combining sexes and roosters were fed separately from the hens, following breeder guidelines.

Pens were cleaned out as needed; however, whenever dirty pens were cleaned out, all other pens received at least a top layer of fresh wood shavings so as to avoid inducing behaviour, such as dust bathing, in only some pens.

4.3.2 Experimental Protocol

Prior to starting the experimental diets, birds were redistributed and pens were standardized to an average weight as close to the overall mean as possible (308.72 ± 1.00 g/bird) by removing 1 – 2 birds per pen. This left 18 pens with 11 birds and 12 pens with 12 birds. At 20 wk, 22 of the smallest and least thrifty birds were culled. During the rearing period, 2 birds (0.58%) were found dead and 7 more (2.05%) were euthanized due to injury, infection, sexing error or beak deformities. During the laying period, 2 birds (0.64%) were found dead and 15 more (4.81%) were euthanized due to lameness and injury.

4.3.2.1 Dietary Treatments

Upon arrival at the research facility, the chicks were randomly allocated to 1 of 6 dietary treatments, each with 5 replicate pens. This experiment was of a 3x2 factorial design, with 3 different diets and 2 feeding regimes. The 2 different feeding regimes tested were daily feeding and skip-a-day (SAD) feeding; with SAD birds were fed twice the daily allocation every other day. This treatment commenced once the birds reached 4 wk of age and ended at 22 wk, as per breeder guidelines. The 3 experimental diets tested were a commercial (C) diet, and 2 diets containing soybean hulls (SBH) and either a feed-grade quality (F) or purified (P) appetite suppressant (calcium propionate, CaP; Table 4.1). Therefore, there were 2 treatment groups that were fed the same diet, with 1 fed daily and the other fed on a SAD basis, for all 3 diet types. A total of 4 rooms were used to house the birds (12 pens total per room), with 2 rooms for daily birds and 2 rooms for SAD birds. To avoid disruption to birds not being fed while others were, daily and SAD birds were not housed in the same rooms, thereby confounding room with feeding frequency. One of the rooms housing the daily fed birds was also used to house the males used for this experiment (4 pens) and other females used for preference testing (4 pens, see Chapter 5). Therefore, 1 pen of each daily-fed diet types was housed in 3 of the last remaining 4 pens. In the other room housing daily-fed birds, 4 pens of each diet type were randomly distributed within the room. Two rooms were used to house the SAD birds; diet types as evenly distributed across rooms as possible, with 4 or 5 pens empty in each of the rooms.

Diets that contained SBH and CaP were composed of a basal amount of the commercial crumble with the SBH and CaP being additional ingredients (Table 4.1). Alternative Starter diets comprised of a basal amount of the commercial control diet (59%), diluted with SBH (40%) and CaP (1%). As the birds aged, the inclusion rate of CaP increased; Grower 1 included 3% CaP and Grower 2 included 5%. Therefore, the basal amount of the commercial component decreased accordingly; 57% and 55% for Grower 1 and Grower 2, respectively. However, for the first 18 d, all birds were fed a commercial chick starter (Crude Protein = 17.7%). All birds were fed daily following lights-on at 08:00. Following breeder recommendations, all birds were fed on an *ad-libitum* basis from d 1-7 and were subsequently feed-restricted from d 8 onwards. Both experimental diets were formulated according to age of the bird: Starter crumble from 0-6 wk, Grower 1 crumble from 6-12 wk, Grower 2 crumble from 12-22 wk and Layer crumble from 22 wk onwards (Table 4.1). These diets were analyzed to determine exact nutrient content (Agrifood Laboratories, Guelph, Ontario, Canada). The Layer diet was not analyzed; however, all birds were fed the same commercial crumble during the laying period.

At d 19, birds in the F and P treatments were switched from the commercial starter crumble to the alternative starter diet. Birds in these treatments were allocated a larger volume of feed per day due to the fibrous dilution and inclusion of calcium propionate in the F and P diets (Table 4.2). This increase depended on the age of the bird; 41%, 43% and 45% more feed for Starter, Grower 1 and Grower 2, respectively. At 22 wk of age, just prior to coming into lay, all birds started the commercial layer diet. SAD birds were switched back to daily feeding (see Figure 3.2). Data were collected until birds reached 36 wk of age.

4.3.2.2 Feather Scoring

Feather scoring took place at 10, 14, 20, 26 and 36 wk of age. At each time point, 5 – 6 birds per pen were randomly chosen, weighed and then feather scored. Six body parts, including the neck, back, wings, legs, vent and tail, were assessed and given a score from 0 – 5 (Table 4.3). The highest, or worst possible feather score for each bird was 30 (ie. bird completely denuded including tissue damage).

4.3.3 Data Analysis

The statistical analyses for this experiment were performed using the SAS statistical analysis package (SAS 9.2, 2007). At each time point, the scores for all 6 body parts were summed per bird and then averaged per pen. A mixed model ANOVA with repeated measures was performed on pen means with Room and Feeding Frequency as the main plot factors and Diet Type as the subplot factor. Room and Room x Feeding Frequency were accounted for as random effects. Room x Feeding Frequency was included as a random effect because Feeding Frequency was not randomized or evenly distributed across the 4 rooms. The analysis used for handling repeated measures over time was modelled after the method given by Wang & Goonewardene (2004), using a first order auto-correlation covariance structure. Data were +1 log transformed to include scores of 0 and to stabilize variances before analyzing pen means. Orthogonal linear and quadratic contrasts were used to analyze differences in trends over time.

Linear regression models were also used to analyze the correlation between feather condition scores and feather pecking behaviour (measured separately in Chapter 3) during and immediately following feeding bouts.

4.4 RESULTS

Feather scores throughout this experiment ranged from 0 - 14. Nine birds from the daily and SAD-fed C treatments were the only birds with scores higher than 10. The highest score within the alternative diet treatments was 9 (daily F).

At 10, 14 and 20 wk of age, feather scores were positively correlated with feather pecking behaviour observed in the morning following feeding bouts ($P < 0.02$ for 10, 14 and 20 wk respectively), where pens with higher frequencies of feather pecking had worse feather condition (ie. higher scores). From 26 wk onwards, feather pecking behaviour was observed at very low frequencies, and did not correlate with feather condition scores.

4.4.1 Effect of Diet Type

Overall, there was an effect of Diet Type ($P = 0.0002$), however, there was also an interaction of Diet with Time ($P = 0.0007$, Figure 4.1). The scores for all 3 diet types were similar at wk 10, but C birds' feather scores worsened much more quickly over time and were significantly higher at 36 wk in comparison to both the F and P diets (Figure 4.1).

4.4.2 Effect of Feeding Frequency

Overall, there was no effect of Frequency ($P = 0.50$). There was however, a significant interaction of Frequency with Time ($P = 0.015$) with the daily-fed birds' mean feather condition worsening more quickly over time than the SAD-fed birds (Figure 4.2). Both linear (P =

0.0103) and quadratic (P = 0.0120) trends differed over time between the daily and SAD feeding regimes.

4.5 DISCUSSION

Overall, birds from all treatments were relatively well-feathered (especially prior to the onset of lay), and no evidence of cannibalism was observed. Very few birds showed any signs of tissue damage, with most of these cases resulting from bleeding feather follicles, not from direct pecking at the tissue. The birds used in this experiment were all beak-trimmed and were housed in pens at a low density on litter that was changed frequently, providing fresh substrate to support foraging behaviour. It was also common practice at the housing facility to apply pine tar to severely affected areas of the body to prevent further damage. These factors may have affected the level of feather pecking; however, there were still obvious and significant differences among treatments.

Feather condition worsened across time for all treatment groups. However, changes after 22 wk may have been the result of the addition of the roosters to the pens. Scores from the back and neck region may have specifically been influenced by the roosters, as broiler breeder males are vigorous during mating and can pull out feathers in the process (Millman et al., 2000). However, it was impossible to identify what degree of damage the roosters were responsible for, so all scores were included in the analysis.

One of the pens from the daily-fed C diet began feather pecking at 3 wk of age. This outbreak happened only 2 d after treatment diets began and before the SAD feeding began (4 wk of age). Because the treatments had been randomly assigned before the birds were placed, this outbreak of feather pecking may not have been related to the diet type or feeding frequency.

Therefore, the data was analyzed both with and without this pen's feather condition scores (pen included in data shown). Removing this pen from analysis did not change whether the dietary effects were considered significant. It is impossible to determine whether the scores for this pen would have improved had the treatment allocation been anything other than the daily C diet. Therefore, we can only speculate if the propagation and continuation of feather pecking within this pen was due to the dietary treatment.

4.5.1 Effect of Diet Type on Feather Condition

From the data presented, it is clear that both alternative diet types (F and P) had a positive effect on feather condition. This finding supports our initial hypothesis, indicating a decrease in feather pecking from birds fed the alternative diets. Even though feather condition scoring may not directly measure feather pecking behaviour, our data indicate that, at least through 20 wk, feather scores were positively correlated with an increase in pecking behaviour. However, it is impossible to determine whether the decrease in feather condition is exclusively due to an increase in pecking frequency, pecking severity, a combination of the 2 or something completely unrelated. Dixon et al. (2008) suggested there were different motivational factors influencing the performance of gentle and severe pecking. Severe pecks were most similar in morphology to foraging pecks and may be caused by a lack of access to foraging substrates; whereas gentle pecking may be more closely related to preening behaviour (Dixon et al., 2008). For the purpose of the current study, both gentle and severe feather pecking could be associated with chronic hunger as foraging is a component of feeding behaviour and excessive preening or allo-preening could indicate redirected feeding frustration (Duncan & Wood-Gush, 1972). Therefore, a reduction in feeding frustration, or an increase in satiety would likely result in a reduction in both severe and gentle feather pecking. It seems then, that both alternative diets (F and P) were effective at reducing hunger as feather condition worsened more slowly in comparison to the feather condition of the birds raised on the C diet type. While the feather condition scores still increased over time for both alternative diet types, presumably indicating some level of chronic hunger was still present, the rate of increase was slower. Therefore, it is possible that these two alternative diets did not completely extinguish the feeling of hunger for the birds fed these diets. However, the satiating mechanisms in broiler breeders may be impaired due to genetic selection pressure (Bokkers & Koene, 2003), and a state of long term satiety may not be attainable with any type of feed restriction (Hocking, 1993).

Previous studies including CaP in alternative diets for broiler breeders have used either a purified or industrial grade quality of the chemical (Savory et al., 1996; Savory & Lariviere, 2000; Sandilands et al., 2005; Sandilands et al., 2006). However, Savory & Lariviere (2000) suggested that the purified CaP used in a previous experiment (Savory et al., 1996) was more effective than the industrial grade version at both reducing hunger and controlling growth rates when fed *ad-libitum*. The results from the current study suggest that both grades of CaP were able to reduce hunger, represented by the improvement in feather condition. In fact, at 14 wk birds reared with the industrial grade CaP (F diet) had better feather condition than those reared with the purified CaP (P diet). This may not reflect any significant or long lasting difference between the two CaP types, but the industrial grade CaP was just as effective, if not more so, than the purified CaP in reducing hunger and feather pecking.

It is arguable that the better feather condition with both the F and P diets were not a result of an increase in satiety, but rather of a reduction in general activity due to a feeling of malaise. CaP has a very pungent smell and the birds may find it aversive (Buckley et al., 2011b) or it may make them feel ill. While Buckley et al. (2011b) found that birds had a slight preference for a control diet over a diet including calcium propionate, we found no difference in preferences (Chapter 5).

4.5.2 Effect of Feeding Frequency on Feather Condition

Feather condition worsened more quickly for birds that were fed daily compared to their SAD counterparts. This finding did not support our original hypothesis that SAD-birds would show more severe symptoms of chronic hunger and therefore have worse feather condition. The difference in trends over time between the 2 feeding frequencies may reflect the time it took for the birds to become accustomed to the SAD feeding schedule. It may be possible that the SAD-fed birds were receiving enough feed during "on-feed" days to reach a higher level of satiety than daily feedings could allow.

4.6 CONCLUSIONS

The results of this experiment supported our first hypothesis that high-fibre diets including an appetite suppressant would improve feather condition. Therefore, it can be assumed that a reduction in oral stereotypic behaviour represents an increase in satiety. The F diet was the most effective at improving feather condition, meaning it was most effective at reducing hunger.

Interestingly, our hypothesis that SAD feeding would result in poorer feather condition scores and would therefore negatively impact welfare proved incorrect. SAD feeding actually delayed the decrease in feather condition over time. The feather scores of the daily-fed birds worsened at a quicker rate, suggesting that SAD birds grew accustomed to their feeding schedule over time and learned when to expect feed. On "on-feed" days, they may have been receiving enough feed to satisfy their hunger. The ability to reach satiety every other day may be more welfare friendly than never feeling full on a daily feeding schedule.

Table 4. 1 Composition of Commercial (C), Fibre + Feed-Grade CaP (F) and Fibre + Purified CaP (P) diets used in Starter (0 – 6 wk), Grower 1 (6 – 12 wk) and Grower 2 (12 – 22 wk) phases.

	C	**F & P**
Corn (%)		
Starter	60.6	35.8
Grower 1	60.8	36.0
Grower 2	60.8	35.2
Wheat Shorts (%)		
Starter	8.8	5.2
Grower 1	16.0	8.8
Grower 2	16.0	8.1
Soybean Meal (%)		
Starter	24.0	14.2
Grower 1	16.5	9.8
Grower 2	16.5	9.6
Limestone (%)		
Starter	3.14	1.3
Grower 1	3.13	0.65
Grower 2	3.13	N/A
Dicalcium Phosphorus (%)		
Starter	2.0	1.2
Grower 1	2.1	1.2
Grower 2	2.1	1.2
Salt (%)		
Starter	0.34	0.20
Grower 1	0.36	0.21
Grower 2	0.36	0.21
Vitamin-Mineral Premix (%)		
Starter	1.0	0.59
Grower 1	1.0	0.59
Grower 2	1.0	0.58
Methionine (%)		
Starter	0.12	0.07
Grower 1	0.11	0.06
Grower 2	0.11	0.06
Calcium Propionate (%)		
Starter	N/A	1.44
Grower 1	N/A	3.19
Grower 2	N/A	5.05
Soybean Hulls (%)		
Starter	N/A	40.0
Grower 1	N/A	39.5
Grower 2	N/A	40.0

Table 4. 2 Percent inclusion (as analyzed) for Moisture, Protein, Calcium, NDF, Crude Fibre, Fat as well as M.E. (MCal/kg) and Calcium:Phosphorus Ratio in the Commercial (C), Fibre + Feed-Grade calcium propionate (F) and Fibre + Purified calcium propionate (P) diets during the Starter and Grower periods.

	C	F	P
Moisture (%)			
Starter	9.03	9.24	6.73
Grower 1	9.98	11.25	9.55
Grower 2	8.26	8.58	8.11
Protein (%)			
Starter	17.07	16.06	12.02
Grower 1	15.65	14.72	9.72
Grower 2	14.92	12.84	12.63
Ca:P[1] Ratio			
Starter	1.72	1.95	2.26
Grower 1	1.93	1.95	1.70
Grower 2	1.06	2.70	2.65
Calcium (%)			
Starter	1.31	1.09	1.22
Grower 1	1.62	1.06	0.87
Grower 2	0.87	1.51	1.36
NDF[2] (%)			
Starter	11.31	26.48	28.93
Grower 1	11.17	26.81	24.42
Grower 2	12.93	29.84	43.35
Crude Fibre (%)			
Starter	3.87	12.97	14.06
Grower 1	3.28	14.42	10.89
Grower 2	3.25	15.04	14.80
Fat (%)			
Starter	2.62	1.46	1.92
Grower 1	2.43	1.64	2.47
Grower 2	2.89	1.48	1.87
M.E.[3] (MCal/kg)			
Starter	2.48	1.89	1.81
Grower 1	2.48	1.68	2.03
Grower 2	2.68	1.78	1.76

[1] Ca:P, Calcium to Phosphorus ratio
[2] NDF, neutral detergent fibre
[3] M.E., metabolizable energy

Table 4. 3 Feather scoring scheme adapted from Bilick & Keeling (1999); LaBrash & Scheideler (2005); Bright et al. (2006).

Score	**Description**
0	Completely covered
1	Slight damage – wet, broken feathers, up to 10% of feathers missing from a given area
2	10-50% of feathers missing from a given area (no blood or tissue damage)
3	>50% of feathers missing from a given area (no blood or tissue damage)
4	10-50% of feathers missing from a given area **including** blood or tissue damage
5	>50% of feathers missing from a given area **including** blood or tissue damage

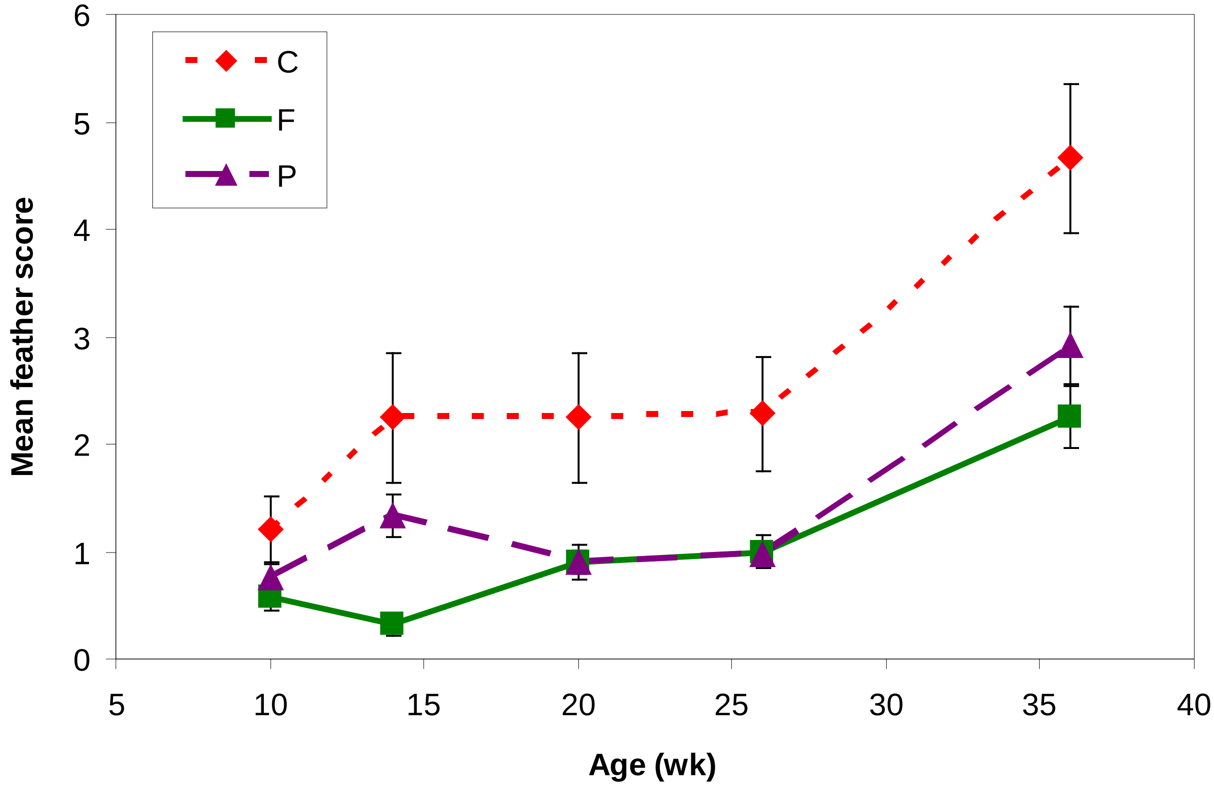

Figure 4. 1 Effect of diet type (commercial, C; feed-grade CaP + fibre, F; purified CaP + fibre, P) and time on mean feather scores (raw mean ± pooled SEM), Diet x Time interaction, *P* = 0.0007. Higher feather scores denote worse feather condition (Table 4.3).

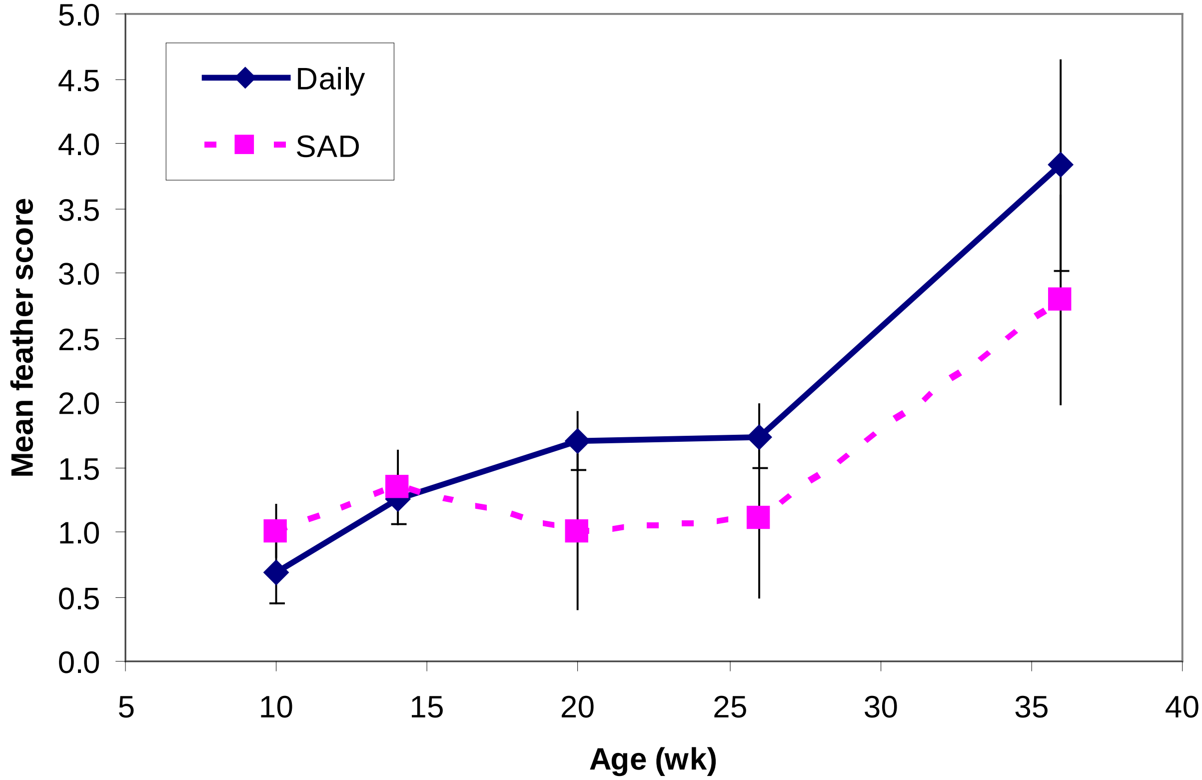

Figure 4. 2 Effect of feeding frequency (daily or skip-a-day, SAD) and time on mean feather scores (raw mean ± pooled SEM), Feeding Frequency x Time interaction, *P* = 0.0150.

CHAPTER 5: USING A Y-MAZE TEST TO ASSESS WHETHER BROILER BREEDER HENS PREFER A QUANTITAVELY OR QUALITATIVELY RESTRICTIVE DIET [3]

5.1 ABSTRACT

Broiler chickens grow extremely quickly, rendering the breeding stock incapable of maintaining healthy body weights when fed *ad-libitum* during rearing. As a result, broiler breeders are severely feed restricted, commonly causing stereotypic behaviour indicative of chronic hunger. Alternative diets reduce stereotypic behaviour, but it is unclear if broiler breeders find the bulking and appetite suppressing ingredients used in these diets aversive. This study investigated preferences of broiler breeder females given the choice between quantitatively (control, C) or qualitatively restrictive (F) diets. In addition, preference between 2 alternative diets, with different sources of the same appetite suppressing chemical (feed-grade calcium propionate (CaP) vs. purified CaP (P)) were assessed using 12 immature cockerels. Both F diet consisted of the control diet diluted with 40% soybean hulls and 1-5% CaP. Thirty-seven pullets were tested. To control for the effects of rearing diet, 17 were reared on the C diet and 20 were reared on F. Females were trained to associate each diet with a feeder colour (blue or red) and location (left or right). All diet/colour/location combinations were tested. Males were given free access to both the F and P diets in a closed economy two pan choice test over 4 d. Following 4 d of training, each pullet was tested over 4 d using a closed economy Y-maze. Data were analyzed using a mixed model (SAS 9.2), Chi Square and Fisher's Exact tests (R 2.9.2). Overall, no dietary preference was revealed, indicating that broiler breeders do not find fibre dilution and

[3] A paper based on this chapter will be submitted to *Animal Welfare* for publication.

appetite suppressant to be aversive. We also found little differences regarding the sensory properties of the F or P diets. There was an effect of rearing diet on colour choice ($P = 0.039$), as F-reared birds chose the red feeder more often than the blue feeder. This does not support our hypothesis that opportunities to eat more would be preferred. However, on an individual basis, 17 pullets were consistent in their choice of diet/colour/location combination over all 4 testing periods. Seven others were consistent on tests 2 through 4. This suggests that some birds have preferences, but are quite individual. Alternatively, the training regime may not have been sufficient to allow birds to learn the association between the diets and their satiating properties.

5.2 INTRODUCTION

Modern broiler chickens have been, and continue to be, genetically selected for extremely quick growth. Currently, broilers can reach market weight in less than 6 wk, with this time frame shortening with every new generation (Rauw et al., 1998; Renema & Robinson, 2004). This genetic selection for increased weight gain and muscle deposition is coupled with huge appetites to meet the demands of such rapid growth. As broilers are fed on an *ad-libitum* basis, the ability to eat to satiety is not a welfare concern. However, for the parent generation ("broiler breeders"), *ad-libitum* feeding is detrimental to their health, since it leads to obesity and to increased risks of lameness, ascites, premature death and poor reproductive success (Mench, 2002; de Jong & Guémené, 2011). As a result, it is common practice to feed-restrict broiler breeders to ensure they can maintain optimal health and productivity. However, restricted feeding negatively impacts the welfare of broiler breeders as they are generally fed only 25-35% of what they would eat given free choice (Savory et al., 1993; Ross Breeder Manual, 2007). At the peak of restriction, these birds can consume their daily ration in less than 10 min and afterwards are still highly motivated to feed immediately following feed intake (Savory et al., 1993). This severe feed restriction leads to chronic hunger and associated behavioural symptoms such as excessive drinking, increased aggression and activity levels, increased pecking at non-food objects and increased feather pecking (Duncan & Wood-Gush, 1972; Sandilands et al., 2006; de Jong & Guémené 2011).

Attempts at reducing hunger, while maintaining healthy body weights in broiler breeders, have largely focused on altering the contents of the diet (Savory et al., 1996; Sandilands et al., 2005; Tolkamp et al., 2005; Sandilands et al., 2006) or feeding schedule (de Jong et al., 2005b). Some of the more effective dietary alterations include diluting a commercial diet with non-nutritive fibre sources, such as oat hulls (Savory & Lariviere, 2000; Sandilands et al., 2005; Tolkamp et al., 2005; Sandilands et al., 2006), sugar-beet pulp and softwood sawdust (Savory et al., 1996). There has also been some indication that including an appetite suppressant (such as calcium propionate), alone or in combination with fibrous fillers, is effective at reducing some of the negative behavioural indicators associated with hunger (Savory et al., 1996; Sandilands et al., 2005; Sandilands et al., 2006). While the behavioural impacts of feed restriction have been widely investigated, very little research has focused on whether there is a preference for or an aversion to the alternative diets. If broiler breeders find the diets aversive, this may negatively impact their welfare, essentially swapping one welfare problem for another.

It has been shown that feed restricted sows prefer a concentrated diet over a high fibre diet when given the choice (Guillemet et al., 2007). However, that study only revealed differences in palatability, and did not address whether sows could discriminate the differences in the satiating properties of the diets. When given free choice, broiler chickens have been shown to consume diets or a combination of diets that most closely contain the optimum protein and energy content (Shariatmadari & Forbes, 1993; Siegel et al., 1997). However, the studies that have looked at dietary preferences do not account for animals that are feed restricted and may weigh certain characteristics of the feed differently than animals fed *ad-libitum*. Aspects that benefit the animals in the long term (ie. level of satiety) may be more important for a chronically hungry animal than short-term effects such as palatability. Very few studies involving alternative diets for broiler breeders have investigated the birds' dietary preferences. Savory et al. (1996) found that the majority of birds reared on both a commercial mash and a diet with 50 g/kg calcium propionate inclusion preferred the commercial mash when given a choice. Buckley et al. (2011a) conducted similar experiments and they were able to replicate the findings of Savory et al. (1996). Buckley et al. (2011a) also compared a commercial control diet to a diet diluted with 300 g/kg oat hulls and found no preference between the 2 diets. However, there has been no data indicating whether hungry broiler breeders have a preference for diets with both fibre dilution and an appetite suppressant. Therefore the goal of this study was to determine if feed restricted broiler breeder hens had a preference for a quantitatively restricted diet (commercial control diet, C) or a qualitatively restricted diet (F) that included a fibre source and an appetite suppressant. It was hypothesized that feed-restricted broiler breeder hens would prefer the F diet as it allowed the opportunity to eat a larger volume of feed.

5.3 MATERIALS AND METHODS

All of the procedures used in this experiment were approved by the University of Guelph's Animal Care Committee and were in accordance with the guidelines outlined by the Canadian Council for Animal Care.

5.3.1 Birds

One-day-old Ross 708 broiler breeder females (n=47) and males (n=12) were donated (courtesy of Aviagen, via Horizon Poultry, Alabama, USA) for this experiment. All birds were hatched in Huntsville, Alabama, USA and transported for rearing at the OMAFRA Arkell Poultry Research Station (Guelph, ON, Canada). All of the birds were vaccinated against local diseases in accordance with the research farm's vaccination protocol. All birds were beak trimmed at 1 d of age at the hatchery using an infrared beam in order to minimize damage caused by feather pecking. All birds were reared according to the programs outlined by the breeding company (Aviagen, 2007). For the first 3 d of life, birds were housed with a lighting regime of 23L:1D at 20 lux. From then on the lighting schedule was as follows: 12L:12D (20 lux) from d 4-21 and 8L:16D (4-7 lux) from d 22 to wk 22. Producer recommendations for heating were followed with a gradual reduction in heating (from 32°C on d 1 to 21°C on d 42, Aviagen 2007). Chicks were provided with a heated mat up until 1 wk of age.

Upon arrival to the research farm, females were randomly allocated (3 groups of 12 and 1 of 11) to 1 of 4 identical pens (1.83 x 2.36 m) and assigned to 1 of 2 treatments (see *5.3.2.1 Dietary Treatments*). The males were housed in 4 pens (3 per pen), among a larger group of males used for Chapter 3 & 4 and were fed a standard commercial crumble. Pen set-up and design were identical to those outlined in Chapter 3.

Birds were wing-banded with small numbered metal clips at 5 wk of age. Birds were weighed weekly to track growth on a per pen basis up until the time of wing-banding, then individually after that.

Prior to training, 3 females were euthanized. Two of the birds were from the F treatment and were euthanized on d 2 and 3 for health reasons. These birds were both replaced with extra birds. At 9 wk of age, 1 bird from the C treatment was euthanized for health reasons.

5.3.2 Experimental Protocol

5.3.2.1 Dietary Treatments

Upon arrival at the research facility, the female chicks were randomly allocated to 1 of 2 dietary treatments. Each treatment had 2 replicate pens. Females in the control treatment (C) were reared on a commercial crumble and birds in the alternative treatment (F) were reared on a fibrous alternative crumble, incorporating 40 g/kg soybean hulls and 1-5 g/kg calcium propionate (increasing with age). However, for the first 14 d, all birds were fed a commercial chick starter diet (Crude Protein = 17.7%). All birds were fed daily following lights-on at 08:00. Following breeder recommendations, all birds were fed on an *ad-libitum* basis from d 1-7 and were subsequently feed-restricted from d 8 onwards. Both experimental diets were formulated according to age of the bird: Starter crumble from 0-6 wk, Grower 1 crumble from 6-12 wk, Grower 2 crumble from 12-22 wk (see Table 5.1 for diet composition). Diets were analyzed for composition (Agrifood Laboratories, Guelph, ON, Canada).

At d 15, birds in the F treatment were switched from the commercial starter crumble to the alternative starter diet. Birds in the F treatment were allocated a larger volume of feed per day due to the fibrous dilution and inclusion of calcium propionate in this diet (Table 5.2).

5.3.2.2 Y-Maze Test Training

Starting at 11 wk, birds were trained to associate a feeder colour (red or blue) and a location within the pen (right or left) with a feed type (C or F). All of the possible colour/location/feed type combinations were represented (Table 5.3). Each pen contained 3 birds per training combination (2 pens each had 1 group with only 2 birds). During training, only 1 of the feeders was present in order to strengthen an association between the external characteristics of the feeder (colour and location) and the post-ingestive feedback from the different feed types. In their specific groups of 2 or 3, birds were moved into training pens at 15:00 the day prior to training days. The group remained in the training pen with the feeder overnight and were fed the corresponding diet the next morning. The birds were allowed to eat their daily allocation and were left undisturbed for approximately 3 h. These birds were then returned to their home pen. On the next training day, the same group of birds would be presented with the opposite colour/location/feed type combination. The birds experienced each colour/location/feed type combination twice, and so were in the training pens a total of 4 times each. The training period spanned just over 5 wk, with approximately 1-wk intervals between each group's training sessions.

5.3.2.3 Y-Maze Testing

Prior to testing, each pen was standardized to 10 birds per pen by euthanizing 1 or 2 of the smallest birds. During the testing period, 3 birds (from C treatment) were withdrawn from the experiment due to injury or testing error, leaving a total of 37 birds (Table 5.4). Any data collected from these birds prior to their elimination was excluded from the analysis.

Testing began at 17 wk, after training concluded. Unlike the training sessions, all birds were tested individually. The same pens that were used for training were used for testing, except that during testing, both colour/location/feed type combinations were available to the bird. For the testing session, each bird was removed from the home pen before feeding in the morning. The bird was then placed at the front of a testing pen equidistant to both feeders. The birds were allowed to choose a feeder, both containing their daily feed allocation. The bird was deemed to have made a "choice" as soon as its beak touched the feed. This choice was recorded. Once the bird had made a choice, a large piece of plywood was placed across the pen, in order to prevent the bird from accessing the other feeder. Before being brought back to their home pens, each bird was allowed to finish their entire meal (approximately 20 min). It was also necessary to ensure that the birds not being tested that day were finished feeding before the tested birds were brought back. Each bird was tested on 4 separate d, with approximately 1 wk between sessions.

5.3.2.4 Two Pan Choice Test

Twelve males were used to test taste differences between 2 alternative diets, only differing in the source and purity of the appetite suppressing chemical. The F diet (discussed above) was compared to the P diet, containing similar amounts of SBH and CaP, except that a purified quality of CaP (see previous chapters) was used.

Prior to testing, all males were wing banded and fed a standard commercial crumble (C) and were naive to both the F and P diets. At 11 wk of age, males were tested individually on 4 different days. During testing, each male was removed from its home pen and placed within the testing pen. Testing pens contained 2 identical round galvanized metal pan feeders, 1 containing a daily ration of the F diet and the other containing a daily ration of the P diet. Males were placed within the testing pen at 08:00 and were expected to consume their daily ration within the testing pen. Birds were replaced in their home pen after 30 min and each feeder was weighed to determine the amount eaten. Video cameras were used to determine the length of time spent at each feeder during each test. The location (left or right) of each diet type was switched between each of the 4 testing periods for each bird so any side bias was accounted for.

5.3.3 Data Analysis

The statistical analyses were performed using the SAS and R statistical analysis packages (SAS 9.2, 2007; R 2.9.2, 2009). Data were compiled over the 4 testing sessions and were analyzed as a whole, including all birds that were tested. In addition, a bird was considered 'consistent' if, on the last 3 (or all) testing sessions, they chose the same option. In SAS, data were transformed by taking the arcsine of the square root of the proportion of times each bird chose either option for Diet Type, Colour or Location. Data were analysed using a PROC MIXED procedure with Rearing Diet and Training Combo as main factors. Repeated measures were accounted for with Pen nested within Rearing Diet. Fisher's Exact tests were also used to analyze Rearing Diet effects on choices for Colour, Location and Diet Type made by the 24 consistent birds. For comparing overall proportions, Chi Square tests were used. Raw means are reported in the text, tables and figures.

5.3.3.1 Two Pan Choice Test

Chi Square tests in the R statistical package were used to analyze the average percent of each diet type eaten by each cockerel over all 4 testing d and the average amount of time spent at the first feeder by diet type.

5.4 RESULTS

5.4.1 Diet Choice

For all 37 birds tested, there was no effect of Rearing Diet (P = 0.988), Training Combination (P = 0.256) nor an interaction (P = 0.292) between the two on choice of Diet Type. There was also no significant difference in proportion of times either diet was chosen (P = 0.461). The proportion of times the birds chose the "novel" diet (ie. F diet chosen by the birds reared on the C diet and the C diet by the birds reared on the F diet) over their home pen diet did not differ either (*P* = 0.479).

5.4.2.1 Two Pan Choice Test

On average, more time was spent at the first feeder when it contained the F diet (*P* = 0.0321, 277.1 sec for F vs. 228.9 sec for the P diet). However, there was no difference between the amount of each diet eaten by each cockerel over all 4 testing d (*P* = 0.6745, 47.9% for the F diet vs. 52.1 % for the P diet).

5.4.2 Colour Choice

There was no effect of Training Combination (*P* = 0.342) nor an interaction between Rearing Diet and Training Combination (*P* = 0.926) on choice of Colour. However, there was an effect of Rearing Diet on Colour choice (Figure 5.1, *P* = 0.039). The birds reared with the F diet chose the red feeder more often than they chose the blue feeder and more often than the C reared birds chose the red feeder. When analyzed as 4 separate days, differences were found on the first (Figure 5.2, $P < 0.0001$), second (*P* = 0.019) and fourth day (*P* = 0.019). However, on the third testing day, there was no significant effect of Rearing Diet on Colour choice (*P* = 0.333). The C-reared birds showed no overall colour preference (P = 0.279). There was no interaction between Colour and Diet choice for all 37 birds (Fisher's Exact, *P* = 0.981) or for those birds who chose red more often (*P* = 0.789).

5.4.3 Location Choice

For all 37 birds tested, there was no effect of Rearing Diet (*P* = 0.839), Training Combination (*P* = 0.346) nor an interaction (*P* = 0.502) between Rearing Diet and Training Combination on Location choice.

5.4.4 Consistent Birds

Of the 37 birds tested, 24 of these were classified as being 'consistent'. Seventeen of these birds chose consistently for all 4 testing sessions and 7 additional birds were consistent in their 2^{nd}, 3^{rd} and 4^{th} testing sessions. There was a trend toward significance (*P* = 0.059) for Diet Choice of the 7 birds that were consistent over the last 3 sessions; 6 of the 7 switched from choosing C in the first testing session to choosing F for the rest of the sessions. Of all the consistent birds, 10 of them chose the C diet and 14 of them chose the F diet, which was not statistically significant (*P* = 0.414). Similar to the results for all 37 birds, there was no difference (*P* = 0.682) between the numbers of times the novel diet was chosen over the home pen diet. There was no effect of Rearing Diet (*P* = 0.30) on choice of Diet Type (Figure 4.3). Rearing Diet also had no effect on the choice of Colour (*P* = 0.10) or Location (*P* = 0.32).

5.5 DISCUSSION

The aim of this study was to identify if hungry broiler breeder hens could distinguish the difference in satiating properties of 2 diets and if there was a dietary preference. We also aimed at determining a preference for or against 2 alternative diets based on their sensory properties.

As a group, the females showed no preference for either diet (C vs. F) regardless of the diet type with which they were reared. However, even though the data did not support our hypothesis, a lack of preference for the C diet could mean that the birds did not find the F diet aversive. Similar results have also been reported elsewhere (Buckley et al., 2011a; Buckley et al., 2011b). Both Buckley et al. (2011a) and Savory et al. (1996) showed that birds preferred control diets in comparison to a diet containing CaP, but this preference was not exclusive. However, no preferences were evident in a choice test between a control and a high-fibre diet

(Buckley et al., 2011a). There are a number of possible reasons why no dietary preferences were revealed.

It is hard to determine whether the birds learned the task presented to them. The birds were expected to associate a colour primarily and a location secondarily with a certain type of feed, as has been done previously (Buckley et al., 2011a). This being said, the birds were also expected to be able to distinguish a difference in the satiating properties of the 2 diet types. It would seem that this should be possible to accomplish since the diet types affected behaviour presented in previous chapters. However, it may be that the amount of training these birds received was insufficient to create a link between the diet's satiating ability and its corresponding feeder's visual characteristics. During each training session, the birds spent approximately 3 h in the training pen with the feeder after feeding. It has been suggested that the physical limitations of the upper digestive tract are responsible for mediating short-term satiety (Richardson, 1970; Savory & Smith, 1987). Therefore, it is likely that 3 h should have been long enough for the birds to feel the satiating effects of each diet type while still in visual contact with the associated feeder. The birds were expected to be capable of choosing between a more energy dense and assumedly more palatable diet versus a more filling but perhaps less palatable diet. Therefore, there were two different characteristics of the feed that the chickens needed to assess – satiation and taste. Had there been a preferred diet, it would be difficult to determine which aspect the birds found more important. However, because there was no preference, it may be possible that there were not enough training sessions and the birds were still in the process of learning the differences between the feeds and the corresponding feeders' characteristics. Alternatively, due to the increased genetic selection for fast growth and huge appetites, it may be that the satiating mechanisms in these chickens are impaired (Bokkers &

Koene, 2003). This could mean the birds have no way in which to tell the difference between the satiating properties of the 2 diets, resulting in only palatability affecting their preferences.

It is possible that the consistent birds represent those that did learn the task. Based on chance alone, only 5 of the 37 birds should have been 'consistent'. Therefore, perhaps the consistent birds had learned, but no group preference was elicited. It is also possible that these birds were consistently basing their choices on a colour or location preference. They could also have chosen randomly for the first testing session and then maintained their choice throughout the rest of the sessions. It has been suggested that chickens show low levels of spontaneous alternation behaviour (Hughes, 1989; Haskell et al., 1998), which could mean that once a bird has initially chosen a feeder, its future choices will become more rigid and inflexible over time. It is arguable that this species characteristic might make two-choice preference testing useless and difficult to analyze. However, this cannot account for the 7 birds that switched from their initial choice on the first testing session and were consistent for the 2nd through 4th testing sessions. Therefore, it may be more likely that these 7 birds were the ones that learned the task. Of these 7 birds, 6 of them switched from choosing C the first time to F for the next 3 sessions. This may indicate that the F diet was more preferred by those birds that actually learned the task.

Hunger can be a positive motivator as well as a negative stressor (D'Eath et al., 2009). It may be that broiler breeder hens are too hungry for the level of learning required by the present task. It has been suggested that preference tests that involve choosing between 2 positive outcomes or rewards (food, in this experiment) are harder to learn than tasks that involve 1 non-rewarded option (Buckley et al., 2011a). Buckley et al. (2011a) were able to teach broiler breeders to consistently pick a food option in a food vs. no food task but not able to teach them to differentiate between different meal sizes using the same training and testing methodology.

Birds reared on the F diet chose the red feeders more often than they chose the blue feeders. Ham & Osorio (2007) indicated that colours in the orange-red hue range are generally preferred in domestic poultry. There is also some indication that blue and violet hues may be equally preferred, but sometimes are avoided in favour of orange and red hues (see review in Ham & Osorio, 2007). This might explain why the birds in the F diet preferred the red feeder. However, we would predict the same preference from the C birds, but this was not the case as there was no colour preference within this group of birds. Although, because F birds drank more often than the C birds (see Chapter 3), an affinity for red may have developed, as part of the nipple drinker was red.

Although the males remained at the first feeder they choice for longer when it contained the F diet, there was no difference in the total proportion consumed of each diet. This may indicate a slight difference sensory properties of the diets as the males were more likely to leave the feeder earlier when eating the diet containing the purified CaP. However, there does not appear to be a lasting aversion to the P diet as it was eaten as much as the F diet was.

5.6 CONCLUSIONS

Welfare concerns over broiler breeders' level of chronic hunger has led researchers to develop alternative diets that reduce hunger-related stereotypic behaviour. These alternative diets include an appetite suppressant and high-fibre content, ingredients which may be aversive to the birds. We did not find a preference between the C and F diets, nor a lasting preference between the F and P diets. This may indicate that there is no specific aversion to the alternative diet, or that the task of choosing a preferred diet was not learned. Therefore, further studies using modified preference testing experimental designs are needed to identify the true dietary preference of broiler breeder hens.

Table 5. 1 Composition of diet (C, Commercial and F, Fibre & Feed-Grade calcium propioate) used in Starter (0 – 6 wk), Grower 1 (6 – 12 wk) and Grower 2 (12 – 22 wk) phases.

	C	F
Corn (%)		
Starter	60.6	35.8
Grower 1	60.8	36.0
Grower 2	60.8	35.2
Wheat Shorts (%)		
Starter	8.8	5.2
Grower 1	16.0	8.8
Grower 2	16.0	8.1
Soybean Meal (%)		
Starter	24.0	14.2
Grower 1	16.5	9.8
Grower 2	16.5	9.6
Limestone (%)		
Starter	3.14	1.3
Grower 1	3.13	0.65
Grower 2	3.13	N/A
Dicalcium Phosphorus (%)		
Starter	2.0	1.2
Grower 1	2.1	1.2
Grower 2	2.1	1.2
Salt (%)		
Starter	0.34	0.20
Grower 1	0.36	0.21
Grower 2	0.36	0.21
Vitamin-Mineral Premix (%)		
Starter	1.0	0.59
Grower 1	1.0	0.59
Grower 2	1.0	0.58
Methionine (%)		
Starter	0.12	0.07
Grower 1	0.11	0.06
Grower 2	0.11	0.06
Calcium Propionate (%)		
Starter	N/A	1.44
Grower 1	N/A	3.19
Grower 2	N/A	5.05
Soybean Hulls (%)		
Starter	N/A	40.0
Grower 1	N/A	39.5
Grower 2	N/A	40.0

Table 5. 2 Percent inclusion (as analyzed) for Moisture, Protein, Calcium, NDF, Crude Fibre, Fat as well as M.E. (MCal/kg) and Calcium:Phosphorus Ratio in the Commercial (C) & Fibre & Feed-Grade calcium propionate (F) diets during Starter (0 – 6 wk), Grower 1 (6 – 12 wk) and Grower 2 (12 – 22 wk) phases.

	C	F
Moisture (%)		
Starter	9.03	9.24
Grower 1	9.98	11.25
Grower 2	8.26	8.58
Protein (%)		
Starter	17.07	16.06
Grower 1	15.65	14.72
Grower 2	14.92	12.84
Ca:P[1] Ratio		
Starter	1.72	1.95
Grower 1	1.93	1.95
Grower 2	1.06	2.70
Calcium (%)		
Starter	1.31	1.09
Grower 1	1.62	1.06
Grower 2	0.87	1.51
NDF[2] (%)		
Starter	11.31	26.48
Grower 1	11.17	26.81
Grower 2	12.93	29.84
Crude Fibre (%)		
Starter	3.87	12.97
Grower 1	3.28	14.42
Grower 2	3.25	15.04
Fat (%)		
Starter	2.62	1.46
Grower 1	2.43	1.64
Grower 2	2.89	1.48
M.E.[3] (MCal/kg)		
Starter	2.48	1.89
Grower 1	2.48	1.68
Grower 2	2.68	1.78

[1] Ca:P, Calcium to Phosphorus ratio
[2] NDF, neutral detergent fibre
[3] M.E., metabolizable energy

Table 5. 3 Allocation of birds to testing combinations. All possible training and testing combinations and numbers of birds trained and tested for each based on Feed Type, Location (left/right) and Colour (red/blue) of the feeder (commercial (C) and fibre + feed-grade calcium propionate (F)).

	Location		**Number of birds trained**	**Number of birds tested**
	Right	**Left**		
Feed Type/Colour	C/Red	F/Blue	11	6
	C/Blue	F/Red	12	11
	F/Blue	C/Red	11	10
	F/Red	C/Blue	12	10

Table 5. 4 Number of birds placed at d 1, trained and tested per pen and treatment diet (commercial (C) and fibre + feed-grade calcium propionate (F)).

		Number of Birds		
Pen	**Rearing Diet**	**At placement**	**Trained**	**Tested**
A	C	11	11	9
B	C	12	11	8
C	F	12	11	10
D	F	12	11	10

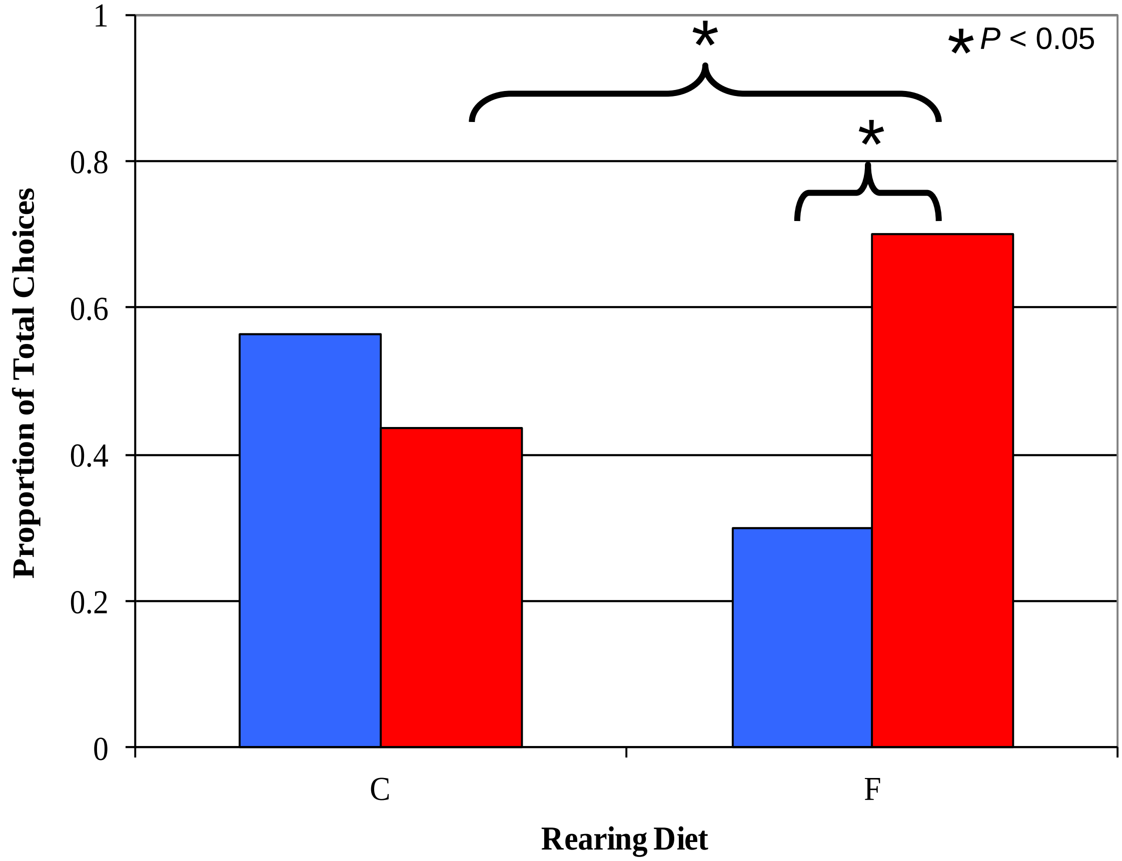

Figure 5. 1 Proportion of times (over all 4 testing sessions, for all 37 birds) each feeder colour (blue or red) was chosen, by rearing diet type (commercial (C) and fibre + feed grade calcium propionate (F)).

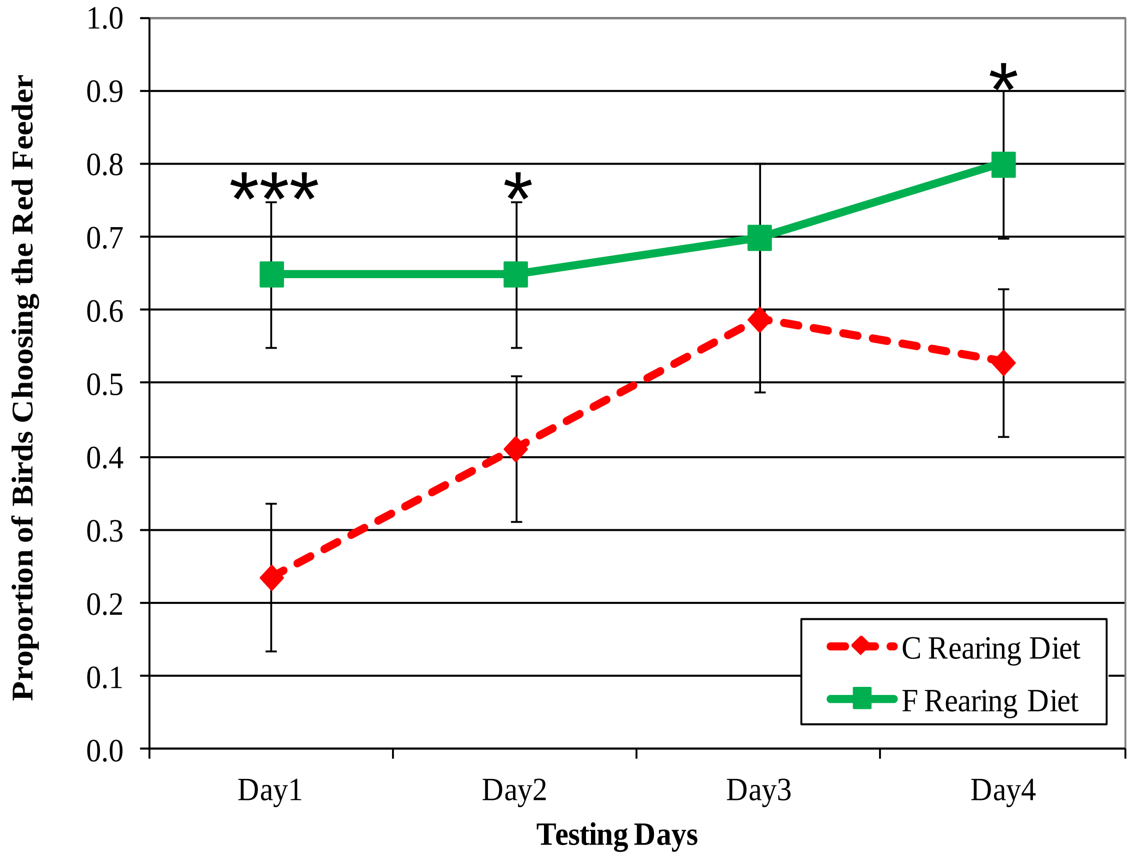

Figure 5. 2 Effect of rearing diet (commercial (C) or fibre + feed-grade calcium propionate (F)) and testing day on the proportion of all 37 birds that chose the red feeder.
*$P < 0.05$
***$P < 0.0001$

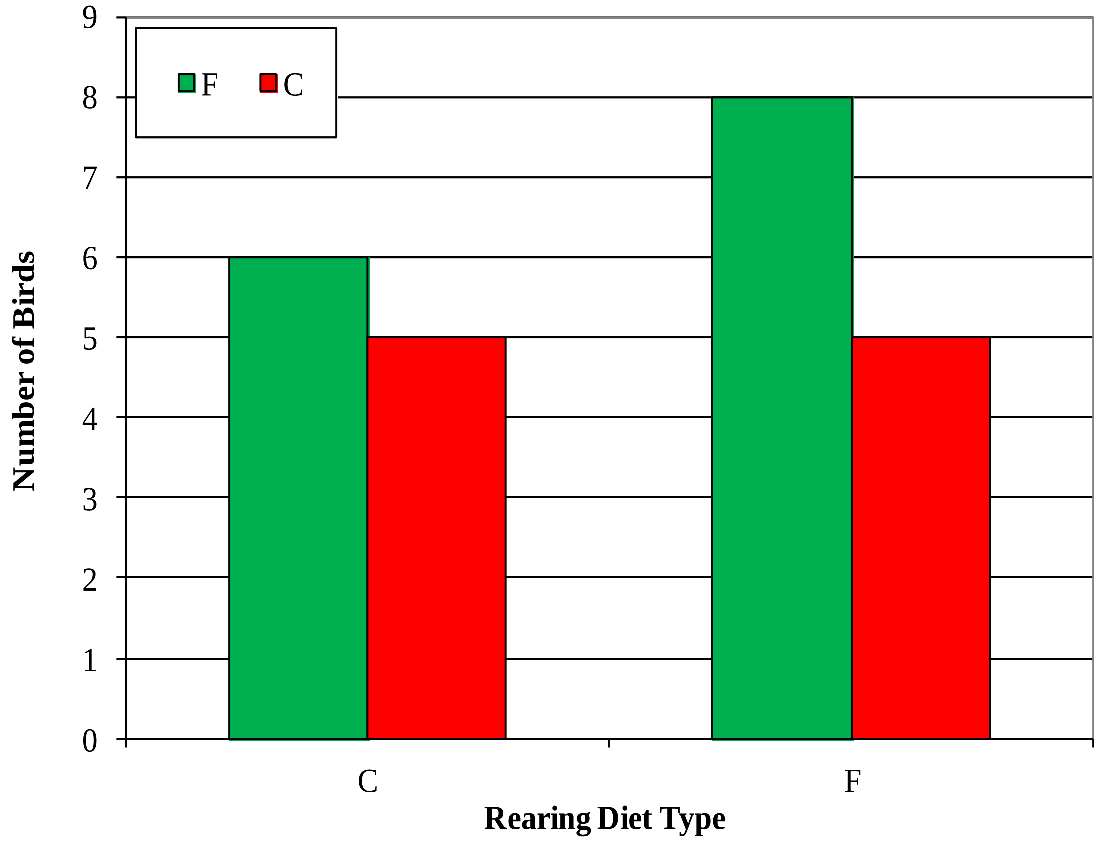

Figure 5. 3 Effect of rearing diet (commercial (C) or fibre + calcium propionate (F)) on the number of birds that consistently chose either the C or F diet (P = 0.30).

CHAPTER 6: DISCUSSION AND CONCLUSIONS

6.1 GENERAL DISCUSSION

The agricultural industry has been subjected to demands from consumers for more food at a lower cost. The meat chicken industry especially has undergone very rapid changes in genetics and nutrition to meet these demands. Birds that grow quickly, efficiently and have large breast muscle yield are being selected to propagate the genetic lines. Every year, growth rates increase, so much so that age at market weight is more than 15 days younger than in the 1960's (Rauw et al., 1998; Renema et al., 2007). Although feed efficiency has increased in the last 50 years, birds are still eating more than ever before due to huge appetites (Rauw et al., 1998; Renema et al., 2007), leading to major welfare concerns for any meat-type bird that is subjected to feed restriction.

Because broiler breeders are bred specifically to produce fast growing progeny, they have the same genetic potential to grow as quickly and efficiently as broilers. However, to ensure optimal health and productivity during rearing and into lay, broiler breeders must be severely feed restricted to limit excessive growth. As discussed in previous chapters, long term feed restriction leads to frustration, chronic hunger and associated behavioural problems, like stereotypic pecking. Attempts at alleviating these problems have included the use of alternative diet types with high levels of dietary diluents or appetite suppressants. By using such diets, the volume of feed rationed per day could be increased without increasing caloric intake. In addition, the inclusion of calcium propionate, acting as an appetite suppressant, reduces hunger levels without increasing feed allowance. The objectives of the research presented in this thesis were to demonstrate the efficacy of an alternative diet for reducing hunger and related behavioural problems. Previous research has indicated a welfare benefit with diets including a stable fibre source and increasing levels of an appetite suppressant (Sandilands et al., 2005; Sandilands et al., 2006), by almost entirely eliminating the occurrence of stereotypic behaviour. However, most of the research concerning hunger reduction techniques for broiler breeders has been carried out in the United Kingdom; the fibre source (oat hulls) may not be as commercially applicable in North America. For that reason, a more readily available fibre source (soybean hulls, SBH) was tested instead. In addition, differences in the efficacy of the source of CaP have been indicated in two studies (Savory et al., 1996; Savory & Lariviere, 2000). Therefore, we compared two alternative diets, both with 400 g/kg SBH inclusion. Along with the SBH, the first alternative diet (F) incorporated a feed-grade or industrial quality of CaP and the second (P) included a purified version. In addition, the two experimental diets, plus a control diet, were fed on either a daily or skip-a-day (SAD) basis, resulting in a total of six dietary treatments.

Overall, the data presented in this thesis support our hypothesis that both the alternative diets were more successful at reducing hunger than their control counterpart. Feather condition scores indicated that the F birds had the best feather condition, possibly due to less feather pecking behaviour. The behavioural data indicated that the F diet resulted in the greatest reduction in hunger as these birds feather-, object- and aggressively pecked the least and were less active than control birds. The P diet appeared to have some beneficial effects as well, although there may be some evidence that the P diet resulted in a feeling of malaise as these birds were observed standing and perching during feeding bouts more often than both the control and F birds. This may be a direct effect of either an increase in satiety or a reluctance to consume the P diet, indicating some level of feed aversion. Unfortunately, the P diet was not included in the preference test described in this study. Even though we did not find any overall preference for or avoidance of the F diet, this may not hold true in a P vs. control preference test. However, there was no preference between the F and P diet when we tested 12 immature cockerels in a closed economy preference test with continuous access to both alternative diet types, to compare palatability differences between the F and P diets (Chapter 5). We did not observe any differences in the volume of each type of feed eaten which negates the suggestion that the P diet may be aversive or cause malaise.

The behavioural benefits of a skip-a-day (SAD) feeding regime are less clear. Our original hypothesis had been that the SAD schedule would result in more hunger-related behaviour due to the lack of daily feedings. However, there may be some indication that it increased the feeling of satiety since resting (including standing/sitting and perching) was observed more frequently than with daily-fed birds. Based on the feather pecking results, there was an interaction between diet and feeding frequency on the efficacy of hunger reduction, as the majority of pecking was observed in the SAD-C birds, and the least in SAD-F and SAD-P birds. In addition, alternative SAD birds were less active than the control SAD or daily-fed birds and had better feather condition at 20 and 26 wk of age.

Therefore, to reduce hunger and the associated behaviour indicative of a poor state of welfare, diets that offer a large volume of feed containing an appetite suppressant should be fed to hungry broiler breeders. From the data presented here, even if the benefits of SAD are unclear, there is no indication that it had a negative impact on welfare, and use of this management tool can be left to the discretion of the producer. However, although the alternative diets resulted in increased satiety, there was still evidence of sustained hunger, indicated by the lack of eradication of stereotypic behaviour. It may be that the only way to eliminate hunger without increasing the risks of obesity, lies in altering the genetics of the bird. This may not be the responsibility of the producer or breeder, but instead, that of the educated consumer through their purchasing power. The relatively recent genetic changes causing increased appetites and growth rates in broilers resulted from consumer demands for large white meat portions (breast muscle) at ever decreasing costs. Therefore, change in the opposite direction will happen when the consumer demands it. Until then, however, any benefits granted to the birds via the implementation of alternative, high-fibre diets are the only option for bettering the welfare of the growing broiler breeder.

6.2 STUDY CONFOUNDS AND LIMITATIONS

Because birds were not individually identified and were weighed in groups until 8 wk of age, accurately comparing body weight uniformity is difficult. Additionally, birds that were noticeably smaller than the group mean were euthanized, resulting in less variability within the pen. Consequently, the body weight uniformity data presented here most likely cannot be compared to target or recommended levels based on breeder guidelines, and comparisons between treatment groups may not be entirely valid.

Optimal video data collection was inhibited by a limited number of security cameras. Because there were twice as many pens as cameras, one camera was split between two adjacent pens with only half of the pens being recorded per observation day. Because of this, 14 days of video data was combined into 7 Time Periods to create complete data sets for a more comprehensive statistical analysis. Because of this, Time Periods 1 – 3 recorded the same group of pens during the SAD on- and off-feed days, meaning on-feed days for pens A – C and off-feed days for pens D – E were recorded for the first three Time Periods. Therefore, there is a possibility that conclusions drawn from the behavioural data may only reflect certain pens and not the treatment. However, based on anecdotal evidence and casual live observations of these birds, the data presented here most likely represents true differences between treatments. Ideally though, having data from every pen on every day would provide a more complete and accurate dataset. Alternatively, more videos could have been analyzed and more evenly distributed in terms of day and Time Period breakdown. In addition, data from week 4 – 11 were lost due to human error. This may have been a critical adjustment period for the switch from daily to SAD feeding and the overall picture of the behaviour of SAD birds may be completely altered if this data had been included.

Due to lack of time and manpower, the training for the preference tests did not start until 11 wk of age. A lack of space and training pens resulted in very few birds being trained every day, and so the training period spanned a long period of time. In addition, 4 testing periods may have been insufficient to tease out a learned preference for one diet or the other. It is also arguable that because the broiler breeders were so hungry; they chose the first food option they saw, not basing their choice on learned experiences; as such, a two-choice closed economy test may be inappropriate.

6.3 FUTURE RESEARCH

As this study was the first of its kind in North America, further validation studies may be necessary, especially those using similar ingredients. Since body weight uniformity is of high importance in breeder flocks, individual identification will be a necessity in future broiler breeder work. Because choice and preference may more directly indicate the subjective states of the animal, a more appropriate and valid method of testing dietary preferences for hungry broiler breeders should be investigated.

It would be interesting to investigate what level of fibre inclusion broiler breeders would select to incorporate into their diet. By providing the fibre source in a crumble form, the diet is very homogeneous. In order to better understand dietary fibre needs, it may be beneficial to supply the fibre source separately and record at what inclusion level birds consume the fibre. This may also serve as a preference test of sorts, indicating what level of fibre inclusion the birds prefer.

6.4 PRODUCER RECOMMENDATIONS

Reducing hunger-related behaviour via high-fibre diets including an appetite suppressant may currently be the best way to improve welfare for growing broiler breeder females. Based on behavioural data, in combination with feather condition scores, the F alternative diet reduced symptoms of chronic hunger and appeared to have improved overall welfare for the birds. SAD feeding does not appear to negatively affect welfare from 11 wk onward and therefore may be used at the discretion of the producer.

LITERATURE CITED

Alleman, F. & LeClercq, B. (1997). Effect of dietary protein and environmental temperature on growth performance and water consumption of male broiler chickens. *British Poultry Science* **38:** 607—610

Baumeister, A.; Hawkins, W. F. & Cromwell, R. L. (1964). Need states and activity level. *Psychological Bulletin* **61(6):** 438—453

Bennett, C. D. & Leeson, S. (1989). Growth of broiler breeder pullets with skip-a-day versus daily feeding. *Poultry Science* **69(6):** 836—838

Bergeron, R.; Bolduc, J.; Ramonet, Y.; Meunier-Salauen, M. C. & Robert, S. (2000). Feeding motivation and stereotypies in pregnant sows fed increasing levels of fibre and/or food. *Applied Animal Behaviour Science* **70(1):** 27—40

Bilcik, B. & Keeling, L. J. (1999). Changing in feather condition in relation to feather pecking and aggressive behaviour in laying hens. *British Poultry Science* **40(4):** 444—451

Blokhuis, H. J. (1986). Feather-pecking in poultry: its relation with ground pecking. *Applied Animal Behaviour Science* **16(1):** 63—67

Blokhuis, H. J. & Arkes, J. G. (1984). Some observations on the development of feather-pecking in poultry. *Applied Animal Behaviour Science* **12:** 145—157

Bokkers, E. A. M. & Koene, P. (2003). Eating behaviour and preprandial and postprandial correlations in male broiler and layer chickens. *British Poultry Science* **44(4):** 538–44

Bokkers, E. A. M.; Koene, P.; Rodenburg, T. B.; Zimmerman, P. H. & Spruijt, B. M. (2004). Working for food under conditions of varying motivation in broilers. *Animal Behaviour* **68(1):** 105–113.

Bramwell, R. K.; Moyle, J. R.; Yoho, D. E. & Harper, B. S. (2008). Weighing broiler breeder females post-feeding. In The Poultry Site. Retrieved June 20, 2012, from http://www.thepoultrysite.com/articles/1111/weighing-broiler-breeder-females-postfeeding

Bright, A.; Jones, T. A. & Dawkins, M. S. (2006). A non-intrusive method of assessing plumage condition in commercial flocks of laying hens. *Animal Welfare* **15(2):** 113—118

Brouns, F.; Edwards, S. A. & English, P. R. (1994). Effect of dietary fibre and feeding system on activity and oral behaviour of group housed gilts. *Applied Animal Behaviour Science* **39:** 215—223

Buckley, L. A.; Mcmillan, L. M.; Sandilands, V.; Tolkamp, B. J.; Hocking, P. M. & Eath, R. B. D. (2011a). Too hungry to learn? Hungry broiler breeders fail to learn a Y-maze food quantity discrimination task. *Animal Welfare* **20:** 469–481.

Buckley, L. A.; Sandilands, V.; Tolkamp, B. J. & D'Eath, R. B. (2011b). Quantifying hungry broiler breeder dietary preferences using a closed economy T-maze task. *Applied Animal Behaviour Science* **133:** 216–227

Burkhart, C. A.; Cherry, J. A.; van Krey, H. P. & Siegel, P. B. (1983). Genetic selection for growth rate alters hypothalamic satiety mechanisms in chickens. *Behavior Genetics* **13(3):** 295—300

Clifton, P. (1979). Temporal patterns of feeding in the domestic chick. I. Ad libitum. *Animal Behaviour* **27:** 811–820

Collias, N. E. (1952). The development of social behavior in birds. *The Auk* **69:** 127—159

Cooper, J. J. (2004). Consumer demand under commercial husbandry conditions: practical advice on measuring behavioural priorities in captive animals. *Animal Welfare* **13:** 47—56

Dawkins, M. S. (1989). Time budgets in red junglefowl as a baseline for the assessment of welfare in domestic fowl. *Applied Animal Behaviour Science* **24:** 77–80.

Dawkins, M. S. (1998). Evolution and animal welfare. *The Quarterly Review of Biology* **73(3):** 305–328

Dawkins, M. S. & Layton, R. (2012). Breeding for better welfare: genetic goals for broiler chickens and their parents. *Animal Welfare* **21(2):** 147–155

de Beer, M. & Coon, C. N. (2007). The effect of different feed restriction programs on reproductive performance, efficiency, frame size and uniformity in broiler breeder hens. *Poultry Science* **86(9):** 1927–39

de Castro, J. M. & Balagura, S. (1975). Relationship between endogenous, natural feeding patterns and body composition in the rat. *Physiology & Behavior* **15(6):** 635–9

de Jong, I. C.; Enting, L. H.; van Voorst, A. & Blokhuis, H. J. (2005a). Do low-density diets improve broiler breeder welfare during rearing and laying? *Poultry Science* **84(2):** 194–203

de Jong, I. C.; Fillerup, M. & Blokhuis, H. J. (2005b). Effect of scattered feeding and feeding twice a day during rearing on indicators of hunger and frustration in broiler breeders. *Applied Animal Behaviour Science* **92:** 61–76 de Jong, I. C. & Guémené, D. (2011). Major welfare issues in broiler breeders. *World's Poultry Science Journal* **67:** 73—82

de Jong, I. C.; van Voorst, A. S. & Blokhuis, H. J. (2003). Parameters for quantification of hunger in broiler breeders. *Physiology & Behavior* **78(4-5):** 773–783

de Jong, I. C.; Van Voorst, S.; Ehlhardt, D. A. & Blokhuis, H. J. (2002). Effects of restricted feeding on physiological stress parameters in growing broiler breeders. *British Poultry Science* **43:** 157—168

DEFRA. (2007). Schedule 1: General conditions under which farmed animals must be kept. In The Welfare of Farmed Animals (England) Regulations 2007. Retrieved May 5, 2012, from www.legislation.gov.uk/uksi/2007/2078/schedule/1/made

Denbow, D. M. (1989). Peripheral and central control of food intake. *Poultry Science* **68(7):** 938—947

Denbow, D. M. (1994). Peripheral regulation of food intake in poultry. *Journal of Nutrition* **124:** 1349—1354

Dixon, L. M. (2008). Feather pecking behavior and associated welfare issues in laying hens. *Avian Biology Research* **1(2):** 73–87

Dixon, L. M.; Duncan, I. J. H. & Mason, G. (2008). What's in a peck? Using fixed action pattern morphology to identify the motivational basis of abnormal feather-pecking behaviour. *Animal Behaviour* **76:** 1035–1042

Douglas, M. W.; Cunnick, J. E.; Pekas, J. C.; Zimmerman, D. R. & von Borell, E. H. (1998). Impact of feeding regimen on behavioral and physiological indicators for feeding motivation and satiety, immune function, and performance of gestating sows. *Journal of Animal Science* **76:** 2589—2595

Duncan, I.J.H.; Horne, A. R.; Hughes, B. O. & Wood-Gush, D. G. M. (1970). The pattern of food intake in female Brown Leghorn fowls as recorded in a Skinner box. *Animal Behaviour* **18:** 245–255.

Duncan, I. J. H. & Petherick, J. C. (1991). The implications of cognitive processes for animal welfare. *Journal of Animal Science* **69:** 5017–5022

Duncan, I. J. H. & Wood-Gush, D. G. (1971). Frustration and aggression in the domestic fowl. *Animal Behaviour* **19(3):** 500—504

Duncan, I. J. H. & Wood-Gush, D. G. (1972). Thwarting of feeding behaviour in the domestic fowl. *Animal Behaviour* **20(3):** 444–51

D'Eath, R. B.; Tolkamp, B. J.; Kyriazakis, I. & Lawrence, A. B. (2009). "Freedom from hunger" and preventing obesity: the animal welfare implications of reducing food quantity or quality. *Animal Behaviour* **77(2):** 275–288

Forbes, J. M. & Kyriazakis, I. (1995). Food preferences in farm animals: why don't they always choose wisely? *The Proceedings of the Nutrition Society* **54(2):** 429–40

Glatz, P. C. (2002). Claw abrasives in layer cages: A review. *International Journal of Poultry Science* **1(1):** 1–5

Guillemet, R.; Comyn, S.; Dourmad, J.-Y. & Meunier-Salaün, M.-C. (2007). Gestating sows prefer concentrate diets to high-fibre diet in two-choice tests. *Applied Animal Behaviour Science* **108:** 251–262

Ham, A. D. & Osorio, D. (2007). Colour preferences and colour vision in poultry chicks. *Proceedings of the Royal Society of London* **274(1621):** 1941—1948

Harlander-Matauschek, A.; Piepho H. P. & Bessei, W. (2006). The effect of feather eating on feed passage in laying hens. *Poultry Science* **85:** 21—25

Harlander-Matauschek, A.; Wassermann, F.: Zentek, J. & Bessei, W. (2008). Laying hens learn to avoid feathers. *Poultry Science* **87(9):** 1720–4

Haskell, M.; Forkman, B. & Waddington, D. (1998). An investigation into the occurrence of spontaneous alternation behaviour in the domestic hen. *Behavioural Processes* **43(1):** 43–51

Hetland, H.; Choct, M. & Svihus, B. (2004). Role of insoluble non-starch polysaccharides in poultry nutrition. *World's Poultry Science Journa*l **60(4):** 415–422

Hetland, H.; Svihus, B. & Krogdahl, A. (2003). Effects of oat hulls and wood shavings on digestion in broilers and layers fed diets based on whole or ground wheat. *British Poultry Science* **44(2):** 275–82

Hocking, P M. (1993). Welfare of broiler breeder and layer females subjected to food and water control during rearing : Quantifying the degree of restriction. *British Poultry Science* **34(1):** 37–41.

Hocking, P. M.; Hughes, B. O. & Keer-Keer, S. (1997). Comparison of food intake, rate of consumption, pecking activity and behaviour in layer and broiler breeder males. *British Poultry Science* **38(3):** 237–40

Hocking, P. M.; Maxwell, M. H. & Mitchell, M. A. (1996). Relationships between the degree of food restriction and welfare indices in broiler breeder females. *British Poultry Science* **37(2):** 263—278

Hocking, P.M.; Zaczek, V.; Jones, E. K. M. & Macleod, M. G. (2004). Different concentrations and sources of dietary fibre may improve the welfare of female broiler breeders. *British Poultry Science* **45(1):** 9–19

Hogan, J. A. (1971). The development of a hunger system in young chicks. *Behaviour* **39:** 128—201

Howie, J. A.; Tolkamp, B. J.; Avendano, S. & Kryiazakis, I. (2009). The structure of feeding behavior in commercial broiler lines selected for different growth rates. *Poultry Science* **88:** 1143—1150

Hughes, B. O. & Duncan, I. J. H. (1972). The influence of strain and environmental factors upon feather pecking and cannibalism in fowls. *British Poultry Science* **13(6):** 525 – 547

Hughes, R. N. (1989). Lack of spontaneous alternation in favor of perseveration in domestic fowls and pigeons. *Behavioural Processes* **20:** 85—92

Inglis, I. R.; Forkman, B. & Lazarus, J. (1997). Free food or earned food? A review and fuzzy model of contrafreeloading. *Animal Behaviour* **53(6):** 1171—1191

Ingram, D. R.; Hatten, L. F. & McPherson, B. N. (2001). Effects of initiation age of skip-a-day feed restriction on skeletal development in broiler breeder males. *Journal of Applied Poultry Research* **10:** 16–20

Johnston, A.; Burne, T. & Rose, S. (1998). Observation learning in day-old chicks using a one-trial passive avoidance learning paradigm. *Animal Behaviour* **56(6):** 1347–1353

Jones, E. K. M.; Zaczek, V.; MacLeod, M. & Hocking, P. M. (2004). Genotype, dietary manipulation and food allocation affect indices of welfare in broiler breeders. *British Poultry Science* **45(6):** 725–37

Julian, R. J. (1998). Rapid growth problems: ascites and skeletal deformities in broilers. *Poultry Science **77**(12):* 1773–80

Katanbaf, M. N.; Dunnington, E. A. & Siegel, P. B. (1989). Restricted feeding in early and late-feathering chickens. 1. Growth and physiological responses. *Poultry Science* **68(3):** 344—351

Kirkden, R. D. & Pajor, E. A. (2006). Using preference, motivation and aversion tests to ask scientific questions about animals' feelings. *Applied Animal Behaviour Science* **100:** 29–47

Kostal, L.; Savory, C. J. & Hughes, B. O. (1992). Diurnal and individual variation in behaviour of restricted-fed broiler breeders. *Applied Animal Behaviour Science* **32(4):** 361–374

Kristensen, H. H.; Prescott, N. B.; Perry, G. C.; Ladewig, J. & Ersboell, A. K. (2007). The behaviour of broiler chickens in different light sources and illuminances. *Applied Animal Behaviour Science* **103:** 75—89

Kyriazakis, I.; Tolkamp, B. J. & Emmans, G. (1999). Diet selection and animal state: an integrative framework. *The Proceedings of the Nutrition Society* **58(4):** 765–72

LaBrash, L. F. & Scheideler, S. E. (2005). Farm feather condition score survey of commercial laying hens. *Journal of Applied Poultry Reseearch* **14(4):** 740—744

Lambton, S. L.; Knowles, T. G.; Yorke, C. & Nicol, C. J. (2010). The risk factors affecting the development of gentle and severe feather pecking in loose housed laying hens. *Applied Animal Behaviour Science* **123:** 32—42

Lawrence, A. B. & Terlouw, E. M. C. (1993). A review of behavioral factors involved in the development and continued performance of stereotypic behaviors in pigs. *Journal of Animal Science* **71(10):** 2815—2825

Leeson, S. & Morrison, W. D. (1978). Effect of feather cover on feed efficiency in laying birds. *Poultry Science* **4:** 1094—1096

Leeson, S. & Summers, J. D. (1985). Effect of cage versus floor rearing and skip-a-day versus every-day feed restriction on performance of dwarf broiler breeders and their offspring. *Poultry Science* **64(9):** 1742—1749

Leeson, S. & Walsh, T. (2004). Feathering in commercial poultry. II. Factors influencing feather growth and feather loss. *World's Poultry Science Journal* **60(1):** 52—63

Lindqvist, C.; Lind, J. & Jensen, P. (2009). Effects of domestication on food deprivation-induced behaviour in red junglefowl, *Gallus gallus*, and White Leghorn layers. *Animal Behaviour* **77(4):** 893–899

Lindqvist, C.; Zimmerman, P. & Jensen, P. (2006). A note on contrafreeloading in broilers compared to layer chicks. *Applied Animal Behaviour Science* **101:** 161—166

Martrenchar, A. (1999). Animal welfare and intensive production of turkey broilers. *World's Poultry Science Journal* **56:** 143—152

Mason, G.; Clubb, R.; Latham, N. & Vickery, S. (2007). Why and how should we use environmental enrichment to tackle stereotypic behaviour? *Applied Animal Behaviour Science* **102:** 163—188

Mason, G. & Mendl, M. (1997). Do the stereotypies of pigs, chickens and mink reflect adaptive species differences in the control of foraging? *Applied Animal Behaviour Science* **53:** 45—58

Mench, J. A. (1991). Research note: Feed restriction in broiler breeders causes a persistent elevation in corticosterone secretion that is modulated by dietary tryptophan. *Poultry Science* **70:** 2547—2550

Mench, J. A. (2002). Broiler breeders : feed restriction and welfare. *World's Poultry Science Journal* **58:** 23–29

Merlet, F.; Puterflam, J.; Faure, J. M.; Hocking, P. M.; Magnusson, M. S. & Picard, M. (2005). Detection and comparison of time patterns of behaviours of two broiler breeder genotypes fed ad libitum and two levels of feed restriction. *Applied Animal Behaviour Science* **94:** 255—271

Millman, S. T.; Duncan, I. J. H. & Widowski, T. M. (2000). Male broiler breeder fowl display high levels of aggression toward females. *Poultry science* **79(9):** 1233–41

Nielsen, B. L. (2004). Behavioural aspects of feeding constraints: do broilers follow their gut feelings? *Applied Animal Behavioural Science* **86:** 251–260

Nielsen, B. L.; Thodberg, K.; Malmkvist, J. & Steenfeldt, S. (2011). Proportion of insoluble fibre in the diet affects behaviour and hunger in broiler breeders growing at similar rates. *Animal* **5(8):** 1247–58

Oyawoye, E. O. & Krueger, W. F. (1990). Potential of chemical regulation of food intake and body weight of broiler breeder chicks. *British Poultry Science 31***(4):** 735–42

Powell, T. S. & Gehle, M. H. (1976). Effect of various pullet restriction methods on performance of broiler breeders. *Poultry Science* **55(2):** 502—209

Provenza, F. D. (1995). Postingestive feedback as an elementary determinant of food preference and intake in ruminants. *Journal of Range Management* **48(1):** 2—17

Pym, R. A. E. & Dillon, J. F. (1974). Restricted food intake and reproductive performance of broiler breeder pullets. *British Poultry Science* **15(3):** 37–41

Rauw, W.; Kanis, E.; Noordhuizen-Stassen, E. & Grommers, F. (1998). Undesirable side effects of selection for high production efficiency in farm animals: a review. *Livestock Production Science 56***(1):** 15–33

Renema, R. A. & Robinson, F. E. (2004). Defining normal: comparison of feed restriction and full feeding of female broiler breeders. *World's Poultry Science Journal* **60(4):** 508–522

Renema, R. A.; Rustad, M. E. & Robinson, F. E. (2007). Implications of changes to commercial broiler and broiler breeder body weight targets over the past 30 years. *World's Poultry Science Journal* **63(3):** 457–472

Richards, M. P.; Rosebrough, R. W.; Coon, C. N. & McMurty, J. P. (2010). Feed intake regulation for the female broiler breeder: In theory and in practice. *Journal of Applied Poultry Research* ***19*****:** 182–193

Richardson, A. J. (1970). The role of the crop in the feeding behaviour of the domestic chicken. *Animal Behaviour* **18(4):** 633–9

Robert, S.; Matte, J. J.; Farmer. C.; Girard, C. L. & Martineau, G. P. (1993). High-fibre diets for sows: effects on stereotypies and adjunctive drinking. *Applied Animal Behaviour Science* **37(4):** 297—309

Rosales, A. G. (1994). Managing stress in broiler breeders: A review. *Journal of Applied Poultry Science* **3:** 199—207

Sandilands, V.; Tolkamp, B.; Savory, C. & Kyriazakis, I. (2006). Behaviour and welfare of broiler breeders fed qualitatively restricted diets during rearing: Are there viable alternatives to quantitative restriction? *Applied Animal Behaviour Science* **96:** 53–67

Sandilands, V.; Tolkamp, B. J. & Kyriazakis, I. (2005). Behaviour of food restricted broilers during rearing and lay – effects of an alternative feeding method. *Physiology & Behavior* **85(2):** 115–23

Savory, C. J. (1980). Diurnal feeding patterns in domestic fowls: A review. *Applied Animal Ethology* **6(1):** 71—82

Savory, C. J. (1981). Correlations between meals and inter-meal intervals in Japanese quail and their significance in the control of feeding. *Behavioural Processes* **6:** 23–36.

Savory, J. (2010). Nutrition, feeding and drinking behaviour, and welfare. In The Welfare of Domestic Fowl and Other Captive Birds. *Animal Welfare* **9(2):** 165—187

Savory, C. J.; Hocking, P. M.; Mann, J. S. & Maxwell, M. H. (1996). Is broiler breeder welfare improved by using qualitative rather than quantitative food restriction to limit growth rate? *Animal Welfare* **5:** 105–127.

Savory, C. & Lariviere, J. (2000). Effects of qualitative and quantitative food restriction treatments on feeding motivational state and general activity level of growing broiler breeders. *Applied Animal Behaviour Science* **69(2):** 135–147

Savory, C. J. & Mann, J. S. (1999). Stereotyped pecking after feeding by restricted-fed fowls is influenced by meal size. *Applied Animal Behaviour Science* **62:** 209–217.

Savory, C J. & Maros, K. (1993). Influence of degree of food restriction , breeder chickens age and time of day on behaviour of broiler. *Behavioural Processes* **29:** 179–189.

Savory, C. J.; Maros, K. & Rutter, S. M. (1993). Assessment of hunger in growing broiler breeders in relation to a commercial restricted feeding programme. *Animal Welfare* **2:** 131–152

Savory, C. J.; Seawright, E. & Watson, A. (1992). Stereotyped behaviour in broiler breeders in relation to husbandry and opioid receptor blockade. *Applied Animal Behaviour Science* **32(4):** 349–360

Savory, C. J. & Smith, C. J. V. (1987). Are there hunger and satiety factors in the blood of domestic fowl? *Appetite* **8:** 101—110

Savory, C. J.; Wood-Gush, D. G. M. & Duncan, I. J. H. (1978) Feeding behavior in a population of domestic fowls in the wild. *Applied Animal Ethology* **4:** 13–27

Schütz, K. E.; Forkman, B. & Jensen, P. (2001). Domestication effects on foraging strategy, social behaviour and different fear responses: a comparison between the red junglefowl (Gallus gallus) and a modern layer strain. *Applied Animal Behaviour Science* **74:** 1—14

Schütz, K. E. & Jensen, P. (2001). Effects of resource allocation on behavioural strategies: A comparison of red junglefowl (Gallus gallus) and two domesticated breeds of poultry. *Ethology* **107:** 753—765

Shariatmadari, F. & Forbes, J. M. (1993). Growth and food intake responses to diets of different protein contents and a choice between diets containing two concentrations of protein in broiler and layer strains of chickens. *British Poultry Science* **34(5):** 959—970

Sherry, D. F. (1977). Parental food-calling and the role of the young in the Burmese red jungle fowl (Gallus gallus Spadiceus). *Animal Behaviour* **25:** 594–601.

Siegel, P. B.; Picard, M.; Nir, I.; Dunnington, E. A.; Willemsen, M. H. A. & Williams, P. E. V. (1997). Responses of meat-type chickens to choice feeding of diets differing in protein and energy from hatch to market weight. *Poultry Science* **76:** 1183–1192

Shields, S. J.; Garner, J. P. & Mench, J. A. (2004). Dustbathing by broiler chickens: a comparison of preference for four different substrates. *Applied Animal Behaviour Science* **87:** 69—82

Suboski, M. D. (1987). Environmental variables and releasing-valence transfer in stimulus-directed pecking of chicks. *Behavioural and Neural Biology* **47(3):** 262—274

Sunder, G. S.; Kumar, C. V.; Panda, A. K.; Gopinath, N. C. S.; Raju, M. V. L. N.; Rama Rao, S. V. & Reddy, M. R. (2008). Effect of measured energy restriction and age intervals on growth, nutrient digestibility, carcass parameters, bone characteristics and stress in broiler breeders during the rearing period. *Asian-Australian Journal of Animal Science* **21(7):** 1038–1047

Sørensen, L. B.; Møller, P.; Flint, A.; Martens, M. & Raben, A. (2003). Effect of sensory perception of foods on appetite and food intake: a review of studies on humans. *International Journal of Obesity* **27(10):** 1152–66

Terlouw, E. M. C.; Lawrence, A. B. & Illisu, A. W. (1991). Influences of feeding level and physical restriction on development of stereotypies in sows. *Animal Behaviour* **42:** 981—991

Thomas, D. W. & Mayer, J. (1968). Meal taking and regulation of food intake by normal and hypothalamic hyperphagic rats. *Journal of Comparative and Physiological Psychology* **66(3):** 642–53

Tolkamp, B. J.; Sandilands, V. & Kyriazakis, I. (2005). Effects of qualitative feed restriction during rearing on the performance of broiler breeders during rearing and lay. *Poultry Science* **84(8):** 1286–93

Van Krimpen, M. M.; Kwakkel, R. P.; Reuvekamp, B. F. J.; Van Der Peet-Schwering, C. M. C.; Den Hartog, L. A. & Verstegen, M. W. A. (2005). Impact of feeding management on feather pecking in laying hens. *World's Poultry Science Journal* **61(4):** 663–686

Wang, Z. & Goonewardene, L. A. (2004). The use of MIXED models in the analysis of animal experiments with repeated measures data. *Canadian Journal of Animal Science* **84(1):** 1—11

Wauters, A. M. & Richard-Yris, M. A. (2002). Mutual influence of the maternal hen's food calling and feeding behavior on the behavior of her chicks. *Developmental Psychobiology* **41(1):** 25–36

Wolanski, N. J.; Renema, R. A.; Robinson, F. E.; Carney, V. L. & Fancher, B. I. (2007). Relationships among egg characteristic, chick measurements and early growth traits in ten broiler breeder strains. *Poultry Science* **86(8):** 1784–1792

Yo, T.; Siegel, P. B.; Faure, J. M.; Picard, M. (1998). Self-selection of dietary protein and energy by broilers grown under a tropical climate: adaptation when exposed to choice feeding at different ages. *Poultry Science* **77(4):** 502—508

Yuan, T.; Lien, R. J. & McDaniel, G. R. (1994). Effects of increased rearing period body weight and early photostimulation on broiler breeder egg production. *Poultry Science* **73:** 792—800

Zuidhof, M. J.; Robinson, F. E.; Feddes J. J. R.; Hardin, R. T. & Wilson, J. L. (1995). The effects of nutrient dilution on the well-being and performance of female broiler breeders. *Poultry Science* **74(3):** 441—456