Behavioural implications of precision feeding broiler breeders

by

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Abstract

Broiler breeders require feed restriction to maintain high production rates of hatching eggs. However, feed restriction, conventionally managed during the rearing period through skip-a-day feeding, creates welfare concerns as broiler breeders exhibit behaviours indicative of hunger and frustration. A novel precision broiler breeder feeding system provided small individual meals to each bird multiple times throughout a day, only if their BW was less than a target BW. The primary objective of this thesis was to determine the behavioural consequences of precision feeding broiler breeders in comparison to a conventional, skip-a-day feeding schedule. As such, this thesis did not measure physiological indicators of hunger as a result of feed restriction nor did it focus on internal factors (e.g. genetics) that impact hunger motivation in broiler breeders. Instead, objectives focused on the external factors (i.e. allocation of restricted feed) related to broiler breeder hunger motivation. The behavioural indicators of hunger motivation are referred to as perception of hunger in this thesis. Two experiments were run concurrently to examine and compare measures of perceived hunger, and therefore hunger motivation, including: restlessness, dust-bathing, foraging, object pecking, feather pecking, aggression, and social order fluctuations. Behaviour observations suggest that precision feeding reduced, but did not eliminate hunger motivation and may have the potential to better satisfy foraging frustration in broiler breeders, compared to skip-a-day feeding. However, precision feeding increased aggression compared to skip-a-day feeding. Therefore, it appears that while precision feeding decreased hunger motivation of broiler breeders, it does not appear to have fully eliminated hunger-related frustration.

Preface

This thesis is an original work by Teryn Gilmet. Funding for this project was provided by Alberta Livestock and Meat Agency Ltd., Agriculture & Food Council, Danisco Animal Nutrition, Alberta Innovates Bio Solutions, Poultry Industry Council, Alberta Hatching Egg Producers, Canadian Hatching Egg Producers, and Alberta Chicken Producers. In-kind support for this project was provided by Xanantec Technologies Inc. Publication is intended for Chapters 3 and 4 with co-authors M.J. Zuidhof and C.J. Bench. The research project, of which this thesis is a part, received research ethics approval from the University of Alberta Research Ethics Board, Precision Broiler Breeder Feeding System, AUP00000121, June 9, 2014.

Dedication

After writing this thesis, the most challenging part was to convey how grateful and thankful I am in a letter of dedication to my family and mentor. I am so lucky to have been blessed with such amazing role models and supportive people in my life. No words will ever do justice to how thankful I am.

To my parents, you have opened so many doors for me and allowed me to pursue my dreams; I will be forever thankful for the opportunities you have given me. I dedicate this thesis to you because I would not be in this position had it not been for your endless support, guidance, and love. Mum, you have always been my role model, my confidant, and my best friend; together we are a team that can get through anything. I would not be where I am today without your patient and empathetic nature that could calm even the largest storms. Dad, your sense of humor, endless support, curiosity about chickens, chicken goggles, and your genuine nature, has always inspired me. I took so much pride in how you would tell family and friends about my beloved 'girls.' Thank you Mum and Dad for the sacrifices you have made, and continue to make, to get me here today and Calgary tomorrow.

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List of Abbreviations

°C	Degrees Celsius
AGI	Agonistic index
AM	Ante meridiem
AME	Apparent metabolizable energy
ARI	Aggressive index
BW	Body weight
CA	California
Ca	Calcium
cm	Centimetre
CONV	Conventional skip-a-day feeding
CP	Crude protein
D	Dark
DI_{ai}	Dominance index
DEFRA	Department for Environment, Food, and Rural Affairs
ESF	Electronic Sow Feeder
FN	Non-fed days
FY	Fed days
g	Gram
hr	Hour
Kg	Kilogram
L	Light
M	Metre
n	Sample size
min	Minute
NC	North Carolina
OIE	World Organization for Animal Health
P	Phosphorous
PM	Post meridiem
PF	Precision Feeding

PFS	Precision Broiler Breeder Feeding System
Train	Number of birds trained
USA	United States of America

1.0 Introduction

Broiler breeders are feed-restricted to control growth and maximize egg production (Mench, 2002). Genetic selection of broiler chickens for rapid growth rate has also led to selection for increased appetite (Siegel and Wisman, 1966). This appetite in broiler breeders is undesirable as eating to satiety can increase the incidence of obesity-related diseases (Savory and Maros, 1993) and decrease production rates (Hocking et al., 1987). Although broiler breeders require feed restriction for health reasons, feed restriction also creates welfare concerns as birds are chronically hungry (de Jong et al., 2005). Currently, a conventional method of feeding broiler breeder pullets is using a skip-a-day schedule. However, feeding on alternating days is considered detrimental to a broiler breeder's well-being as birds experience prolonged periods without feed (DEFRA, 2007). Therefore, methods of feed management which can improve the welfare of broiler breeders are required. A novel precision broiler breeder feeding system allows the allocation of multiple small meals throughout each day to individual birds. It was hypothesized that providing feed more frequently than skip-a-day feeding may improve bird well-being.

The primary objectives of this thesis were: 1) to determine behavioural consequences of precision feeding broiler breeder pullets in comparison to a skip-a-day feeding schedule; and, 2) to provide recommendations for management of birds in future precision systems. Five objectives focused on hunger motivation, through measuring behavioural perception of hunger, in broiler breeders. Two experimental studies were run concurrently to examine and compare behavioural measurements of hunger in precision and skip-a-day-fed broiler breeder pullets.

A literature review on the behavioural implications of feed-restricting broiler breeders is given in Chapter 2 of this thesis. The subsequent two chapters describe studies designed to investigate the behavioural consequences of precision feeding broiler breeders. Chapter 3 investigates the effect of precision feeding of broiler breeders on restlessness, foraging, feather pecking, and object pecking behaviours in comparison to skip-a-day feeding. Chapter 4 compares the prevalence of aggression and social rank fluctuations in precision feeding and skip-a-day-fed broiler breeders. The fifth chapter comprises a synthesis of the two experiments and provides recommendations for the management of broiler breeders in future precision feeding systems.

1.2 Objectives

The primary objective of this thesis was to determine the behavioural consequences of precision feeding of broiler breeder pullets in comparison with conventional skip-a-day feeding. Within this primary objective, two experimental studies had specific objectives to which included a comparison of restlessness, and the prevalence of aggression and aberrant behaviours such as stereotypic feather and object pecking in precision-fed versus skip-a-day-fed broiler breeders. It was hypothesized that precision feeding of feed-restricted broiler breeders decreases the prevalence of behaviours which are indicative of welfare concerns. Specific objectives were:

1) Determine whether precision feeding affected restlessness by comparing amount of standing and walking to skip-a-day-fed broiler breeder pullets.
2) To identify whether precision-fed broiler breeders foraged more or less compared with a skip-a-day-fed broiler breeders.
3) Determine whether the multiple small meals allocated by a precision feeding system resulted in broiler breeder pullets exhibited more or less oral behaviours compared to skip-a-day feeding.
4) To identify whether broiler breeder pullets fed with a precision feeding system exhibited more or less aggression in comparison to skip-a-day-fed broiler breeder pullets.
5) Identify whether broiler breeder pullets fed with a precision feeding system exhibited more or less social rank fluctuations in comparison to skip-a-day-fed broiler breeder pullets.

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2.0 Literature Review

2.1 Red Jungle Fowl and Broiler Breeders

To evaluate the behavioural needs of a production animal, ethologists compare the behaviour of domesticated species to its wild-type. The Red Jungle Fowl, the common ancestor to all chickens, was domesticated approximately 8,000 years ago (Fumihito et al., 1994). Previous research has shown the behaviour repertoires of Red Jungle Fowl and domesticated chickens to be similar (Thorpe, 1965). Therefore, the behaviour of Red Jungle Fowl can be regarded as a basis of comparison to domesticated chickens.

Domestication occurs as a specific population’s genetics are altered as a result of morphological or behavioural selection by humans over thousands of generations (Schütz et al., 2001). Poultry were domesticated to fulfill various roles such as entertainment, religion, and food (Miao et al., 2013). Specifically, poultry have been artificially selected to produce table eggs (e.g. laying hens), meat (e.g. broilers), and hatching eggs (e.g. broiler breeders and egg layers). As a phenotypic trait, behaviour is modified during the process of domestication (Trut et al., 2009). During domestication, behaviour types (i.e. species repertoire) are neither eliminated nor created as only the frequency of behaviours is changed (Price, 1999).

Although behaviours are not created during domestication, altered frequency of behaviours can result in aberrant behaviours as a result of the quantitative difference of natural poultry behaviour. Thus, aberrant behaviours such as vices or stereotypies (repetitive, unvarying behaviour patterns which have no obvious goal or function; Ödberg 1978) have occurred through artificial selection and quantitative behavioural modification of broiler breeders. Performance of stereotypic or vice behaviour by wild Red Jungle Fowl would not be expected due to the natural environment being conducive to natural behaviours. Vices may still be exhibited by Red Jungle Fowl but not to the intensity as seen in broiler breeders. Thus, domesticated poultry have the same qualitative behaviour repertoire as Red Jungle Fowl and can be compared accordingly for quantitative differences.

Broiler breeders are normally housed in captive, free-run environments where food and water are consistently allocated. Food is often fed to broiler breeders in a communal feeding trough while water is typically given *ad libitum.* The life cycle of broiler breeders consist of a brooding phase (0-7 days), rearing phase (7 days -15 weeks of age), a pre-laying phase (16-22 weeks of age), and a laying phase (23 to approximately 64 weeks of age; Aviagen, 2013). Broiler breeders begin laying hatching eggs at approximately 23 weeks of age with a peak production at approximately 31 weeks of age (Aviagen, 2013). The current broiler breeder performance goal is 175 hatching eggs with 84.8% hatchability in a 64-week lifespan of a broiler breeder hen (Aviagen, 2011).

Broiler breeders are the parent-stock of broilers, which are meat-type chickens. In the past 40 years, market age of a 2 kg broiler chicken has been reduced from 63 to 37 days (Willemsem et al., 2010) through intensive artificial selection for increased juvenile growth rate (Dawkins and Layton, 2012). However in selecting for an increased growth rate, an increased broiler appetite has also been indirectly selected for, which can be problematic in broiler breeders (Richards et al., 2010). As broiler breeders live for over a year, an unmanaged appetite can create health and welfare concerns due to obesity (Savory and Maros, 1993) and lameness (Hocking and Duff, 1989; Savory et al., 1993) over time. Obesity in broiler breeders will also cause a decrease in production rates (Hocking et al., 1987). Thus, while broilers have been indirectly selected for an increased appetite, the feed intake of broiler breeders must be managed in order to achieve and maintain optimal health and reproductive performance.

A broiler breeder feed restriction program during rearing consists of *ad libitum* feeding for 2 to 4 weeks post-hatch followed by severe feed restriction until the onset of lay (Aviagen, 2013). Feed restriction is more severe (approximately 25-33% of what birds would eat *ad libitum* ; de Jong et al., 2002) during rearing, compared with laying, as birds do not yet require nutrients for egg laying. During rearing, broiler breeders are feed-restricted to approximately 25% to 33% of what they would consume if fed *ad libitum* (de Jong et al., 2002). At approximately 24 weeks of age, feed restriction of broiler breeders decreases as they are fed 55% of what they would consume in an *ad libitum* feeding system (Savory et al., 1993). Although the degree of feed restriction is less severe during laying, once a decrease in egg production occurs, producers may once again increase feed restriction (Aviagen, 2013).

2.2 Social order

Once a social order is established in the form of a dominance hierarchy amongst domestic chickens, access to resources is positively associated with social rank (Banks et al., 1979). Collias et al. (1966) found semi-wild Red Jungle Fowl hens expressed a social order when competing for food. A social order of domestic poultry is based on feeding competition (Banks, 1979) and is established through aggressive and submissive interactions (Estevez et al., 2003). Within a dominance hierarchy the most dominant birds accumulate the most feed and the least submissive birds consume the least amount of feed (Guhl, 1953). As a result, a stable social order within a domestic flock may decrease body weight uniformity (e.g. in broiler breeders) as dominant birds ingest more feed compared with subordinate birds.

Broiler breeder production systems typically involve housing a large number of broiler breeders together, which require a stable social order to decrease aggressive encounters among conspecifics (Estevez et al., 1997). Aggression (observed as fights, leaps, chases, stand-offs, pecks, threats, and avoidances; Estevez et al., 2002), is used to determine social order, or dominancy hierarchy, in poultry flocks. Bird behaviour can provide information regarding social order. How many aggressive encounters a bird is involved in relative to its flockmates can be determined by dividing the number of aggressive encounters the pullet is involved in by the number of aggressive encounters in its environment (Puppe and Tuchscherer, 1994; reviewed by Langbein and Puppe, 2004). The dominance rank of a bird is determined by the number of wins (or losses) of an individual divided by the total number of aggressive encounters, as previously validated in swine (Beilharz and Cox, 1967) and lemmings (Bowen and Brooks, 1978). How aggressive a bird is determined by dividing the number of aggressive encounters initiated by a bird by the number of aggressive encounters and threats in which that bird was involved. This measurement of the relative aggressive nature of a bird in comparison to how many encounters is involved, has been previously validated in goats (Barosso et al., 2010).

Banks et al. (1979) observed that once a stable social order has been established in a domesticated laying hen flock, the order remains relatively stable and constant for the remainder of time the flock is together, provided that no individuals are added to or leave the flock. Further, Rushen (1982) and Estevez et al. (2003) observed that aggressive acts decrease once a stable social order has been established. However, while Rushen (1982) found aggressive activity between Rhode Island Red x White Leghorn hens peaked at 9-10 weeks, Estevez et al. (2003) found aggression between White Leghorn hens peaked between 6 and 12 weeks. Therefore, formation and following stabilization of social order appear to vary between strains. Nonetheless, once a social order amongst broiler breeders is established, prevalence of aggression decreases and is replaced with demonstrations, without an aggressive encounter, of dominance or submission (Shea et al., 1990). Thus, decreasing rates of aggression may be due to the formation or stabilization of a social order.

Shea et al. (1990) found that as feed becomes increasingly scarce, peck-order violations (e.g. aggressive behaviours that do not conform to the established social order) increase in male broiler breeders. Therefore, feed restriction creates a feed-competitive environment which may destabilize a flock’s social order. Although aggression amongst poultry is related to social order, individual birds make decisions according to the relative costs and benefits of different strategies, (e.g. aggression or non-aggression) at a given time and place (Estevez et al., 2002). Thus, domesticated chickens behave as individuals, coping uniquely to various social situations.

2.3 Optimal foraging theory

Optimal foraging theory is based on the assumption that an animal will use a behavioural strategy which will maximize its fitness through maximizing net energy intake when foraging (Stephens and Krebs, 1986). One strategy to optimize foraging is when an animal will acquire as much caloric energy as possible while minimizing the total amount of time or energy spent when collecting caloric energy (Stephens and Krebs, 1986). This optimization may lead to increased survival or reproductive success (Stephens and Krebs, 1986).

Red Jungle Fowl typically feed on grainy and particulate food pieces that are found in concentrated patches throughout the environment (Mason and Mendl, 1997). In their natural environment, Red Jungle Fowl are at a constant risk of food shortage, due to feed being distributed in small patches within an expansive environment (Mason and Mendl, 1997). Thus, meals are spread throughout the day as birds travel to, from, and between patches containing various concentrations of food. Increased time spent foraging likely results in an increase in total food intake as a Red Jungle Fowl is more likely to find food. Additionally, the longer one feeds in a patch, the more energy is required to find feed in that patch (Cowie, 1977). Thus, the decision to leave a patch in search of a new patch of food must be made before the current patch is depleted. Foraging allows Red Jungle Fowl to actively avoid and respond to food shortages within the environment by leaving a patch of food before it becomes depleted, in search of a new bountiful food patch. Therefore, the Red Jungle Fowl typically encounters periods of feast and famine throughout each day.

Strategies allow an individual to work towards maximizing its energy intake while minimizing the energetic costs of foraging. Andersson et al. (2001) compared energetic costs of foraging strategies in a domesticated Swedish bantam and a hybrid of the Red Jungle Fowl and the domesticated Swedish bantam. Energetic costs were measured by the number of movements (how often birds moved between patches) across various distances (190 cm or 390 cm) between two separated patches of food, both of which eventually became exploited. Both hybrid and domesticated fowl exhibited strategies that coincided with the optimal foraging theory by exhibiting decreased time in depleted food patches or leaving a food patch before it was completely exploited. Hybrid fowl adopted more costly foraging strategies compared with domesticated fowl as the hybrid fowl moved between patches more than domesticated fowl, without ingesting more feed. Domesticated poultry use less costly foraging strategies compared with hybrid fowl because the producer provides feed to the domesticated chickens, dissolving the functional need for birds to forage (Andersson et al., 2001). Thus, the foraging behaviour of domesticated poultry has been inadvertently modified in comparison to hybrid birds.

Estevez et al. (1997) introduced a tolerance hypothesis regarding aggression in broilers. Tolerance in this hypothesis refers to social and aggression avoidance due to a high cost (e.g. energy, injury, and decreased resource acquisition) of aggression. Benefits of a tolerant social system are minimal time and energy spent on aggressive encounters (Estevez et al., 1997). *Ad libitum* fed broilers (cross-bred Hubbard) exhibited a social order which supported the tolerance hypothesis (Estevez et al., 1997). Further, Estevez et al. (2002) observed White Leghorn pullets displayed fewer aggressive encounters when 60 pullets, compared with 15, were at the same food patch. These results supported the tolerance hypothesis as aggression displayed by domestic poultry is dependent on the cost and benefits of behavioural strategies at a specific time and place (Estevez et al, 2002). Therefore, the best strategy will result in maximal energetic gain for the bird. An aggressive encounter may result in a bird gaining substantially more resources. Contrary to this, a bird may benefit more from using less energetically costly behaviours, such as tolerating the presence of conspecifics when aggression will not result in optimal energetic intake (Estevez et al., 1997).

2.4 Foraging as a behavioural need

A behavioural need is defined as a strongly motivated behaviour that is present regardless of the appropriateness of the environment (Duncan, 1998). Behavioural needs are thus controlled largely by internal factors (e.g. motivation) as external factors (e.g. environment) do not determine the presence or absence of the exhibited behaviour (Duncan, 1998). Behavioural needs of domesticated poultry include perching (Olsson and Keeling, 2000), foraging, nesting, and possibly dust-bathing (Duncan, 1998). When an animal's behavioural need is thwarted, frustration will result (Petherick and Rushen, 1997). As such, it is recommended that broiler breeders be given opportunities to perform behavioural needs in order to minimize potential welfare concerns (Duncan, 1998).

Zoo-housed Red Jungle Fowl exhibited foraging behaviours for more than 90% of the time between dawn and dusk (Dawkins, 1989). These birds also preferred to forage throughout the day even when their feed was provided in a trough (Dawkins, 1989). de Jong et al. (2005b) found broiler breeder pullets who were fed daily foraged for approximately 6.4 % of observations during the light period (scan sampled every 2 min during alternating half hours beginning at 07:00 h and ending at15:00 h). As such, domestic poultry are motivated to ground peck and scratch for food as part of foraging behaviour, though to a lesser extent than their wild-type.

Functionally, foraging is a feed-seeking behaviour that would lead to increased survival of Red Jungle Fowl. In a domesticated environment, food is provided to an animal in a consistent location and allocating energy towards finding food is unnecessary (Gustafson et al., 1999). However, foraging behaviours are still exhibited by broiler breeders (de Jong et al., 2003; 2005a; 2005b; Hocking et al., 2005; Morrissey et al., 2014a). Further to this, birds that consume their allocated feed rapidly may still perform foraging behaviours after ingestion (Duncan, 1998). This presence of foraging in environments not conducive to foraging behaviour, such as environments where food is provided in troughs to birds, suggests foraging to be a behavioural need of domesticated poultry.

2.5 Broiler breeder welfare

According to the World Organization for Animal Health (OIE, 2012), “animal welfare refers to the state of the animal” and encompasses biological functioning, natural behaviour, and feelings of an animal. As such, the biological functioning of broiler breeders is subjected to a welfare dilemma; broiler breeders require feed restriction to avoid obesity but experience chronic hunger as a result of feed restriction (de Jong et al., 2005a). Further, feed restriction may compromise natural behaviours of broiler breeders as the behavioural need to forage may not be satisfied when feed is restricted. Feed restriction also creates hunger in broiler breeders, which may increase aggression, thereby compromising the feelings (e.g. through inducing fear) of the birds. The concern regarding broiler breeder welfare presented in this thesis is thus not whether to utilize feed restriction, but how to best manage broiler breeder feed allocation in order to improve broiler breeder welfare.

2.5.1 Hunger motivation

Hunger is a subjective state that is not well defined throughout the literature (D’Eath et al., 2009). Motivation state is affected by both external and internal factors. For example, hunger motivation in broiler breeders is affected by both the increased appetite of broiler breeders as a result of genetic selection (internal) and the availability and allocation of feed in the environment (external). This thesis did not measure physiological indicators of hunger as a result of feed restriction nor did it focus on internal factors (e.g. genetics) that impact hunger motivation in broiler breeders. This thesis focuses instead on the behavioural consequences of precision feeding in comparison to a conventional, skip-a-day feeding schedule. The behavioural indicators of hunger motivation are referred to as perception of hunger in this thesis. One example of this is that increased activity levels and re-directed foraging behaviours in broiler breeders have been suggested as indicators of chronic hunger stress and hunger motivation due to feed restriction (Savory et al., 1993).

As broiler breeders require feed restriction to avoid obesity-related disease, feed restriction cannot be eliminated from broiler breeder management. Currently, feeding systems which do not provide feed to broiler breeders on a daily basis are not allowed in the United Kingdom due to welfare concerns of prolonged periods without feed (DEFRA, 2007). Thus, more frequent feeding of broiler breeders throughout each day may increase the welfare of feed-restricted broiler breeders (as reviewed by Mench, 2002). The underlying assumption is that as behaviours indicative of perception of hunger decrease, it implies a decrease in hunger motivation and improved broiler breeder welfare.

Increased hunger motivation in broiler breeders may be exhibited through increased activity levels. Feed-restricted broiler breeders were generally more active compared with *ad libitum* fed broiler breeders (Savory and Maros, 1993; Hocking et al., 1996; de Jong et al., 2002). Feed-restricted broiler breeders walked and stood more compared with *ad libitum*-fed broiler breeders at 18 weeks of age (Hocking et al., 1996). Specifically, feed-restricted broiler breeders exhibited increased standing prior to expected feeding time compared with other times of the day (Kostal et al., 1992). An increase in standing and walking behaviours was thought to be indicative of hunger (Savory and Maros, 1993).

In addition to decreased activity, *ad libitum*-fed broiler breeders (broiler breeders given an endless amount of feed) exhibited significantly more sitting behaviours compared with restrictively fed broiler breeders (de Jong et al., 2002; Savory and Maros, 1993). Restrictively-fed female broiler breeders spent approximately 5% of observed times resting while *ad libitum*-

fed female broiler breeders spent approximately 30% of those observed times resting (30 second scan sampling for 10 min per pen at 13:00 h; Hocking et al., 1993). Additionally, Savory et al. (1992) found that restrictively-fed female broiler breeders did not rest during mornings (09:00 – 11:30) and spent 14% and 9% of time resting during afternoons (15:00 – 16:30), at 11 and 18 weeks, respectively. In contrast, *ad libitum*-fed female broiler breeders spent 56% and 40% of morning time resting and 53% and 51% of afternoons resting at 11 and 18 weeks, respectively (Savory et al., 1992). Therefore, as increased activity may indicate increased hunger motivation, decreased activity may thus indicate decreased hunger motivation (Sandilands et al., 2005).

Under feed restriction, maintenance and play behaviours should decrease in favour of energy conservation. Under quantitative restriction, time spent on comfort behaviours by broiler breeder pullets was negatively related with hunger (e.g. preening, autopecking, nibbling, stroking, wing flapping and stretching; de Jong et al., 2003). Dust-bathing (a bird squatting or lying and rubbing its body in the substrate) is thought to remove excess feather lipids and promote good plumage condition of a chicken (Olsson and Keeling, 2005). Dust-bathing has previously been studied as a hunger-related comfort behaviour (Hocking et al., 1993; Hocking et al., 1996; Hocking et al., 2001; Jones et al., 2004; de Jong et al., 2005b; Merlet et al., 2005; Sandilands et al., 2006; Morrissey et al., 2014a), likely because dust-bathing is thought to indicate contentment and would only be exhibited if birds experienced decreased hunger-motivation. However, research regarding dust-bathing and hunger in broiler breeders has produced inconclusive results as its prevalence is minimal and therefore difficult to analyze (Hocking et al., 1993; de Jong et al., 2005a; Hocking et al., 2001). However, Morrissey et al. (2014a) found skip-a-day-fed broiler breeder pullets dust-bathed and feather pecked more than daily-fed birds. As skip-a-day-fed pullets endure prolonged periods without feed, it is expected that they would perform fewer comfort behaviours compared with daily-fed broiler breeders. Therefore, the relationship between dust-bathing and hunger of restrictively-fed broiler breeders is currently unknown.

2.5.2 Foraging motivation

The motivation in broiler breeders to forage is two-fold; it is a resource-motivated behaviour correlated with hunger and it is a behavioural need of poultry (Duncan, 1998). Duncan (1998) argues that behaviours consist of both an appetitive phase and a consummatory phase. In the context of broiler breeder feeding behaviour, foraging would be an example of an appetitive phase while ingestion would be an example of a consummatory phase. The appetitive aspect of foraging behaviour in wild fowl is made up of a complex series of smaller behaviours such as walking, bill probing, ground scratching, and ground pecking. However, during the rearing phase, daily-fed broiler breeders will ingest their meal in approximately ten minutes or less, with minimal need to seek feed (Savory et al., 1996). Ten minutes of feeding behaviours is a relatively short period of time compared to wild-type feeding behaviour, which occurs throughout every day (Dawkins, 1989). Rapid consumption of feed leaves the need to forage largely unsatisfied as the behavioural sequence of searching, locating, and ingesting feed is greatly reduced.

Jensen and Toates (1997) proposed a general motivation model in which motivation is affected by both external (environmental) and internal (genetic) stimuli. An animal will integrate these stimuli and translate them into behaviour which relies on specific feedbacks to satisfy a motivation and stop the behaviour. External factors (e.g. minimal feed in a feed-restricted environment) can increase foraging motivation in broiler breeders as lack of feed furthers the need to perform feed-seeking behaviours. Internal factors (hunger and metabolism) can also increase broiler breeder foraging as the bird attempts to locate feed to sate itself. However, even when a broiler breeder is sated after one large meal, rapid ingestion of feed may not satisfy the bird's need to forage, causing the broiler breeder to forage during post-consumption (Duncan, 1998). As such, foraging behaviours post meal consumption may indicate lack of satiety or an unsatisfied need to forage. As foraging motivation continues to build up, the broiler breeder may enter a state of stress (or frustration) due to the inability to exhibit sufficient foraging behaviour. Eventually, unfulfilled foraging behaviours can become re-directed towards other birds or objects in the form of pecking. Unmitigated, these re-directed pecking behaviours may become abnormal repetitive behaviours and eventually become an abbreviated behaviour with a fixed action pattern (stereotypic in nature). This, in turn, can create a welfare concern for both the bird performing the behaviour due to a unsatisfied behavioural need and, potentially, its flock mates.

Stereotypies that are primarily elicited post-consumption, are proposed to be indicative of an unsatisfied foraging behaviour (Mason and Mendl, 1997). Feed restriction in broiler breeders has been identified as a primary cause of stereotypic oral behaviours (Duncan and Wood-Gush, 1972; Rushen, 1984). Foraging frustration, an inability to successfully forage for food, is likely manifested in feed-restricted broiler breeders as stereotypic object pecking (Savory et al., 1992; Sandilands et al., 2005) and feather pecking (Morrissey et al., 2014a). Object pecking can include drinker, pen wall, or empty feeder pecking. Feed-restricted broiler breeders have exhibited an increase in stereotypic drinker pecking (Kostal et al., 1992; Savory et al., 1992), empty feeder pecking (Kostal et al., 1992; Savory and Maros, 1993), and pen wall pecking (Savory and Kostal, 2006) compared to their *ad libitum* counterparts. It is also interesting to note that Kostal et al. (1992) concluded individual birds tended to 'specialize' in only displaying stereotypic pecking at either the drinker or the feeder. When the drinker or feeder was removed, birds spent more time exhibiting non-stereotypic behaviour such as preening and standing. Therefore, while broiler breeders will show signs of foraging frustration in general, individual birds may express hunger frustration uniquely.

Feather pecking is defined as one bird using its beak to grasp and pull another bird's feathers, and can be classified as gentle, aggressive, or severe (Savory, 1995). Gentle feather pecking is the nibbling or exploratory pecking of another's feathers (Dixon et al., 2008) and is not a welfare concern (Blokhuis and Arkes, 1984). Aggressive feather pecking occurs when one bird stabs its beak at another bird's head or neck, and has been correlated with social order formation in a poultry dominancy hierarchy (Savory, 1995). Aggressive pecking can lead to bruising, bleeding and possibly death if persistent and the subordinate bird is unable to escape. Severe feather pecking involves grasping and potentially removing the feathers of a flockmate (Dixon et al., 2008). Severe feather pecking, a problematic behaviour observed in commercial laying hens and broiler breeders, is a welfare concern and is thought to be the result of re-directed foraging behaviour (e.g. de Haas et al., 2010). However, more research regarding feather pecking is required to determine its prevalence and causation in broiler breeders specifically (de Jong and Guémené, 2011).

If there is nothing on the ground for birds to peck at, Johnsen and Vestergaard (1996) hypothesized that feathers of flock-mates become an alternative stimulus for foraging material. Thus, feather pecking develops from ground foraging as a re-directed foraging behaviour in laying hens (Johnsen and Vestergaard, 1996). In broiler breeders, Hocking et al. (2005) found the presence of litter decreased feather pecking. However, in another study, providing environmental enrichment (wood shavings and string) did not decrease feather pecking among broiler breeders (Hocking and Jones, 2006). Morrissey et al. (2014b) found that feather condition, indicative of feather pecking, was greater in skip-a-day-fed broiler breeders compared to daily-fed broiler breeders. It was hypothesized that skip-a-day-fed broiler breeders experienced increased satiety every other day and therefore exhibited decreased feather pecking overall in comparison to daily-fed broiler breeders (Morrissey et al., 2014b). As such, it is likely a combination of hunger-related aggression and an unsatisfied behavioural need to forage that stimulates feather pecking behaviours in broiler breeders. While it is necessary to feed-restrict broiler breeders, reducing the hunger motivation in feed-restricted broiler breeders may lessen foraging frustration and the corresponding welfare concerns (de Jong et al., 2005a).

2.5.3 Aggression

Feeding behaviour is intensified when birds are hungry (Savory et al., 1978). This intensification of feeding behaviour likely exacerbates aggression in broiler breeders. Duncan and Wood-Gush (1971) found that feed-frustration increases aggression amongst laying hens (Brown Leghorns) because dominant birds initiate more aggressive encounters. Shea et al. (1990) found that broiler breeder males display high levels of aggressive encounters due to feed restriction. Feed-restricted male broiler chickens, fed every second day, were more aggressive at the feed trough than their *ad libitum*-fed counterparts (Mench, 1988). It should be noted that the behaviour of feed-restricted male broilers is likely different than feed-restricted female broiler breeders due to hormonal and body weight differences. Further, the increase of broiler growth rate and appetite since 1988 (when Mench reported aggression in feed-restricted broilers) has likely changed broiler and broiler breeder behaviour, due to increased hunger motivation. However, research regarding aggression amongst broiler breeder pullets is minimal. Although

Morrissey et al. (2014a) investigated aggression amongst pullets during or immediately after feeding bouts, scan sampling methodology and the rapid action of aggressive pecks did not allow these authors to reach a solid conclusive result. Therefore, further research regarding aggression among broiler breeder pullets is required. However, due to previous findings of increased aggression amongst feed-restricted male broilers and broiler breeders, it is hypothesized that broiler breeder pullets will also exhibit aggression when feed restricted due to increased hunger motivation.

As feeding competition occurs in broiler breeders, aggression at the feed trough is likely to increase due to increased motivation and competition to eat. However, in a skip-a-day feeding system, male broilers and broiler breeders were more aggressive during the days they were not fed compared with the days on which they were fed (Mench, 1988; Shea et al., 1990, respectively). It appears then, that broiler breeder aggression may not be eliminated as feed restriction, while required to prevent obesity, increases competition amongst birds. However, a feeding method which mitigates aggression amongst broiler breeders may improve broiler breeder welfare.

2.6 Comparison to group-housed gestating sows fed with an electronic sow feeder

Both broiler breeders and gestating sows are domesticated production animals that are feed-restricted in order to maintain optimal reproductive health. The Wild Boar, ancestor to domesticated swine, was domesticated approximately 9000 years ago (McDevitt et al., 2013). Wild Boar, like Red Jungle Fowl, allocate a majority of their day to food foraging behaviours (Russo et al., 1997). Both species ingest particulate food that is spread throughout the environment, requiring exploration of the environment (Mason and Mendl, 1997). Although the behavioural patterns of foraging between Wild Boar and Red Jungle Fowl differ, foraging is a significant part of both species behavioural repertoires (Stolba and Wood-Gush, 1980; Dawkins, 1989, respectively). It is no surprise then that both broiler breeders and gestating sows exhibit problematic behaviours stemming from hunger and inability to exhibit sufficient amounts of foraging behaviours when fed a restricted diet.

Similar to broiler breeders, oral stereotypies performed by gestating sows are likely caused and enhanced by feed restriction (Lawrence and Terlouw, 1993). Mason and Latham (2004) investigated the prevalence of stereotypies worldwide and estimated 82.6% of broiler breeders and 91.5% of confined sows exhibit stereotypic behaviours. Gestating sows exhibit oral stereotypic behaviours indicative of foraging frustration (examples: bar biting, sham chewing, tongue rolling, and/or inter-sow aggression such as vulva biting; Terlouw et al., 1991). Stereotypic behaviours in broiler breeders and gestating sows are likely caused by hunger and are enhanced when the animals can not sate their hunger (Savory and Maros, 1993; Rushen, 1984, respectively).

2.7 Feeding management methods

Competitive feeding systems offer no protection to an animal while it feeds and non-competitive feeding systems offer protection to individual animals while feeding (Bench et al., 2013). Methods of feeding management, such as feeding type or schedule, can be categorized as simultaneous systems, in which all animals in a pen are fed at the same time, or sequential systems, in which feed is allocated to individuals animals serially. Simultaneous feeding methods can be further divided into competitive or non-competitive feeding systems, while sequential feeding methods are always non-competitive.

Sequential feeding systems are intended to be non-competitive by design. For example, electronic sow feeders (ESF) allow individual gestating sows to eat pre-allocated amounts of feed in a protected stall. A non-competitive feeding system such as an ESF is intended to give protection from aggression to the eating sow. However, individual, or sequential feeding of sows has been shown to only partially alleviate aggression related to feed restriction, as sequential feeding systems may cause animals to wait for access to a feeding system (Spoolder et al., 1997). As such, the ability of an ESF to decrease aggression amongst sows has not yet been fully determined, as the results in scientific literature on these types of sequential, protected feeding systems has reported conflicting results (Bench et al., 2013). While group competition at the feed trough is eliminated in a sequential feeding system, entrance to the feed trough requires sows to become aggressive in order to gain entry into the ESF (Spoolder et al., 1997). Thus, sequential feeding creates a new opportunity for aggression as seen specifically in vulva biting of sows in ESF (Rizvi et al., 1998).

Even after being fed their allotted amount, dominant sows quickly return to queue at the ESF entrance, attempting to acquire more feed (Spoolder et al., 1997). As dominant animals repeatedly queue for successful or unsuccessful feed bouts, subordinate sows receive less time at the feeder, possibly compromising their welfare and/or creating more aggression as sows become increasingly hungry. Hunter et al. (1988) observed that 20 sows fed with a daily ESF feeding schedule established a stable social ranking, determined by a stable feeding order, which allowed all sows to eat at least once a day. While a stable social ranking develops in group housing environments with sequential feeding, increased activity levels due to hunger and feeding motivation may still encourage aggression.

Overall, swine research has progressed further with regard to problematic behaviours related to feed restriction and stereotypic behaviours compared with broiler breeder research. Thus, when developing possible solutions regarding feather pecking, aggression, and abnormal behaviours of broiler breeders, one should analyze whether methods of gestating sow management are applicable to broiler breeder husbandry to address this research gap.

2.8 Introduction to broiler breeder feed restriction management systems

Broiler breeder feeding management includes the amount, type, and schedule of feed allocation. Feeding systems can also impact foraging duration and greatly affect behaviour, and ultimately, broiler breeder welfare. Broiler breeders, like sows, can be fed simultaneously or sequentially. Example of simultaneous, competitive methods of feeding broiler breeders include scatter feeding or, more commonly, feed provided in a communal trough using either daily or skip-a-day feeding schedules. Simultaneous, non-competitive feeding systems are not currently practical and do not exist for commercial broiler breeder flocks as they would require protective stalls for each broiler breeder. A sequential feeding system that allocates feed to individuals in separate bouts for an extended period has not previously been scientifically investigated for broiler breeder production systems.

Both simultaneous and sequential feeding systems allow for qualitative or quantitative feed restriction. Qualitative feed restriction involves increasing feeding time through the inclusion of reduced quality feed which is typically high in appetitive suppressants such as calcium propionate (Morrissey et al., 2014) or non-nutritive 'fillers' such as oat hulls (Savory et al., 1996), soybean hulls (Morrissey et al., 2014). Quantitative feed restriction reduces the amount of nutrient-rich feed available to the broiler breeders which subsequently reduces the duration of feeding period. Quantitative feed restriction is the most common broiler breeder feeding management system (Mench, 2002). The two most commonly used quantitative feed restriction methods during the rearing period are skip-a-day and daily feeding of broiler breeders (Mench, 2002). Overall, quantitative feed restriction has been shown to cause higher incidences of problematic behaviours, such as increased activity levels (Morrissey et al., 2014a) and abnormal oral behaviours (Savory et al., 1996) compared with qualitative feed restriction in broiler breeders. However, the significance of welfare benefits produced by qualitative restriction is inconclusive as broiler breeders still perform behaviours indicative of hunger, such as increased activity (Savory et al., 1996; de Jong et al., 2005a). Furthermore, using qualitative restriction in a sequential feeding system may exacerbate aggression by extending waiting at the system's entrance by increasing feeding duration (Bench et al., 2013).

2.8.1 Simultaneous feeding methods

Competition between simultaneously fed, unprotected broiler breeders (eg. at a group trough) occurs via displacement, as one bird pushes another bird away from the distributed feed. As broiler breeders are highly motivated to eat, simultaneous, competitive systems may lead to increased aggression between broiler breeders, as previously identified in sows (Andersen et al., 1999). Feeding competition creates a welfare concern and may reduce the likelihood of some birds ingesting the recommended nutrients, as determined by the projected growth curve. Up until now, a solution to feeding competition between broiler breeders has been to present a simultaneous feeding area large enough (recommended pan feeder space per bird: d 0 to 35: 2 in; d 36 to 70: 3; d 71 to 105: 4 in.; Aviagen, 2013) to spread out feed sufficiently. However, even when a sufficient feeding space is provided to broiler breeders, flock uniformity will still be affected by the flock social order as the most dominant bird will likely ingest the most feed

(Guhl, 1953). Additionally, when feeding broiler breeders in a large trough, feed allocation is determined by the average weight of the broiler breeders in the flock. When allocating feed according to the average body weight, the under- and overweight birds will not ingest the recommended amount of feed. As birds ingest more or less feed that is required to maintain their BW at the target body weight, uniformity is likely to decrease amongst the flock, possibly resulting in decreased production rates.

2.8.1.1 Skip-a-day feeding

Simultaneous, unprotected feeding on a skip-a-day schedule, is a conventional standard practice of broiler breeder feeding management in North America. Skip-a-day feeding is the allocation of twice the amount of the daily feed at a restricted level, on alternate days during the rearing period (Mench, 1988; Morrissey et al., 2014a). Feeding on alternating days creates a welfare concern as birds consume their feed in a short period of time and then experience prolonged periods (approximately 47 hours) without feed (DEFRA, 2007). Anecdotally, skip-a-day feeding increases the uniformity of a broiler breeder flock, however, scientific evidence to support this claim is lacking (Gibson et al., 2008). Mench (1988) previously found skip-a-day-fed male broiler chickens were more aggressive than their *ad libitum* counterparts and that aggressive pecking was most prevalent around the empty feeder during the mornings the broilers were not fed. Morrissey et al. (2014a) also reported skip-a-day-fed broiler breeder pullets feather pecked more during feeding bouts than daily-fed broiler breeder pullets. These results suggest prolonged periods without feed may increase aggression amongst broiler breeders.

2.8.1.2 Limited daily feeding

In limited daily feeding of broiler breeders, which is also a simultaneous and unprotected feeding method, birds are given their allocated feed daily, typically in one bout. Skip-a-day-fed birds must endure approximately 47 hours without feed; daily-fed birds endure approximately 23 hours without feed. Although daily-fed broiler breeders did not have different feather scores compared to skip-a-day-fed broiler breeders, feather damage of daily-fed broiler breeders increased over time more rapidly than skip-a-day-fed birds, suggesting an increase in feather pecking (Morrissey et al., 2014b). However, as their study included the laying period, the authors could not conclude whether feather damage was due to feather pecking, mating behaviours, or both (Morrissey et al., 2014b). Limited daily feeding of broiler breeders increases activity levels (Savory and Maros, 1993) and object pecking behaviours of broiler breeders (Savory et al., 1992) in comparison to *ad libitum* feeding. Therefore, limited daily feeding does not appear to satisfy hunger or foraging motivation of broiler breeders.

2.8.1.3 Scatter-feeding

Scatter-feeding, the distribution of feed in the litter to increase the duration of foraging behaviour, is an example of a simultaneous, competitive feeding system. However, like qualitative restriction, the benefits of scatter feeding are still unclear (de Jong et al., 2005b). van Middelkoop et al. (2000) reported that scattering feed prolongs feeding duration and stimulates foraging behaviours. This stimulation of foraging behaviours may explain why de Jong et al. 2005b) found that scatter feeding reduced the prevalence of object pecking in comparison to feeding twice a day, as the behavioural need to forage was better satisfied. However, de Jong et al. (2005b) did not find a reduction in foraging behaviours or activity levels between scatter-fed broiler breeders and broiler breeders fed from a trough. Therefore, de Jong et al. (2005b) could not conclude that scatter-feeding reduces hunger or foraging frustration.

2.8.2 Sequential non-competitive methods

In a sequential non-competitive feeding system, individuals are protected while eating, thereby eliminating displacement behaviours, or aggressive behaviours which move an animal away from the feeding area. However, queuing for entry to a feeding system may create aggression, as observed in an increase in vulva biting in gestating sows fed with an ESF (Gjein and Larssen, 1995). As broiler breeders are subjected to chronic hunger stress and display aggressive tendencies, competition to enter a sequential feeding system may exacerbate aggression.

2.8.2.1 Precision Broiler Breeder Feeding System

The Precision Broiler Breeder Feeding system (PFS) is a novel non-competitive, sequential feeding system for broiler breeders (Zuidhof et al., 2014). Precision feeding allows individual birds to be fed multiple small meals throughout each day if the bird's BW is less than a target body weight. However, if the bird's BW is more than the target BW, the bird is not provided access to the feed and is ejected from the station (similar to an ESF in group-housed sows). However, it is not known whether aggression, social rank, and stereotypies in precision-fed (PF) broiler breeders using this type of system are similar to sows fed in ESF systems.

The PFS consists of a pre-stage area and a feeding area (Appendix A). The pre-stage area is where the bird is initially weighed and the feeding area is where the bird is given feed. An individual bird enters the pre-stage area and has its BW recorded and compared to a prescribed target BW (e.g. a growth curve recommended by the genetic company (i.e. Aviagen, 2011)). If the broiler breeder BW is equal to or below the hourly updated target BW, the bird can enter the feeding area and is given a small meal (e.g. 25g) in a short duration of time (e.g. one minute) and then is ejected from the station. However, if the weight of the broiler breeder is over the target

BW, the bird is not allowed to enter the feeding area and is immediately ejected from the pre-stage area.

Although Red Jungle Fowl typically encounter periods of feast or famine, restrictively fed broiler breeders are in a consistent state of famine, with an exception of quick bouts of feast every one or two days. As broiler breeders are able to enter the PFS repetitively, regardless of their BW, PFS entries may simulate the foraging behaviours of the Red Jungle Fowl. Further, the PFS theoretically enables broiler breeders to eat multiple small meals throughout each day, the PFS may better simulate the grazing behaviours of Red Jungle Fowl. Thus, the PFS may cause restrictively fed broiler breeders to perceive fewer famine incidences, and therefore reduce hunger motivation, in comparison to conventionally fed broiler breeders. However, as previously discussed, queuing behaviour of sequential feeding systems may create competition to enter the feeding system and broiler breeders may experience increased aggression at the entrance to PFS, due to competition. Therefore, the PFS may increase aggression in a broiler breeder flock, while decreasing the hunger motivation in broiler breeders.

2.9 Hypotheses and Objectives

The primary objective of this thesis was to determine the behavioural consequences of precision feeding broiler breeders in comparison to a conventional, skip-a-day feeding schedule. As such, this thesis did not measure physiological indicators of hunger as a result of feed restriction nor did it focus on internal factors (e.g. genetics) that impact hunger motivation in broiler breeders. Instead, the primary objective of this thesis focused on the external factors (i.e. allocation of restricted feed) related to broiler breeder hunger motivation as measured through behavioural indicators of perceived hunger.

Broiler breeders were feed-restricted to 25-33% of what they would eat *ad libitum* (de Jong et al., 2002) in both feeding system treatments. By providing multiple small meals throughout each day, the PFS may better simulate natural grazing behaviour, by reducing the time between meals. Therefore, precision feeding may reduce hunger motivation in broiler breeders in comparison to broiler breeders fed with a skip-a-day schedule. Within the main objective of this thesis, the first specific objective was to investigate if the PFS affected restlessness in broiler breeders by comparing prevalence of standing and walking in PF and CONV pens. As such, the null hypothesis was that the restlessness (i.e. as measured using standing and walking) of PF and skip-a-day-fed broiler breeders will not differ. If the null hypothesis was rejected, it was concluded that broiler breeders from the feeding system with a higher prevalence of standing and walking also exhibit behaviours indicative of higher perceived hunger, and therefore higher hunger motivation.

As broiler breeders ingest their feed rapidly, their behavioural need to forage (i.e. ground pecking and ground scratching) may not be satisfied due to a reduction in appetitive behaviours. It is recommended that broiler breeders be given opportunities to perform behavioural needs in order to minimize potential welfare concerns (Duncan, 1998). Therefore, the second objective of this thesis was to identify whether prevalence of foraging behaviour was different between broiler breeders fed with a PFS or a skip-a-day system. The null hypothesis was that the prevalence of foraging behaviours will be equal in PF and skip-a-day-fed broiler breeders. If the null hypothesis was rejected, it was concluded that the feeding system with the higher prevalence of ground pecking and scratching behaviours increased satisfaction of the broiler breeders need to forage.

As broiler breeders enter the PF station in search of feed, entering the PFS may act as foraging behaviour in PF broiler breeders which may decrease the presence of re-directed foraging behaviours. As such, use of PFS may decrease the prevalence of stereotypies in comparison to skip-a-day feeding. Therefore, the third objective was to determine whether the use of the PFS resulted in fewer broiler breeders exhibiting a different number of stereotypic oral behaviours compared to skip-a-day feeding. The null hypothesis was that the number of broiler breeders performing stereotypic pen wall, drinker, feeder and feather pecking would be comparable in broiler breeder flocks fed with the PFS compared with broiler breeder flocks fed with a skip-a-day feeding system. If this null hypothesis was rejected, it would be concluded that the feeding system with the lower prevalence of stereotypic pen wall, drinker, feeder, and feather pecking reduced foraging frustration of broiler breeders.

Although sequential feeding of gestating sows eliminated aggression at the feed trough, it re-directed aggression to the ESF entrance (Spoolder et al., 1997). A related fourth objective was to identify whether broiler breeders fed with a sequential PFS exhibited reduced aggression in comparison to simultaneously fed broiler breeders on a skip-a-day schedule or simply re-directed aggression to around the PFS. As such, the null hypothesis was that aggression, as determined by the prevalence of aggressive pecks and fights, around the PFS or skip-a-day communal round hanging feeders, would be equal in PF and skip-a-day-fed broiler breeders. If this null hypothesis was rejected, it was concluded that the broiler breeders which experienced more aggression did so as a result of whether the feeding system was sequential or simultaneous.

Decreasing the availability of feed increases the frequency of social order violations; feed-restricted male broiler breeders exhibited increased aggressive behaviour that does not conform to a bird's social rank (Shea et al., 1990). Therefore, the fifth and final objective was to identify whether broiler breeders fed with a PFS exhibited a different number of social order fluctuations in comparison to skip-a-day-fed broiler breeders. As such, the null hypothesis was that the number of social order fluctuations, as determined by a change in social rank from low to high or vice versa, will be equal between PF and skip-a-day-fed broiler breeders. If this null hypothesis was rejected, it would be concluded that the feeding management system with broiler breeders which experienced more social rank fluctuations caused more social order instability.

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3.0 Feeding and foraging behaviours in precision-fed and skip-a-day-fed broiler breeders[1]

3.1 Abstract

Broiler breeder chickens are feed-restricted to control growth and maximize chick production. Feed restriction creates welfare concerns as conventional skip-a-day feeding can result in increased activity levels and oral stereotypies during the rearing period. A precision feeding system provided small meals to individual birds multiple times throughout a day if their BW was less than a target BW. Objectives of this study were: 1) to investigate whether precision feeding affected restlessness in broiler breeder pullets by comparing prevalence of standing and walking levels to a skip-a-day flock; and, 2) to investigate whether precision feeding affected foraging frustration by comparing foraging and stereotypic oral behaviours in precision feeding and skip-a-day-fed broiler breeders. Using a randomized complete block design, precision feeding and skip-a-day pens were each represented in 6 blocks (n = 6) with 45 Ross 308 pullets per pen. Skip-a-day-fed pullets were fed at 10:30 AM on alternating mornings. Precision-fed pullets were fed multiple small meals daily. Live behavior observations of pullets (15 min per pen, 12 focal birds) were conducted during morning (08:00 – 09:00) and afternoon (13:30 – 15:45) sessions once a week, from 10 to 21 weeks of age. Behaviours observed during instantaneous 1 min scan sampling included: stand/walk, forage, sit, feather peck, dust-bathe, peck at wing-tag, pecking of the drinker, feeder, or pen wall, and 'other' behaviours. Means were considered significant when $P < 0.05$. Feeder and pen wall pecking did not differ between treatments. Skip-a-day-fed pullets performed more stand/walk (6.15 ± 0.05 vs. 5.69 ± 0.05), forage (3.29 ± 0.05 vs. 3.04 ± 0.04), and feather peck (0.16 ± 0.01 vs. 0.03 ± 0.01) behaviours

[1] This chapter will be submitted for potential publication to Applied Animal Behaviour Science and is formatted in accordance with its conventions and instructions to authors

compared with precision-fed pullets, respectively. Precision-fed pullets performed more sitting (0.23 ± 0.01 vs. 0.15 ± 0.01) and drinker pecking (2.60 ± 0.01 vs. 0.15 ± 0.01) behaviours compared with skip-a-day-fed pullets, respectively. Skip-a-day-fed pullets stood most during the mornings on the days they were fed. Feather pecking and foraging were not consistently inversely related, suggesting feather pecking in broiler breeders may have additional causes beyond re-directed foraging. An increase in drinker pecking suggested hunger motivation is still present in a precision-fed flock. In conclusion, compared with skip-a-day feeding, precision feeding appeared to decrease but did not eliminate hunger motivation in feed-restricted broiler breeder pullets.

3.2 Introduction

Genetic selection of broiler chickens for rapid growth has also led to selection for increased appetite (Siege1 and Wisman, 1966). An increased appetite is undesirable in broiler breeders as eating to satiety can increase the prevalence of obesity-related diseases (Hocking et al., 1996) and reduce reproductive performance (Hocking et al., 1987). As such, broiler breeder feed intake is restricted to approximately 25-33% of what broiler breeders would eat *ad libitum* (de Jong et al., 2002) in order to maintain optimal health and reproductive performance. However, feed restriction also creates welfare concerns as broiler breeders exhibit behaviours indicative of hunger and foraging frustration. The current conversation regarding welfare of broiler breeders and feed restriction does not focus on whether or not to use feed restriction. Instead, research primarily investigates how to implement feed restriction so as to decrease the hunger motivation in broiler breeders. It has been suggested that more frequent feeding may improve the welfare of broiler breeders (Mench, 2002).

Hunger motivation in broiler breeders is affected by both the increased appetite of broiler breeders (internal) and the availability of feed in the environment (external). The behavioural indicators of hunger motivation are referred to as perception of hunger in this study. Increased activity levels and re-directed pecking behaviours suggest broiler breeders experience restlessness due to chronic hunger (de Jong et al., 2005) and foraging frustration (Savory et al., 1993). Further, rapid consumption of feed in a feed restricted environment, due to hunger and competition, likely leaves a broiler breeder's behavioural need to forage unsatisfied. For example, already 22 years ago, during daily feeding of broiler breeders during rearing, feed is often consumed in less than 10 minutes (Savory et al., 1993). Ten minutes of feeding behaviours is a relatively short period of time compared to wild-type feeding behaviour, occurs for approximately 95% of the time between dawn and dusk (Dawkins, 1989). The unfulfilled need to forage, combined with hunger motivation caused by feed restriction, may result in feather pecking (de-Haas et al., 2010), or object pecking behaviours (Kostal et al., 1992). Unmitigated, these re-directed pecking behaviours may become abnormal repetitive behaviours and eventually become an abbreviated behaviour with a fixed action pattern (stereotypic in nature; Ödberg, 1978).

Feather pecking is largely thought to be a re-directed foraging behaviour (de Haas et al., 2010) which has negative welfare implications for both the performer and recipient. However, more research is needed regarding the prevalence of feather pecking in female broiler breeders as its incidence has only been minimally studied (de Jong and Guémené, 2011). Object pecking, which can include pen wall, drinker, and feeder pecking, is a welfare concern as it indicates u fulfilled foraging motivation (de Jong et al., 2005) and foraging frustration (Mason and Mendl, 1997). Previous studies have found feed-restricted broiler breeders display more drinker pecking

(Kostal et al., 1992; Savory et al., 1992), empty feeder pecking (Kostal et al., 1992; Savory and Maros, 1993), and pen wall pecking (Savory and Kostal, 2006) compared with *ad libitum* broiler breeders.

A conventional form of feed restriction in North America is skip-a-day feeding (CONV), which allocates approximately twice the restricted daily amount of feed on alternate days during the rearing period (Morrissey et al., 2014a). In the United Kingdom, skip-a-day feeding has been banned as animals must be fed at least once in every 24 hours (DEFRA, 2007), likely due to welfare concerns of prolonged periods without feed. An alternative Precision Broiler Breeder Feeding system (PFS) was designed at the University of Alberta to provide multiple small meals continuously to individual broiler breeders (Zuidhof et al., 2014). Although precision-fed (PF) broiler breeders are still feed restricted, it was hypothesized that due to shorter periods between meals, PF broiler breeders may experience decreased hunger motivation compared to CONV broiler breeders.

The primary objective of this study was to determine the behavioural consequences of precision feeding broiler breeders in comparison to a conventional, skip-a-day feeding schedule. As such, this study did not measure physiological indicators of hunger as a result of feed restriction nor did it focus on internal factors (e.g. genetics) that impact hunger motivation in broiler breeders. Instead, the primary objective of this study focused on the external factors (i.e. allocation of restricted feed) related to broiler breeder hunger motivation as measured through behavioural indicators of perceived hunger. Within this main objective, specific study objectives were: 1) to investigate if the PFS affected restlessness in broiler breeders by comparing prevalence of standing and walking in PF and CONV pens; and, 2) to investigate if the PFS affected perceived hunger by prevalence of foraging, feather pecking and object pecking behaviours in PF and CONV treatments. We sought to test the hypothesis that restlessness (as measured by standing and walking) and amount of foraging, object pecking and feather pecking would differ between PF and CONV flocks. Specifically, we hypothesized that PF pullets would exhibit less restlessness and aberrant pecking due to decreased hunger motivation compared with CONV pullets.

3.3 Materials and methods

The animal protocol for this study was approved by the University of Alberta Animal Care and Use Committee for Livestock and followed principles established by the Canadian Council on Animal Care (CCAC, 2009).

3.3.1 Animals, housing, and diets

Broiler breeder pullets (n=540, Ross 308; Aviagen, Huntsville, Alabama, United States) were reared at the University of Alberta's Poultry Research Centre (Edmonton, Alberta, Canada) from 0 to 22 weeks of age. Prior to 9 weeks of age, the floor pressure of all pens was 4.084 kg/m^2 and pullets began feed restriction at 3 weeks of age. From 3 weeks of age, PF pullets were fed daily in floor troughs and CONV pullets were fed on alternating days from round hanging feeders. Pullets were individually weighed at 9 weeks of age and then randomly assigned to one of 12 pens, resulting in 45 pullets per pen, with a floor pressure of 8.712 kg/m^2 per bird. Floor pressure increased with age and as such, floor pressure of all 12 pens was reduced to 11.132 kg/m^2 at 15 weeks of age (week six of the study). The pullets were exposed to a photoschedule of 23L:1D (d 0 to d 2), 19L:5D (d 3), 16L:8D (d 4), 14L:10D (d 5), 12L:12D (d 6), 11L:13D (d 7). Light intensity decreased from 80 lux at d 0 to 30 lux at d 6. On d 9, a photoperiod of 10L:14D at 10 lux was applied to each pen for the duration of the trial. A standard temperature schedule was used that began at 28°C on d 0 and decreased in a linear fashion to 21°C until d 9. The set temperature was 21°C for the entire study. Each pen contained a depth of approximately 5.0 cm of pine shavings and two suspended nipple drinkers (3.2 pullets per nipple). At 13 weeks of age, a pail of litter (77 L) was removed from each pen and two pails containing fresh litter (77 L each), were added to each pen to maintain dry litter conditions. Each PF pen contained one feeding station (4.8 cm of feeder space) and each CONV pen contained three round hanging feeders, providing 10 cm of feeder space per pullet. All pullets were reared on a mash starter diet (AME: 2,900 kcal/kg, CP:19%,) and then were switched to a mash grower diet (AME: 2,865 kcal/kg, CP: 15%) at 3 weeks of age. For identification purposes, all pullets were wing banded with a radio frequency identification tag on their left wing.

3.3.2 Treatments and Experimental Design

Feeding system treatments in the current study were: CONV, in which broiler breeders were provided a restricted amount of feed on alternate mornings and precision feeding, in which broiler breeders were provided multiple small meals throughout each 24-hr period from a computerized feeding station. Feed allocation for the CONV treatment was based on breeder-recommended BW targets (Aviagen, 2011; Figure 3.1). The PF treatment was composed of three BW curves: Ross 708 (Aviagen, 2013), Ross 308 (Aviagen, 2013), and 'Step'. Interpolated Ross 308 and 708 target BW were updated hourly. The Step BW target followed the Ross 308 target (Aviagen, 2013) but increased BW targets only every 3 weeks, simulating over- and under-feeding of broiler breeders that may occur in industry. Therefore, the Step BW target was identical to Ross 308 BW targets every 1.5 weeks. In spite of the focal birds being on three target BW curves, there was less variation in BW in the PF treatment compared with the CONV treatment. Average body weight of PF pens followed the Ross 308 BW target curve (Figure 3.1). Therefore, the PF target BW curves were not considered in further analyses.

Each PFS consisted of a pre-stage area and a feeding area, which were connected with a door (Appendix C). The pre-stage area was the location where the bird was initially weighed to determine feeding eligibility and the feeding area was where the bird was fed. Once weighed in the pre-stage, if a broiler breeder weighed more than or equal to its target BW, it was ejected from the pre-stage area. If a broiler breeder weighed less than its target BW, the bird was allowed to enter the feeding area and was provided free access to 25 g of feed for 1 min. At the end of the 1 min period, the broiler breeder was ejected from the feeding area. The average meal size per PF broiler breeder was 10.32 g (Figure 3.2). Once a broiler breeder was ejected from the station, the remaining feed was weighed and recorded. The required amount of feed was then added to remaining feed to equal 25 g for the meal of the next pullet.

If a bird BW was at least 250 g below the target BW it was given three minutes to ingest 75g of feed, prior to ejection. Precision-fed pullets that weighed less than 70% of the breeder-recommended weekly BW were identified as in need of PFS training. Training involved manually guiding each identified bird to the station entrance daily. At 15 weeks of age, training shifted to every second day to encourage birds to enter the PFS on their own. Training was considered complete when a pullet entered the station by itself more than four times over a period of 48 hr or when a pullet weighed 70% or more of the breeder-recommended BW. Precision-fed pullets in this experiment entered the station 25 times on average a day and received approximately 8 meals per day (Figure 3.3). Precision feeding systems were considered non-operational when any error mode of the PFS rendered the station inactive. Machine downtime data was calculated for each pen by summing the number of minutes each PFS was non-operational within each week. On average, there was 4:47:07 minutes of machine downtime per day and 18:35:34 minutes of machine downtime per week (Figure 3.4).

Each feeding system (CONV, PF) appeared once in each of six environmentally-controlled chambers (Appendix A) for a randomized completed block design with 6 replicate pens per treatment (Figure 3.2). Pen served as the experimental unit, while 12 focal birds served as the sampling unit for behaviour observations.

3.3.3 Data collection

3.3.1.1 Behaviour observation data

Tail feathers of 12 randomly chosen focal birds (Martin and Bateson, 2009) per pen (four birds per each PF target BW curve in PF pens only) were sprayed with green livestock marker (Raidex, Dettingen an der Erms, Germany) during 9 weeks of age. If a focal bird died during the trial, another bird from the same pen and BW curve was randomly chosen to replace it in order to maintain 12 focal birds per pen and control for equal representation of BW curves in focal birds.

Behaviour observers were evaluated to ensure they were able to differentiate between marked and non-marked tail feathers of focal and non-focal pullets at 10 lux. Observers were trained to code each of the behaviours listed in Table 3.1. Observers were also evaluated weekly to ensure an inter-observer reliability of at least 90% throughout the trial. Behaviour observations began at 10 weeks of age and were conducted using instantaneous scan sampling (Martin and Bateson, 2009) at 1 min sample intervals, according to whether a specific behaviour (Table 3.1) occurred at a single observation sample point (Slater, 1978). All observed behaviours were considered mutually exclusive. Observations were concluded after 21 weeks of age.

Four trained observers rotated through the six chambers, with two observers per pen during each observation session. Observations of each pen took place once during a morning session (08:00 to 09:55) and once during an afternoon session (13:45 to 15:40) on the same observation day, once per week. Each pen was observed for 15 min during each session, with 5 min allocated to allow for observer travel between chambers and broiler breeder acclimatization to observer presence (32 sample points/pen per week; 384 sample points/pen; 4,608 sample points total for all pens over the 12 week study). The order in which pens were observed during observation sessions in each week was randomized. However, during the 12 week experiment, each pen, was observed during each 15 min time slot in each observation session (both AM and PM) twice. Observations occurred on the same day each week, except during 21 weeks of age, in which observations occurred one day earlier due to the beginning of photostimulation. Because CONV pullets were fed on alternating days, during the observation days there were seven days in which CONV pullets were fed (fed-days) and five days they were not fed (non-fed days). Observation data from each 15 min pen observation session was collected from both observers and summed for each scan sampled minute, resulting in 12 focal bird behaviours for each minute.

3.3.1.2 Feather coverage data

Individual feather coverage data for each focal pullet was recorded by one of two trained individuals through manual feather scoring. Feather scoring occurred on the same day each week. Individual feather coverage scores of the: 1) head and neck; and, 2) back and rump were conducted. Feather coverage scores ranged from an ‘a’ (no or slight feather damage) to ‘c’ (at least one featherless area ≥ 5 cm in diameter) according to a modified version of the Welfare Quality® Assessment Protocol for Poultry for plumage damage in laying hens (Welfare Quality®, 2009; Appendix B; Table 3.2). To achieve an overall feather score per bird, the scores of the two regions were combined as: (0) All body parts have score ‘a’; (1) one or more body parts have score ‘b’; (2) one or more body parts have score ‘c’. Ongoing assessment of the two feather coverage areas ensured consistency of feather coverage data collection throughout the trial. The proportions of pullets with feather scoring categories of 0, 1, and 2 were calculated per pen per week.

3.3.5 Statistical Analysis

Data were analyzed as generalized linear mixed models using the GLIMMIX procedure in SAS statistical software v9.4 (SAS Institute; Cary, NC). All models specified a Poisson distribution with a log link function (Kaps and Lamberson, 2004). Type 3 statistics were requested and the inverse link (ilink) option specified to return least squares means on the same scale as the original data. The random term in all models included chamber (block). Time of day (AM, PM) was also considered a block. Block effects and their first order interactions were presented where significant ($P < 0.05$). Least squares means were calculated and a Bonferroni means separation test was used. Main effects and differences between least squares means were considered statistically significant where the probability of the null hypothesis being true was less than 0.05. A tendency was defined as $0.05 \leq P \leq 0.10$ and P-values greater than $P > 0.1$ were considered not significant. Non-significant independent variables were removed from models. Because dust-bathing and pecking at individual identification (Table 3.1) occurred too infrequently to analyze, both were pooled into the 'other' behaviour category.

Models of behaviour data over the entire 12 week trial (which included fed and non-fed days of CONV pullets) included fixed effects of treatment (CONV, PF), age, and the two-way interactions of treatment by age. The models of behaviour data for CONV and PF pullets on fed-days only included the fixed effects of treatment. The model of CONV pullet behaviour on fed- and non-fed days included fixed effects of feed schedule (fed-days, non-fed days). Data from PF pens were excluded from this analysis. The model for feather coverage damage data included the fixed effects of treatment, age, and treatment x age interaction. The CORR procedure of SAS v9.4 (SAS Institute; Cary, NC) was used to determine the correlations (Spearman rank) between feather damage scores, feather pecking, and foraging behaviour within each treatment.

Results in tables are the least squares mean of the number of focal birds performing a specific behaviour per pen per sample point per observation session ± standard error. Results are displayed as the least squares mean divided by the total number of focal birds (12) in order to express the proportion of focal pullets performing a specific behaviour.

3.4 Results

3.4.1 PF vs. CONV (both fed- and non-fed days)

The interaction of time of day and treatment on each observed behaviour was significant (Table 3.3), however, there was also no significant difference in wall ($P = 0.9946$) or feeder pecking ($P = 0.9940$) between treatments during the mornings or afternoons. Standing/walking was exhibited less in PF pens in the mornings as 20% fewer pullets stood/walked in PF pens compared with CONV pens (CONV: 6.88, PF: 5.52; $P < 0.0001$). In the afternoons, these findings were reversed and PF pullets stood/walked significantly more (CONV: 6.88, PF: 5.52; P < 0.0001) compared with CONV pullets. PF pullets tended to forage more in the mornings compared with CONV pullets (CONV: 3.14, PF: 3.43; P = 0.06). However, these findings were also reversed as in the afternoons 22% less PF pullets exhibited foraging behaviours compared with CONV pullets (CONV: 3.44, PF: 2.69; P < 0.0001). Feather pecking was less prevalent in PF pens as 87% (CONV: 0.16, PF: 0.02; P < 0.0001) and 76% (CONV: 0.17, PF: 0.04; P = 0.0011) fewer PF pullets exhibited feather pecking compared with CONV pullets in the mornings and afternoons, respectively. During the mornings, PF pullets performed a two-fold increase in drinker pecking (CONV: 0.13, PF: 0.37; P < 0.0001) and sitting behaviours (CONV: 0.07, PF: 0.17; P = 0.0005) compared with CONV pullets. However, there were no significant difference in the numbers of drinker pecking (P = 0.7677) or sitting (P = 0.5451) behaviours between treatments in the afternoon. Although prevalence of foraging and standing/walking in treatments changed with time of day, CONV pullets consistently exhibited more feather pecking and PF pullets consistently exhibited more object pecking. The effect of time of day (AM or PM) on each observed behaviour was significant (Table 3.4). Pullets stood/walked, foraged, drinker pecked, and feeder pecked significantly more in the mornings compared with the afternoons. Sitting, wall pecking, feather pecking, and 'other' behaviours were each performed significantly more in the afternoons compared with the mornings.

The effect of age on each behaviour was significant (P < 0.001). The effect of treatment x age on each behaviour was also significant (P < 0.001), however in spite of significant age effects, no temporal pattern was identified in any of the behaviours, with the exception of standing and walking. Standing and walking behaviour (Figure 3.4) in CONV pullets appeared to increase and decrease with fed- and non-fed days, respectively. Precision feeding pullets displayed a large decrease in standing and walking behaviour during 14 weeks of age. This magnitude of decreased standing and walking was not observed in CONV pullets. Feather pecking (Figure 3.5) significantly increased between 13 and 14 weeks of age within both CONV (0.27 ± 0.05; vs. 0.66 ± 0.08, respectively; $P = 0.0115$) and PF pullets (0.02 ± 0.01; vs. 0.71 ± 0.09, respectively; $P < 0.0001$). The number of foraging behaviours (Figure 3.6) was the lowest during 14 weeks of age and then significantly increased at 15 weeks of age in both CONV (1.82 ± 0.13; vs. 4.80 ± 0.19, respectively; $P < 0.0001$) and PF pullets (2.35 ± 0.15; vs. 3.57 ± 0.16, respectively; $P = 0.0002$). Pecking at the drinker (3.7) significantly decreased between 16 and 17 weeks of age in both CONV (0.28 ± 0.04; vs. 0.05 ± 0.02, respectively; $P = 0.0030$) and PF pullets (0.37 ± 0.05, 0.13 ± 0.03; $P = 0.0131$).

There was a significant effect of treatment on all behaviours, except pecking at the feeder ($P = 0.9950$) and pecking at the pen wall ($P = 0.9930$; Table 3.5). Standing and walking behaviour was less prevalent in PF pens with 7% fewer pullets in PF pens observed standing and walking compared with pullets in CONV pens. Foraging and feather pecking behaviours were also less prevalent in PF pens with 8% and 81% fewer PF pullets exhibiting these behaviours than those in CONV pens, respectively. Conversely, the number of pullets observed drinker pecking (CONV: 0.26, PF: 0.15; $P < 0.001$), sitting (CONV: 0.15, PF: 0.23; $P < 0.001$), and displaying 'other' behaviours (CONV: 1.15, PF: 1.71; $P < 0.001$) were all greater in PF compared with CONV pens. Standing and walking and foraging were the most widely observed behaviours, accounting for more than 47% of observed behaviours in both treatments. Aberrant behaviours, including pen wall, feeder, drinker, and feather pecking behaviours accounted for 7 % of observed behaviours in PF pens and 3% of observed behaviours in CONV pens.

3.4.2 PF vs. CONV (fed-days only)

The interaction of time of day and treatment was significant for each behaviour except feeder and feather pecking (Table 3.6). Feather pecking was not significantly different between treatments during the mornings or afternoons of fed-days. During the mornings of fed-days, 34% fewer PF pullets stood/walked compared with CONV pullets (CONV: 8.53, PF: 5.67; P < 0.0001). However, PF pullets foraged more compared with CONV pullets (CONV: 2.32, PF: 4.10; P < 0.0001) during the mornings of fed-days. During the afternoons of fed-days, these findings were reversed as PF pullets stood/walked more (CONV: 4.74, PF: 5.98; P < 0.0001) compared with CONV pullets but 37% fewer PF pullets foraged (CONV: 4.10, PF: 5.98; P < 0.0001) compared with CONV pullets. Also during the mornings of fed-days, PF pullets performed a four-fold increase in drinker pecking (CONV: 0.08, PF: 0.33; P = 0.0021), a seven-fold increase in sitting (CONV: 0.03, PF: 0.21; P = 0.0002), and a two-fold increase in 'other' (CONV: 0.66, PF: 1.56; P < 0.0001) behaviours compared with CONV pullets. During the afternoons, PF pullets performed 44% fewer drinker pecking (CONV: 0.27, PF: 0.16; P = 0.0172) behaviours compared with CONV pullets. Precision feeding pullets performed more wall pecking compared with CONV pullets in the mornings (CONV: 0.01, PF: 0.22; P = 0.0035) and afternoons (CONV: 0.11, PF: 0.25; P = 0.0035). Precision feeding pullets tended to perform more feeder pecking compared with CONV pullets in the mornings (CONV: 0.31, PF: 0.44; P = 0.0771), however there was no significant difference in feeder pecking (P = 0.1010), sitting (P = 0.1054), or 'other' (P = 0.8844) behaviours between treatments in the afternoons. In fact, fewer than 5% of pullets were observed to be sitting in either treatment during fed-days. The effect of time of day (AM or PM) on every observed behaviour was significant (Table 3.7). Pullets stood/walked and pecked at the feeder significantly more in the mornings compared with the afternoons. Foraging, sitting, drinker pecking, wall pecking, feather pecking, and 'other' behaviours were all performed significantly more in the afternoons compared with the mornings.

On fed-days for the CONV treatment, the observed number of all behaviours, except foraging (P = 0.5830), was significantly affected by feed schedule (Table 3.8). On fed-days, 8% and 54% fewer pullets in PF pens were observed standing and walking (CONV: 6.36, PF: 5.83; P = 0.0001) and feather pecking (CONV: 0.13, PF: 0.06; P = 0.0053) than those in CONV pens, respectively. Conversely, the number of pullets observed sitting (CONV: 0.13, PF: 0.29; P = 0.0001), pecking drinkers (CONV: 0.15, PF: 0.24; P = 0.0029), pecking walls (CONV: 0.03, PF: 0.23; P = < 0.0001) and feeders (CONV: 0.28, PF: 0.40; P = 0.0020) were all greater in PF compared with CONV pens (P < 0.01). Standing and walking and foraging were the behaviours most exhibited by focal pullets, accounting for more than 75% of observed behaviours in both treatments. In contrast, fewer than 10% of pullets were observed to be engaged in aberrant pecking behaviours directed at walls, feeders, drinkers, or feathers, combined.

3.4.3 Fed- vs. non-fed days within CONV treatment

The interaction of time of day and feed schedule significantly affected each behaviour in CONV pullets (Table 3.9). Skip-a-day-fed pullets stood/walked significantly more in the mornings of fed-days compared non-fed days (Fed: 8.53, Non-fed: 4.74; P < 0.0001). Standing and walking behaviour during the mornings of fed-days accounted for 71% of observed behaviours while during non-fed days, standing and walking accounted for 40% of observed behaviours. During the mornings of non-fed days, CONV pullets exhibited a two-fold increase in foraging (Fed: 8.53, Non-fed: 4.76; P < 0.0001) and pecking at the feeder (Fed: 0.31, Non-fed: 0.63; P = 0.0077), a six fold increase in sitting behaviour (Fed: 0.03, Non-fed: 0.18; P = 0.0084), a four-fold increase in pecking at the drinker (Fed: 0.08, Non-fed: 0.31; P = 0.0041), and a seven-fold increase in feather pecking (Fed: 0.06, Non-fed: 0.44; P = 0.0012) behaviours compared with the mornings of fed-days. There were also slightly more 'other' behaviours (Fed: 0.66, Non-fed: 1.07; P = 0.0226) and a five-fold increase (though a weak tendency) in wall pecking behaviours (Fed: 0.01, Non-fed: 0.05; P = 0.0948) during the mornings of non-fed days compared with fed-days.

During afternoons of non-fed days, CONV pullets stood/walked more compared with afternoons of fed-days (Fed: 4.74, Non-fed: 6.57; P = 0.0003). During the afternoons of fed-days, CONV pullets displayed more foraging (Fed: 4.10, Non-fed: 3.05; P < 0.0001), more sitting (Fed: 0.53, Non-fed: 0.31; P = 0.0084), and more 'other' behaviours (Fed: 2.26, Non-fed: 1.50; P = 0.0226) compared with non-fed days. In the afternoons, feather pecking tended to occur more during fed-days compared with non-fed days (Fed: 0.27, Non-fed: 0.15; P = 0.0958). Pecking at the drinker, wall, and feeder were not significantly different in CONV pullets during the afternoons of fed- and non-fed days (P > 0.10). Time of day (AM or PM) significantly affected each observed behaviour, except feather pecking (Table 3.10). Skip-a-day-fed pullets stood/walked and pecked at the feeder significantly more in the mornings compared with the afternoons. Foraging, sitting, drinker pecking, wall pecking, and 'other' behaviours were all performed significantly more in the afternoons compared with the mornings by CONV pullets.

'Other' behaviours and pecking at the feeder were not significantly different in CONV pullets between fed- and non-fed days (Table 3.11). Skip-a-day-fed pullets stood/walked more during fed-days compared with non-fed days (Fed: 6.36, Non-fed: 5.60; P = 0.0007). Conversely, the number of pullets observed foraging (Fed:3.08, Non-fed: 3.73; P = 0.0012), sitting (Fed:

0.13, Non-fed: 0.24; P = 0.0083), feather pecking (Fed: 0.13, Non-fed: 0.25; P = 0.0035), and pecking drinkers (Fed: 0.15, Non-fed: 0.23; P = 0.0153), or walls (Fed: 0.03, Non-fed: 0.06; P = 0.0301), were all higher on non-fed-days compared with fed-days. Specifically, 7% of observed behaviours were object pecking or feather pecking on non-fed days, while these behaviours accounted for 5% of observed behaviours on fed-days.

3.4.4 Feather damage

There was no significant effect of feeding system treatments, age, or treatment x age on the prevalence of feather damage scores of 0, 1, or 2 (P > 0.10; Table 3.12). No significant correlation was found between feather pecking, foraging, or any of the feather damage scores of 1 or 2 in either feeding system treatment (P > 0.10). In CONV pullets, there was a relatively weak negative correlation, despite being significant, between feather pecking and foraging behaviours (r^2 = -0.26; P < 0.05, and r^2 = -0.27; P = 0.0275; respectively).

3.5 Discussion

3.5.1 Treatment, feed schedule, and time of day effects on behaviour

Previous literature has identified an increase in broiler breeder activity due to feed restriction (de Jong et al., 2002; Hocking et al., 1996; Savory and Maros, 1993). As such, as hunger increased, hunger motivation increased and was exhibited as an increase in standing behaviours. In the current study, we found CONV pullets stood and walked more compared with PF pullets. Further, a large increase in standing and walking behaviour of CONV pullets during the mornings of fed-days, after pullets had experienced approximately 47 hours without feed, suggests a high hunger motivation. Increased standing and walking during the mornings of fed-days could be due to pullets anticipating feed delivery (Kostal et al, 1992). However, the overall higher amount of standing and walking behaviour in CONV pullets, compared with PF pullets, suggests CONV pullets experience higher restlessness due to increased hunger motivation. Therefore, the current findings suggest that providing pullets with multiple small meals a day may have decreased the broiler breeder's hunger motivation compared to CONV feeding.

An increase in sitting behaviour, or inactivity, has been found to indicate a lower level of hunger (Sandilands et al., 2005). In the current study, although sitting was only observed minimally, CONV pullets sat less compared with PF pullets. However, contrary to expectations, increased sitting behaviour was observed in CONV pullets during days they were not fed. Previous literature has shown broiler breeders can learn their feeding schedule and will anticipate feed delivery (Kostal et al., 1992). As such, increasing sitting behaviour on non-fed days may not indicate satiety, rather it may indicate birds are not anticipating feed delivery. Although inactivity is considered indicative of decreased hunger (Sandilands et al, 2005), sitting may not have reflected a decrease in hunger motivation in the current study. Therefore, it appears that standing and walking behaviour is indicative of hunger motivation more than sitting behaviour is indicative of satiety or comfort.

Foraging is a feed-seeking behaviour and a behavioural need of poultry (Duncan, 1998). A behavioural need is controlled largely by internal factors (e.g. motivation), as external factors (e.g. environment) do not ultimately determine presence or absence of the behaviour (Duncan, 1998). Dawkins (1989) observed that the Red Jungle Fowl, the wild-type to domesticated chicken (Fumihito et al., 1994), spends the majority of its time foraging. Foraging allows Red Jungle Fowl to actively respond to periods of feed shortage. Although domestication has reduced the amount of time modern poultry forage (Schütz and Jensen, 2001), a greater amount of foraging behaviour may indicate more fulfillment of a behavioural need. In the current study, CONV pullets foraged more than PF pullets (Table 3.4), which may indicate better satisfaction of the need to forage in CONV pens.

However, CONV pullets displayed increased foraging behaviours on non-fed days compared with fed-days. Increased foraging behaviour of feed-restricted birds may be linked to an increase in hunger (Merlet et al., 2005). Skip-a-day-fed pullets also displayed increased foraging behaviours during the afternoons of fed-days (Table 3.9). Post-consumption, broiler breeders may still be hungry due to increased appetite as a result of a intensive selection for rapid growth in broilers (Siegel and Wisman, 1966). Further, walking before and pecking the litter after feeding time are thought to be indicative of hunger (Savory and Maros, 1993). Thus, CONV pullets may have exhibited increased foraging behaviours due to hunger and a lack of satiety. However, a broiler breeder that has rapidly ingested its meal may still display foraging behaviours post-consumption as its foraging motivation was not satisfied (Duncan, 1998). Therefore, an increase in CONV pullet foraging behaviour post-consumption may indicate the behavioural need to forage is not satisfied or that pullets are not sated.

Feed is allocated to PF pullets whenever the pullet's BW is below the target BW. This likely creates a random interval environment in which the pullet is not aware of when they will 'find' feed. Therefore the act of entering the station may simulate feed-seeking, or foraging, behaviour. The allocation of multiple small meals per day may also better simulate the Red Jungle Fowl's daily travel between areas of feed and areas without feed (Collias and Collias, 1967) compared with CONV feeding. Thus, while CONV pullets foraged more than PF pullets, it does not appear that the behavioural need to forage is better satisfied in the CONV feeding system. As such, the exhibition of increased foraging behaviour may not always be a positive indicator of welfare as it may indicate feed-seeking or foraging frustration behaviours. Further, the behavioural need to forage is not satisfied, foraging behaviours may become re-directed aberrant behaviours such as stereotypic feather and object pecking.

Feather pecking is thought to be a re-directed ground foraging behaviour in laying hens (Huber-Eicher and Weschler, 1998). As foraging behaviours decrease, feather pecking behaviours should thus increase (Huber-Eicher and Weschler, 1998). However, in the current study, CONV pullets displayed an increase in both foraging and feather pecking behaviours compared with PF pullets. Additionally, only a relatively weak negative correlation between feather pecking and foraging behaviours in CONV pullets was observed in the study, while no significant correlation between feather pecking and foraging in PF pullets was found. Therefore, these findings are not consistent with previous observations that feather pecking is due to re-directed foraging behaviours. Further, CONV pullets displayed increased feather pecking during non-fed days compared with fed-days. As such, increased feather pecking in CONV pullets may be due to prolonged periods without feed.

Skip-a-day-fed pullets may have learned their alternating feed schedule and subsequently exhibited behaviours indicative of hunger motivation during the days they did not expect feed. Conversely, PF pullets could not fully learn their feeding schedule as they were not guaranteed feed every time they entered the station. Therefore, instead of waiting for the next feed delivery, PF pullets experienced a more random feed delivery schedule. A random feed delivery schedule may be akin to a variable ratio schedule of reinforcement of an operant task. In this case, it is unclear what specific feeding-related behaviours were being reinforced in PF pullets. As PF pullets exhibited more than a 3-fold increase in aberrant pecking behaviours (object pecking and feather pecking), the random feed schedule may have increased hunger motivation in PF pullets. Although provision of multiple small meals a day appears to have decreased restlessness in PF pullets, the random feed delivery schedule may have caused an increase in aberrant pecking behaviours.

Another explanation of decreased feather pecking could be that PF pullets experienced decreased hunger motivation compared with CONV pullets. Although PF pullets do not consume as much feed per meal as CONV pullets (due to smaller but more frequent meals), ingestion of multiple small meals per day may decrease hunger motivation, regardless of meal size. In contrast to this, Morrissey et al. (2014b) hypothesized that skip-a-day-fed pullets experienced increased satiety after eating (due to ingesting double the meal size of daily-fed pullets) and therefore exhibited decreased feather pecking in comparison to daily-fed pullets. Although the findings of the current study do not support the theory of Morrissey et al. (2014b), both studies identified a possible relationship between feather pecking and hunger motivation in broiler breeders.

The majority of research into feather pecking in domesticated poultry has been conducted on laying hens. Although it is known that feather pecking occurs amongst broiler breeders, minimal research has been done to determine the degree to which broiler breeders exhibit feather pecking behaviour (de Jong and Guémené, 2011). The current study identified that feather pecking occurred minimally (less than 2% of focal birds feather pecked in this experiment) amongst broiler breeder pullets during observations. Further, the cause of feather pecking in broiler breeders appears to be distinct from laying hens. Although feather pecking in laying hens is thought to be due to an environment not conducive to natural foraging behaviour (Huber-

Eicher and Weschler, 1998), feather pecking in broiler breeders may also be due to feed restriction. The findings in the current study indicate that prolonged periods without feed may increase feather pecking in broiler breeders as a result of perceived hunger not being sufficiently reduced. However, feather pecking was observed in both CONV and PF broiler breeder treatments. Therefore, while providing multiple small deals each day decreased restlessness as one perception of hunger in PF pullets, PF pullets still exhibited feather pecking behaviours indicative of overall unresolved hunger motivation.

Ingestion of small meals should lead to increased foraging behaviours in chickens due to an unfulfilled hunger motivation (Mason and Mendl, 1997). If the broiler breeder does not become satiated post-consumption, increased foraging behaviours may lead to re-directed or stereotypic object pecking in a domestic environment. The current study found object pecking increased with more frequent feeding (PF compared with CONV pullets). Interestingly, during non-fed days, CONV pullets pecked at the drinker and pen wall more compared with fed-days. Thus, while it appears that increased prevalence of post-consummatory periods may have increased object pecking in PF pullets, prolonged periods without feed may have increased object pecking in CONV pullets. Previous research found no influence of daily or skip-a-day feeding schedules on the prevalence of object pecking (Morrissey et al., 2014a). This lack of significant difference found by Morrissey et al. (2014a) could be due to the larger meal sizes provided in both daily and skip-a-day feeding. The small meals allocated by the PFS may have been too small (average: 10.32 g per meal) to satisfy the broiler breeder pullet's hunger motivation. Due to this unsatisfied motivation, PF pullets may have exhibited increased foraging behaviours that eventually became re-directed into object pecking behaviours. Precision-fed pullets may thus benefit from longer meal durations which still allow for multiple small meals each day but better allows for hunger motivation to be reduced.

Because pens were examined with instantaneous scan sampling for 15 minutes per session, it could not be concluded that object or feather pecking were truly stereotypic (i.e. fixed). As such, object pecking and feather pecking can only be categorized as a behavioural vice in both treatments. The current study found PF pullets exhibited more drinker pecking compared with CONV pullets. The location of the drinker (Figure 3.) in relation to the PFS may have caused the significantly higher prevalence of drinker pecking behaviour in PF pullets. The PFS guided bird traffic towards the ends of the pen. In particular, the drinker at the back of each PF pen was in close proximity to where birds waited to enter the PF station. Thus, a drinker location close to the PF station entrance may have encouraged pecking at the drinker as a re-directed foraging behaviour.

A notable difference between treatments was the consistently higher number of 'other' behaviours performed by PF pullets compared with CONV pullets. 'Other' behaviours captured all behaviours not defined in the ethogram such as (but not limited to) dust-bathing, pecking individual identification, preening, system entries, drinking, feeding, and aggression. However, because 'other' behaviours were any behaviour that was not defined for this study, no conclusion can be made regarding the nature of these behaviours. Therefore precision feeding future research may want to expand the behaviour ethogram.

3.5.2 Ontogeny

At 13 weeks of age, a pail of litter (77 L) was removed from each pen and two pails containing fresh litter (77 L each), were added to each pen to maintain dry litter conditions. The effect of the new litter addition coincided with a rise in feather pecking behaviour in both CONV and PF treatments during 14 weeks of age. Although the effect of adding litter was not specifically tested in the current study, the data collected during this time period may provide further insight into behaviours of feed-restricted broiler breeder pullets. A possible explanation of this increase in feather pecking might be that the pullets may have exhibited increased feed-seeking behaviour due to the novelty of the new litter. However, foraging behaviours in both treatments decreased by 14 weeks of age (5 days after litter was added) and feather pecking behaviours increased compared with the previous week. It is possible that as pullets foraged in the new litter material and were consistently unsuccessful in finding feed, feather pecking developed as a re-directed ground foraging behaviour.

At 14 weeks of age, CONV pullets showed a decrease in drinker pecking which was not observed in PF pullets. Skip-a-day-fed pullets may have re-directed foraging to feather pecking while PF pullets re-directed foraging to drinker pecking. The difference in re-directed foraging behaviours between CONV and PF pullets could be due to foraging behaviours being simulated differently in each feeding system. Savory et al. (1992) found the incidence of object pecking increased by approximately 80% between 11 and 18 weeks of age in feed-restricted broiler breeders. In the current study, object pecking decreased with age in both treatments. This difference in results could be due to different housing systems as broiler breeders were individually caged (due to an outbreak of fighting) in the Savory et al. (1992) study compared with free-run in the current study. Further, a decrease in object pecking with age in the current trial could be due to reduced frustration due to decreasing degree of feed restriction as pullets approach the onset of lay (Aviagen, 2013).

It would be expected that as severity of feed restriction lessened due to preparation for photostimulation (after 14 weeks of age in the current experiment), exhibition of standing and walking behaviours would also decrease due to a decrease in hunger motivation. However, prevalence of standing and walking behaviour did not decrease with age. A possible explanation of birds still displaying high levels standing and walking as feed restriction lessened, is that even with decreasing severity of feed restriction, both CONV and PF pullets still experienced a high level of hunger motivation. Further, standing and walking was always the most predominant behaviour in both feeding system treatments. Therefore, while behaviours indicative of foraging frustration (e.g. object pecking; Figure 3.5) decreased with age, pullets in both treatments were still highly hunger motivated, as evidenced by restlessness.

Previous literature reported an inverse relationship between foraging and feather pecking (Blokhuis and Arkes, 1984; Huber-Eicher and Wechsler, 1998). In the current study, a relatively weak negative correlation between feather pecking and foraging behaviours was found in CONV pullets. Different causes of feather pecking have been previously identified in laying hens. For example, gentle feather pecking is thought to be an exploratory behaviour and is not typically considered a welfare concern. In contrast, severe feather pecking is thought to be caused by re-directed foraging which is a welfare concern as it can result in feather loss (Savory, 1995; Rodenburg et al., 2013). Specific feather pecking types and their different causal factors have not yet been investigated in broiler breeders. In this trial, feather pecking was only defined as one bird using its beak to grasp the feathers of another bird. It is possible that we observed different types of feather pecking with unique causes within our definition of feather pecking. Thus, contrary to previous reports, this broad definition of feather pecking may explain why feather pecking behaviour was not clearly correlated with foraging behaviours.

3.5.3 Feather damage

That feather damage of PF pullets was similar to that of CONV pullets was unexpected, given the lower observed prevalence of feather pecking in PF compared with CONV treatments. However, feather coverage scores indicative of feather damage did occur in both feeding system treatments. Further, severe feather damage scores of '2' (featherless areas greater than 5 cm) occurred, albeit minimally, in each feeding system. The Welfare Quality® assessment for plumage damage was based on feather scoring in laying hens and therefore may need to be modified to better fit broiler breeders. The current study suggests feather pecking in broiler breeders may be increased by hunger due to a level of feed restriction not observed in laying hens. Therefore, while this study has provided data on the prevalence of feather pecking in broiler breeders in CONV and PF feeding systems, further research is needed regarding the specific causes of feather pecking in broiler breeders.

3.6 Conclusion

Providing feed-restricted broiler breeder pullets with multiple small meals a day decreased restlessness in pullets compared with CONV feeding. Greater feather pecking behaviour exhibited by CONV pullets compared with PF pullets may indicate increased foraging frustration and hunger motivation due to prolonged periods without feed. However, greater object pecking in PF pullets compared with CONV pullets suggests foraging frustration is still experienced by PF pullets. Therefore, while the PFS changed perception of hunger compared with the CONV system, the PFS does not appear to have eliminated hunger motivation in feed-restricted broiler breeder pullets.

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Table 3.1. Ethogram detailing behaviour measurements.

Behaviour[1]	Definition
Stand/Walk	Bird is positioned on its feet, in an elevated manner and is not performing any other behaviours. Can be stationary or walking.
Forage	Beak motion directed towards the litter and/or scratching of the litter with the feet.
Sit	Bird is positioned low to the ground with body supported by the rump or breast muscle and is not performing any other behaviours.
Feather Peck	One bird uses its beak to grasp and pulls the feather of another bird. A feather can be from any area of the bird's body except the vent or wing.
Feeder Peck	Beak motion directed at a feed trough or the base or walls of the precision feeding system, performed in a stereotypic manner[2] that does not result in ingestion of feed.
Drinker Peck	Beak motion directed at a drinker in a stereotypic manner[2] that does not result in ingestion of water.
Pen Wall Peck	Beak motion directed at the pen wall in a stereotypic manner[2].
Dust-bathe	Bird is positioned low to the ground, with body supported by the breast muscle or side of body. Bird pushes litter with wings or legs, or both.
Peck at Wing-tag	Bird uses beak to peck or pull at its own identification tag or the identification tag of another bird.
Other	Any behaviour that is not a previously listed behaviour.

[1]Behaviour definitions modified from the ethogram of de Jong et al. (2005)

[2]Stereotypic behaviours were defined as repetitive and fixed behaviours with no apparent goal or function (Ödberg, 1978)

Table 3.2. Feather damage scoring criteria[1].

Feather Score	Feather Description
a	No or slight feather damage or wear, nearly complete feathering with no or only single feathers lacking
b	Moderate feather damage or wear, < 5 cm in diameter of featherless area
c	Significant feather damage, at least one featherless area ≥ 5 cm in diameter

[1] To achieve an overall feather score per bird the scores of the 2 body parts are combined according to the following classification: 0: All body parts have score 'a'; 1: one or more body parts have score 'b'; 2: one or more body parts have score 'c'. (Source: Welfare Quality®, 2009)

Table 3.3. Block effect (time of day; AM or PM)[1] and feeding system (skip-a-day (CONV) or precision feeding (PF)) on the number of observed behaviours. Data was collected from 12 focal birds per 6 CONV and 6 PF pens, during 15 minute observation sessions[2]. Observations occurred when pullets were 10 to 21 weeks of age[3]. CONV pullets were fed at 10:30 AM on alternating mornings[4] in communal feed troughs and PF pullets were individually fed multiple small meals per day from a computerized feeding station.

Behaviour[5]	CONV AM[6]		CONV PM		PF AM		PF PM		Time of day x Treatment **P-value**[7]
Stand/walk	$6.88^{a} \pm 0.07$	[0.57]	$5.50^{c} \pm 0.07$	[0.46]	$5.52^{c} \pm 0.07$	[0.46]	$5.86^{b} \pm 0.07$	[0.49]	<0.0001
Forage	$3.14^{b} \pm 0.06$	[0.26]	$3.44^{a} \pm 0.07$	[0.29]	$3.43^{ab} \pm 0.06$	[0.29]	$2.69^{c} \pm 0.06$	[0.22]	<0.0001
Sit Lay	$0.07^{c} \pm 0.01$	[0.01]	$0.32^{a} \pm 0.02$	[0.03]	$0.17^{b} \pm 0.01$	[0.01]	$0.30^{a} \pm 0.02$	[0.03]	<0.0001
Peck drinker[8]	$0.13^{b} \pm 0.01$	[0.01]	$0.18^{b} \pm 0.01$	[0.02]	$0.37^{a} \pm 0.02$	[0.03]	$0.19^{b} \pm 0.01$	[0.02]	<0.0001
Peck wall[8]	$0.00^{b} \pm 1.28$	[0.00]	$0.02^{a} \pm 5.40$	[0.00]	$0.16^{ab} \pm 0.02$	[0.01]	$0.17^{ab} \pm 0.02$	[0.01]	0.0003
Peck feeder[8]	$0.07^{a} \pm 24.34$	[0.01]	$0.03^{b} \pm 10.98$	[0.00]	$0.47^{ab} \pm 0.02$	[0.04]	$0.38^{ab} \pm 0.02$	[0.03]	0.0005
Feather peck	$0.16^{a} \pm 0.01$	[0.01]	$0.17^{a} \pm 0.02$	[0.01]	$0.02^{c} \pm 0.00$	[0.00]	$0.04^{b} \pm 0.01$	[0.00]	0.0059
Other	$0.71^{d} \pm 0.03$	[0.06]	$1.85^{b} \pm 0.05$	[0.15]	$1.38^{c} \pm 0.04$	[0.12]	$2.11^{a} \pm 0.06$	[0.18]	<0.0001

[1] Observations took place during morning (08:00 to 09:55) and afternoon (13:45 to 15:40) sessions on each observation day each week
[2] 32 observations/pen per week; 384 observations/pen; 4608 observations total for all pens over the 12 week study
[3] These weeks included weeks CONV pullets were fed and weeks CONV pullets were not fed
[4] Morning observations of CONV pullets are pre-feeding periods and afternoon observations of CONV pullets are post-feeding periods
[5] a-c means within rows with no common superscript differ significantly (at least P < 0.05)
[6] Count data, (least squares mean of the number of focal birds performing a specific behaviour at any given point in time ± standard error) [Numbers in brackets average proportion of focal birds at any given point in time performing a specific behaviour]
[7] A Bonferonni means separation test was used
[8] Stereotypic behaviours were defined as repetitive and fixed behaviours with no apparent function (Ödberg, 1978)

Table 3.4. Block effect (time of day; AM or PM)[1] on the number of observed behaviours performed by pullets fed with skip a day (CONV) and precision feeding systems. Data was collected from 12 focal birds per pen, 6 skip-a-day and 6 precision feeding, during 15 minute observation sessions[2]. Observations occurred when pullets were 10 to 21 weeks of age[3]. Pullets in CONV pens were fed at 10:30 AM on alternating mornings in communal feed troughs[4] and precision feeding pullets were individually fed multiple small meals per day from a computerized feeding station.

Behaviour	AM[5]	PM	**P-value**
Stand/walk	6.17 ± 0.05 [0.51]	5.67 ± 0.05 [0.47]	<0.0001
Forage	3.28 ± 0.04 [0.27]	3.04 ± 0.04 [0.25]	0.0029
Sit Lay	0.11 ± 0.01 [0.01]	0.31 ± 0.01 [0.03]	0.0034
Peck drinker[6]	0.22 ± 0.01 [0.02]	0.18 ± 0.01 [0.02]	0.0219
Peck wall[6]	0.02 ± 4.18 [0.00]	0.05 ± 8.76 [0.00]	0.0002
Peck feeder[6]	0.18 ± 31.46 [0.02]	0.11 ± 18.92 [0.01]	<0.0001
Feather peck	0.05 ± 0.01 [0.00]	0.09 ± 0.01 [0.01]	0.0016
Other	0.99 ± 0.03 [0.08]	1.97 ± 0.04 [0.16]	<0.0001

[1] Observations took place during morning (08:00 to 09:55) and afternoon (13:45 to 15:40) sessions on each observation day each week
[2] These weeks included weeks skip-a-day (CONV) -fed pullets were fed and weeks CONV pullets were not fed
[3] 32 observations/pen per week; 384 observations/pen; 4608 observations total for all pens over the 12 week study
[4] Morning observations of CONV pullets are pre-feeding periods and afternoon observations of CONV pullets are post-feeding periods
[5] Count data, (least squares mean of the number of focal birds performing a specific behaviour at any given point in time ± standard error) [average proportion of focal birds at any given point in time performing a specific behaviour]
[6] Stereotypic behaviours were defined as repetitive and fixed behaviours with no apparent function (Ödberg, 1978)

Table 3.5. Effect of feeding system (skip-a-day (CONV) or precision feeding (PF)) on the number of observed behaviours. Data was collected from 12 focal birds per 6 CONV and 6 PF pens, during 15 minute observations[1]. Observations occurred when pullets were 10 to 21 weeks of age[2]. Pullets in CONV pens were fed at 10:30 AM on alternating mornings in communal feed troughs and PF pullets were individually fed multiple small meals per day from a computerized feeding station.

Behaviour	CONV [3]		PF		**P-value**
Stand/walk	6.15 ± 0.05	[0.51]	5.69 ± 0.05	[0.47]	<0.0001
Forage	3.29 ± 0.05	[0.27]	3.04 ± 0.04	[0.25]	0.0029
Sit Lay	0.15 ± 0.01	[0.01]	0.23 ± 0.01	[0.02]	0.0012
Peck drinker[4]	0.15 ± 0.01	[0.01]	0.26 ± 0.01	[0.02]	<0.0001
Peck wall[4]	0.01 ± 2.63	[0.00]	0.16 ± 0.01	[0.01]	0.9930[5]
Peck feeder[4]	0.05 ± 16.35	[0.00]	0.42 ± 0.02	[0.04]	0.9950[5]
Feather peck	0.16 ± 0.01	[0.01]	0.03 ± 0.01	[0.00]	<0.0001
Other	1.15 ± 0.03	[0.10]	1.71 ± 0.04	[0.14]	<0.0001

[1] 32 observations/pen per week; 384 observations/pen; 4608 observations total for all pens over the 12 week study
[2] These weeks included weeks CONV pullets were fed and weeks CONV pullets were not fed
[3] Count data, (least squares mean of the number of focal birds performing a specific behaviour at any given point in time ± standard error) [average proportion of focal birds at any given point in time performing a specific behaviour]
[4] Stereotypic behaviours were defined as repetitive and fixed behaviours with no apparent function (Ödberg, 1978)
[5] P > 0.10 were considered not significant

Table 3.6. Block effect (time of day; AM or PM)[1] and feeding system (skip-a-day (CONV) or precision feeding (PF)) on the number of observed behaviours during observation days when CONV pullets were fed[2]. Data was collected from 12 focal birds per 6 CONV and 6 PF pens, during 15 minute observation sessions. Observations occurred when pullets were 10, 12, 14, 16, 18, 20, and 21 weeks of age. CONV pullets were fed at 10:30 AM on alternating mornings[3] in communal feed troughs and PF pullets were individually fed multiple small meals per day from a computerized feeding station.

Behaviour[4]	CONV AM[5]		CONV PM		PF AM		PF PM		Time of day x Treatment **P-value**[7]
Stand/walk	$8.53^{a} \pm 0.10$	[0.71]	$4.74^{c} \pm 0.08$	[0.40]	$5.67^{b} \pm 0.08$	[0.47]	$5.98^{b} \pm 0.09$	[0.50]	0.0001
Forage	$2.32^{c} \pm 0.07$	[0.19]	$4.10^{a} \pm 0.10$	[0.34]	$3.54^{b} \pm 0.09$	[0.30]	$2.60^{c} \pm 0.08$	[0.22]	<0.0001
Sit Lay	$0.03^{c} \pm 0.01$	[0.00]	$0.53^{a} \pm 0.03$	[0.04]	$0.21^{b} \pm 0.02$	[0.02]	$0.40^{a} \pm 0.03$	[0.03]	<0.0001
Peck drinker[6]	$0.08^{c} \pm 0.01$	[0.01]	$0.30^{a} \pm 0.03$	[0.03]	$0.33^{a} \pm 0.03$	[0.03]	$0.17^{b} \pm 0.02$	[0.01]	<0.0001
Peck wall[6]	$0.01^{c} \pm 0.00$	[0.00]	$0.11^{b} \pm 0.02$	[0.01]	$0.22^{a} \pm 0.02$	[0.02]	$0.25^{a} \pm 0.02$	[0.02]	0.0011
Peck feeder[6]	$0.31^{ab} \pm 0.03$	[0.03]	$0.25^{b} \pm 0.03$	[0.02]	$0.44^{a} \pm 0.03$	[0.04]	$0.37^{ab} \pm 0.03$	[0.03]	0.8553[8]
Feather peck	$0.06^{b} \pm 0.01$	[0.01]	$0.27^{a} \pm 0.03$	[0.02]	$0.02^{b} \pm 0.01$	[0.00]	$0.16^{a} \pm 0.02$	[0.01]	0.3181[8]
Other	$0.66^{c} \pm 0.05$	[0.06]	$2.26^{a} \pm 0.10$	[0.19]	$1.56^{b} \pm 0.08$	[0.13]	$2.48^{a} \pm 0.10$	[0.21]	<0.0001

[1] Observations took place during morning (08:00 to 09:55) and afternoon (13:45 to 15:40) sessions on each observation day each week
[2] 32 observations/pen per week; 384 observations/pen; 2688 observations total for all pens
[3] Morning observations of CONV pullets are pre-feeding periods and afternoon observations of CONV pullets are post-feeding periods
[4] a-c means within rows with no common superscript differ significantly (at least $P < 0.05$)
[5] Count data, (least squares mean of the number of focal birds performing a specific behaviour at any given point in time ± standard error) [average proportion of focal birds at any given point in time performing a specific behaviour]
[6] A Bonferonni means separation test was used
[7] Stereotypic behaviours were defined as repetitive and fixed behaviours with no apparent function (Ödberg, 1978)
[8] $P > 0.10$ were considered not significant

Table 3.7. Block effect (time of day; AM or PM)[1] on the number of observed behaviours in skip-a-day (CONV) and precision feeding (PF) pullets during days CONV pullets were fed. Data was collected from 12 focal birds per 6 CONV and 6 PF pens, during 15 minute observation sessions[2]. Observations occurred when pullets were 10, 12, 14, 16, 18, 20, and 21 weeks of age. Pullets in CONV pens were fed at 10:30 AM on alternating mornings[3] in communal feed troughs and PF pullets were individually fed multiple small meals per day from a computerized feeding station.

Behaviour	AM [4]	PM	**P-value**
Stand/walk	6.96 ± 0.07 [0.58]	5.33 ± 0.06 [0.44]	<0.0001
Forage	2.86 ± 0.06 [0.24]	3.26 ± 0.06 [0.27]	0.0008
Sit Lay	0.08 ± 0.01 [0.01]	0.46 ± 0.02 [0.04]	0.0001
Peck drinker[5]	0.16 ± 0.01 [0.01]	0.22 ± 0.02 [0.02]	0.0165
Peck wall[5]	0.04 ± 0.01 [0.00]	0.16 ± 0.01 [0.01]	<0.0001
Peck feeder[5]	0.37 ± 0.02 [0.03]	0.30 ± 0.02 [0.03]	0.0020
Feather peck	0.04 ± 0.01 [0.00]	0.21 ± 0.02 [0.02]	0.0053
Other	1.01 ± 0.05 [0.08]	2.37 ± 0.07 [0.20]	<0.0001

[1] Observations took place during morning (08:00 to 09:55) and afternoon (13:45 to 15:40) sessions on each observation day each week

[2] 32 observations/pen per week; 384 observations/pen; 4608 observations total for all pens over the 12 week study

[3] Morning observations of CONV pullets are pre-feeding periods and afternoon observations of CONV pullets are post-feeding periods

[4] Count data, (least squares mean of the number of focal birds performing a specific behaviour at any given point in time ± standard error) [average proportion of focal birds at any given point in time performing a specific behaviour]

[5] Stereotypic behaviours were defined as repetitive and fixed behaviours with no apparent function (Ödberg, 1978)

Table 3.8. Effect of feeding system (skip-a-day (CONV) or precision feeding (PF)) on the number of observed behaviours during days CONV pullets were fed. Data was collected from 12 focal birds per 6 CONV and 6 PF pens, during 15 minute observation sessions[1]. Observations occurred when pullets were 10, 12, 14, 16, 18, 20, and 21 weeks of age. Skip-a-day-fed pullets were fed at 10:30 AM on alternating mornings in communal feed troughs and PF pullets were individually fed multiple small meals per day from a computerized feeding station.

Behaviour	CONV [2]		PF		**P-value**
Stand/walk	6.36 ± 0.07	[0.53]	5.83 ± 0.06	[0.49]	0.0001
Forage	3.08 ± 0.06	[0.26]	3.03 ± 0.06	[0.25]	0.5830[4]
Sit Lay	0.13 ± 0.02	[0.01]	0.29 ± 0.02	[0.02]	0.0001
Peck drinker[3]	0.15 ± 0.01	[0.01]	0.24 ± 0.02	[0.02]	0.0029
Peck wall[3]	0.03 ± 0.01	[0.00]	0.23 ± 0.02	[0.02]	<0.0001
Peck feeder[3]	0.28 ± 0.02	[0.02]	0.40 ± 0.02	[0.03]	0.0020
Feather peck	0.13 ± 0.01	[0.01]	0.06 ± 0.01	[0.01]	0.0053
Other	1.22 ± 0.06	[0.10]	1.97 ± 0.07	[0.16]	<0.0001

[1] 32 observations/pen per week; 384 observations/pen; 2688 observations total for all pens during 7 weeks
[2] Count data, (least squares mean of the number of focal birds performing a specific behaviour at any given point in time ± standard error)[average proportion of focal birds at any given point in time performing a specific behaviour]
[3] Stereotypic behaviours were defined as repetitive and fixed behaviours with no apparent function (Ödberg, 1978)
[4] n.s. = P > 0.10 were considered not significant

Table 3.9. Block effect (time of day; AM or PM)[1] and feed schedule (fed- vs. non-fed days) on the number of observed behaviours performed by skip-a-day-fed pullets. Data was collected from 12 focal birds per 6 pens during 15 minute observation sessions[2]. Observations occurred when pullets were 10 to 21 weeks of age. Pullets were fed on 10:30 AM on alternating mornings[3].

Behaviour[4]	Fed AM[5]		Fed PM		Non-fed AM		Non-fed PM		Time of day x feed schedule **P-value[6]**
Stand/walk	8.53^{a} ± 0.11	[0.71]	4.74^{c} ± 0.09	[0.40]	4.76^{c} ± 0.10	[0.40]	6.57^{b} ± 0.11	[0.55]	<0.0001
Forage	2.32^{c} ± 0.07	[0.19]	4.10^{a} ± 0.10	[0.34]	4.56^{a} ± 0.12	[0.38]	3.05^{b} ± 0.10	[0.25]	<0.0001
Sit Lay	0.03^{c} ± 0.01	[0.00]	0.53^{a} ± 0.03	[0.04]	0.18^{b} ± 0.02	[0.02]	0.31^{b} ± 0.03	[0.03]	0.0006
Peck drinker[7]	0.08^{b} ± 0.01	[0.01]	0.30^{a} ± 0.03	[0.03]	0.31^{a} ± 0.03	[0.03]	0.18^{ab} ± 0.02	[0.02]	0.0005
Peck wall[7]	0.01^{b} ± 0.00	[0.00]	0.11^{a} ± 0.01	[0.01]	0.05^{ab} ±0.01	[0.00]	0.09^{a} ± 0.01	[0.01]	0.0145
Peck feeder[7]	0.31^{b} ± 0.03	[0.03]	0.25^{bc} ± 0.02	[0.02]	0.63^{a} ± 0.04	[0.05]	0.14^{c} ± 0.02	[0.01]	0.0016
Feather peck	0.06^{c} ± 0.01	[0.01]	0.27^{ab} ± 0.02	[0.02]	0.44^{a} ± 0.04	[0.04]	0.15^{bc} ± 0.02	[0.01]	0.0002
Other	0.66^{c} ±0.05	[0.06]	2.26^{a} ± 0.09	[0.19]	1.07^{b} ± 0.07	[0.09]	1.50^{b} ± 0.08	[0.13]	0.0006

[1] Observations took place during morning (08:00 to 09:55; pre-feeding of fed-days) and afternoon (13:45 to 15:40; post feeding of fed-days) sessions on each observation day each week
[2] 32 observations/pen per week; 384 observations/pen; 2304 observations total for all pens over the 12 week study
[3] Morning observations of CONV pullets are pre-feeding periods and afternoon observations of CONV pullets are post-feeding periods
[4] a-c means within rows with no common superscript differ significantly (at least $P < 0.05$)
[5] Count data, (least squares mean of the number of focal birds performing a specific behaviour at any given point in time ± standard error) [average proportion of focal birds at any given point in time performing a specific behaviour]
[6] A Bonferroni means separation test was used
[7] Stereotypic behaviours were defined as repetitive and fixed behaviours with no apparent function (Ödberg, 1978)

Table 3.10. Block effect (time of day; AM or PM)[1] on the number of observed behaviours exhibited by skip-a-day (CONV) pullets. Data was collected from 12 focal birds from 6 pens each, during 15 minute observation sessions[2]. Observations occurred when pullets 10 to 21 weeks of age[3]. Pullets were fed at 10:30 AM on alternating mornings[4] in communal feed troughs.

Behaviour	AM[5]	PM	**P-value**
Stand/walk	6.38 ± 0.08 [0.53]	5.58 ± 0.07 [0.47]	0.0007
Forage	3.25 ± 0.07 [0.27]	3.54 ± 0.07 [0.30]	0.0012
Sit Lay	0.07 ± 0.01 [0.01]	0.41 ± 0.02 [0.03]	0.0083
Peck drinker[6]	0.16 ± 0.01 [0.01]	0.23 ± 0.02 [0.02]	0.0153
Peck wall[6]	0.02 ± 0.00 [0.00]	0.10 ± 0.01 [0.01]	0.0301
Peck feeder[6]	0.45 ± 0.02 [0.04]	0.19 ± 0.02 [0.02]	0.0004
Feather peck	0.16 ± 0.02 [0.01]	0.20 ± 0.02 [0.02]	0.1832[7]
Other	0.84 ± 0.04 [0.07]	1.84 ± 0.06 [0.15]	<0.0001

[1] Observations took place during morning (08:00 to 09:55) and afternoon (13:45 to 15:40) sessions on each observation day each week

[2] 32 observations/pen per week; 384 observations/pen; 2304 observations total for all pens over the 12 week study

[3] These weeks included weeks CONV pullets were fed and weeks CONV pullets were not fed

[4] Morning observations of CONV pullets are pre-feeding periods and afternoon observations of CONV pullets are post-feeding periods

[5] Count data, (least squares mean of the number of focal birds performing a specific behaviour at any given point in time ± standard error) [average proportion of focal birds at any given point in time performing a specific behaviour]

[6] Stereotypic behaviours were defined as repetitive and fixed behaviours with no apparent function (Ödberg, 1978)

[7] P > 0.10 were considered not significant

Table 3.11. Effect of feed schedule (fed- vs. non-fed days) on the number of observed behaviours exhibited by skip-a-day (CONV) pullets. Data was collected from 12 focal birds per 6 pens each, during 15 minute observation sessions[1]. Observations occurred when pullets were 10 to 21 weeks of age. Pullets were fed at 10:30 AM on alternating mornings in communal feed troughs.

Behaviour	Fed[2]	Non-fed	**P-value**
Stand/walk	6.36 ± 0.07 [0.53]	5.60 ± 0.08 [0.50]	0.0007
Forage	3.08 ± 0.06 [0.26]	3.73 ± 0.08 [0.31]	0.0012
Sit Lay	0.13 ± 0.02 [0.01]	0.24 ± 0.02 [0.02]	0.0083
Peck drinker[3]	0.15 ± 0.01 [0.01]	0.23 ± 0.02 [0.02]	0.0153
Peck wall[3]	0.03 ± 0.01 [0.00]	0.06 ± 0.01 [0.00]	0.0301
Peck feeder[3]	0.28 ± 0.02 [0.02]	0.30 ± 0.02 [0.03]	0.5130[4]
Feather peck	0.13 ± 0.01 [0.01]	0.25 ± 0.02 [0.02]	0.0035
Other	1.22 ± 0.05 [0.10]	1.27 ± 0.05 [0.11]	0.5285[4]

[1] 32 observations/pen per week; 384 observations/pen; 2304 observations total for all pens over the 12 week study
[2] Count data, (least squares mean of the number of focal birds performing a specific behaviour at any given point in time ± standard error) [average proportion of focal birds at any given point in time performing a specific behaviour]
[3] Stereotypic behaviours were defined as repetitive and fixed behaviours with no apparent function (Ödberg, 1978)
[4] P > 0.10 were considered not significant

Table 3.12. Effect of feeding system (skip-a-day (CONV) or precision feeding (PF)) on feather coverage damage[1]. Data was collected weekly from 12 focal birds per 6 CONV and 6 PF pens. Skip-a-day-fed pullets were fed at 10:30 AM on alternating mornings in communal feed troughs and PF pullets were individually fed multiple small meals per day from a computerized feeding station.

Feather damage score[2]	CONV	PF	**P-value**
0	11.58	11.748	0.1809[3]
1	2.51E-3	2.76E-4	0.9996
2	1.99E-6	1.60E-6	0.9986

[1] Feather scoring occurred on the same day each week. Individual feather coverage scores of the: 1) head and neck; and, 2) back and rump were conducted. Feather coverage scores ranged from an ‘a’ (no or slight feather damage) to ‘c’ (at least one featherless area ≥ 5 cm in diameter) according to a modified version of the Welfare Quality® Assessment Protocol for Poultry for plumage damage in laying hens (Welfare Quality®, 2009; Appendix B)
[2] To achieve an overall feather score per bird, the scores of the two regions were combined as: (0) All body parts have score ‘a’; (1) one or more body parts have score ‘b’; (2) one or more body parts have score ‘c’.
[3] P > 0.10 were considered not significant

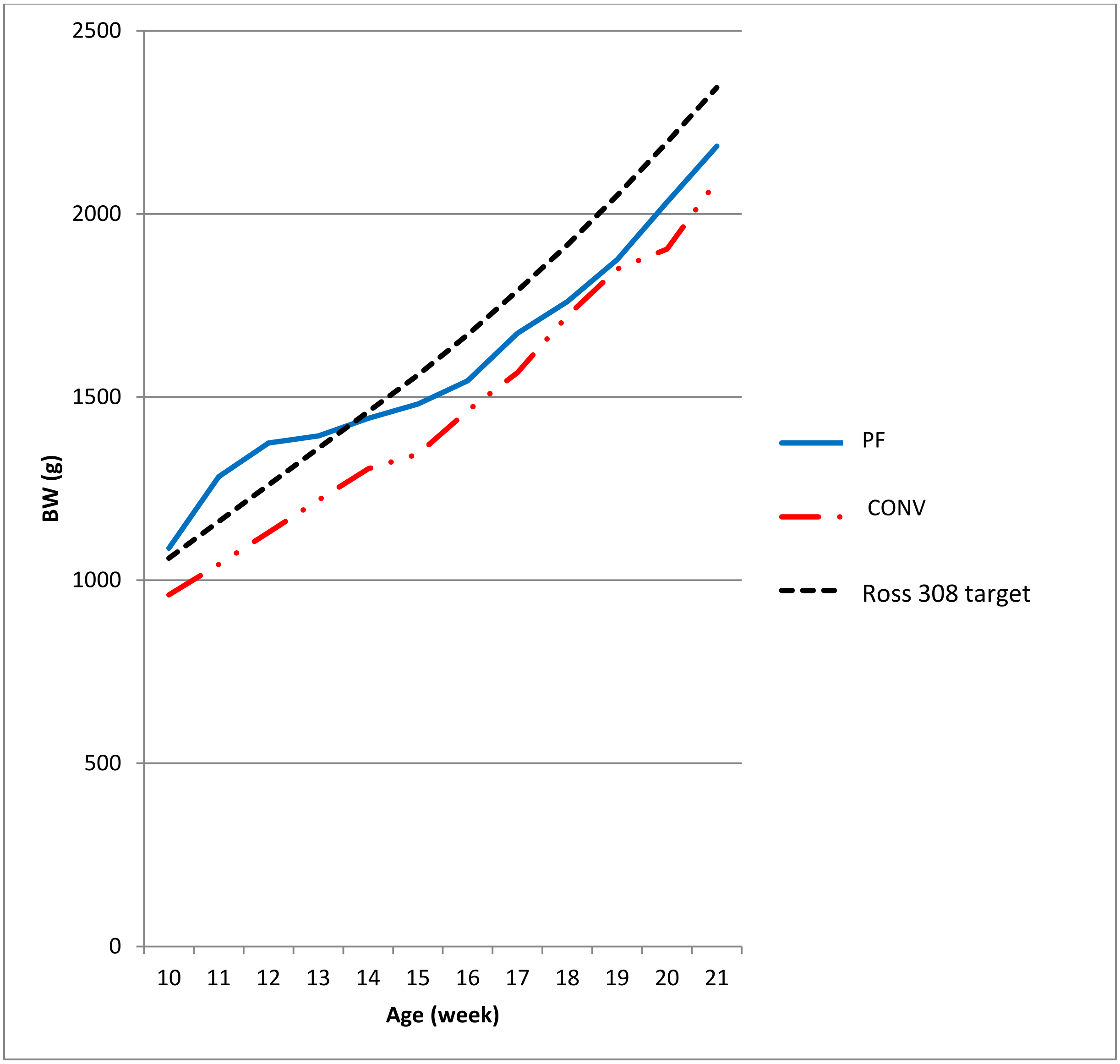

Figure 3.1. Average BW of precision-fed (PF) and skip-a-day-fed (CONV) pullets by week in comparison to weekly Ross 308 target BW (Aviagen, 2011). Feed allocation for the CONV treatment was based on Ross 308 target BW (Aviagen, 2011). The PF treatment was composed of BW targets of three body curves: Ross 708 (Aviagen, 2013), Ross 308 (Aviagen, 2013), and 'Step'. Because BW curves in the PF treatment were equally represented by focal birds (4 focal birds per BW curve), PF BW were combined to form an average weekly BW. Skip-a-day-fed pullets were fed at 10:30 AM on alternating mornings in communal feed troughs and PF pullets were individually fed multiple small meals per day from a computerized feeding station.

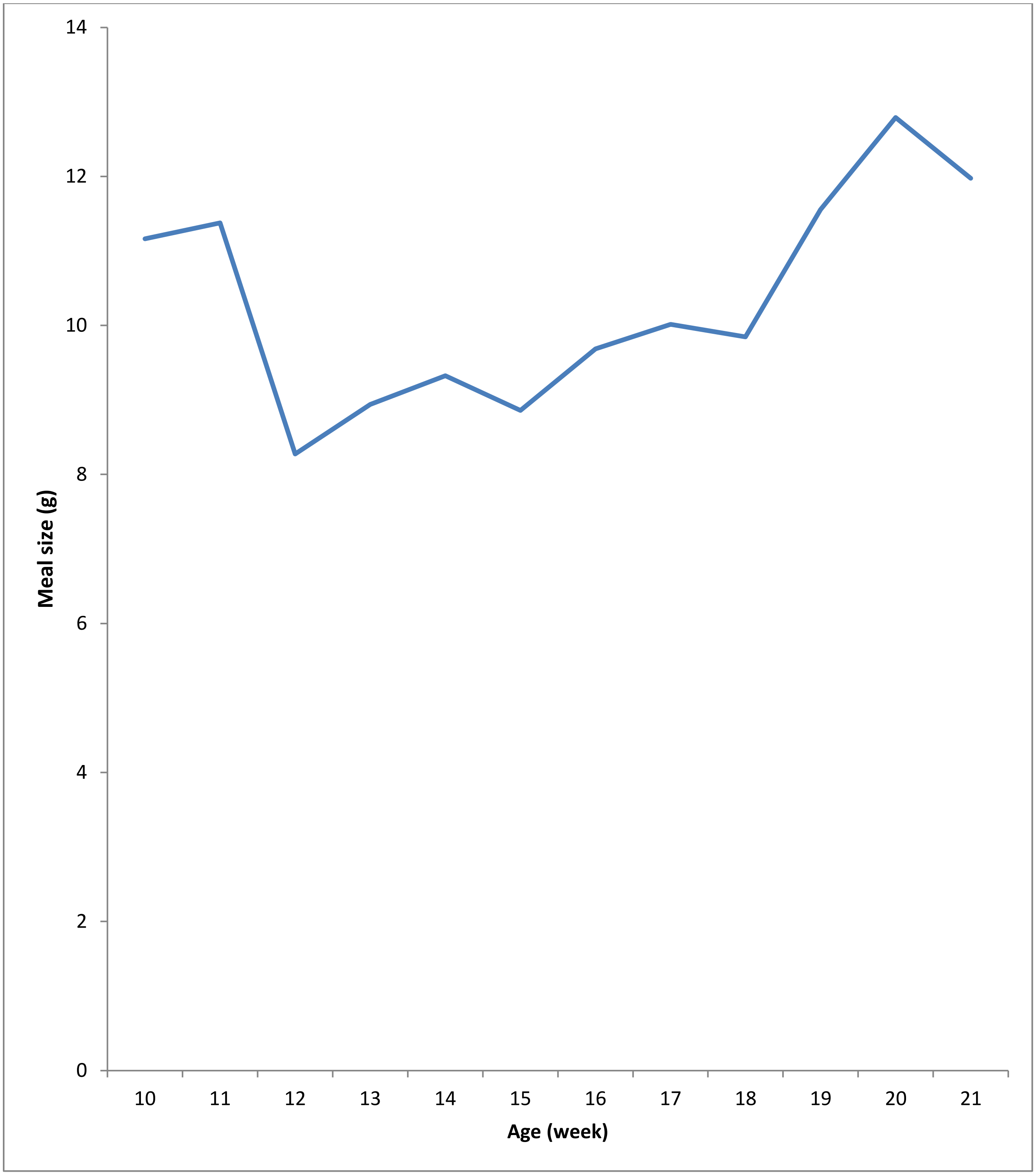

Figure 3.2. Average meal size of precision-fed pullets by age (week). Precision feeding was the continuous allocation of multiple small meals from a computerized feeding station (n = 6). If the bird was under the target BW, it was provided access to 25 g of feed for one minute before ejection from the station. Once the bird was ejected, the amount of feed in the feeder was topped up to 25 g for the next pullet. The average meal size was 10.32 g/meal and the average number of meals per day was 8 for precision-fed pullets from 10 to 21 weeks of age.

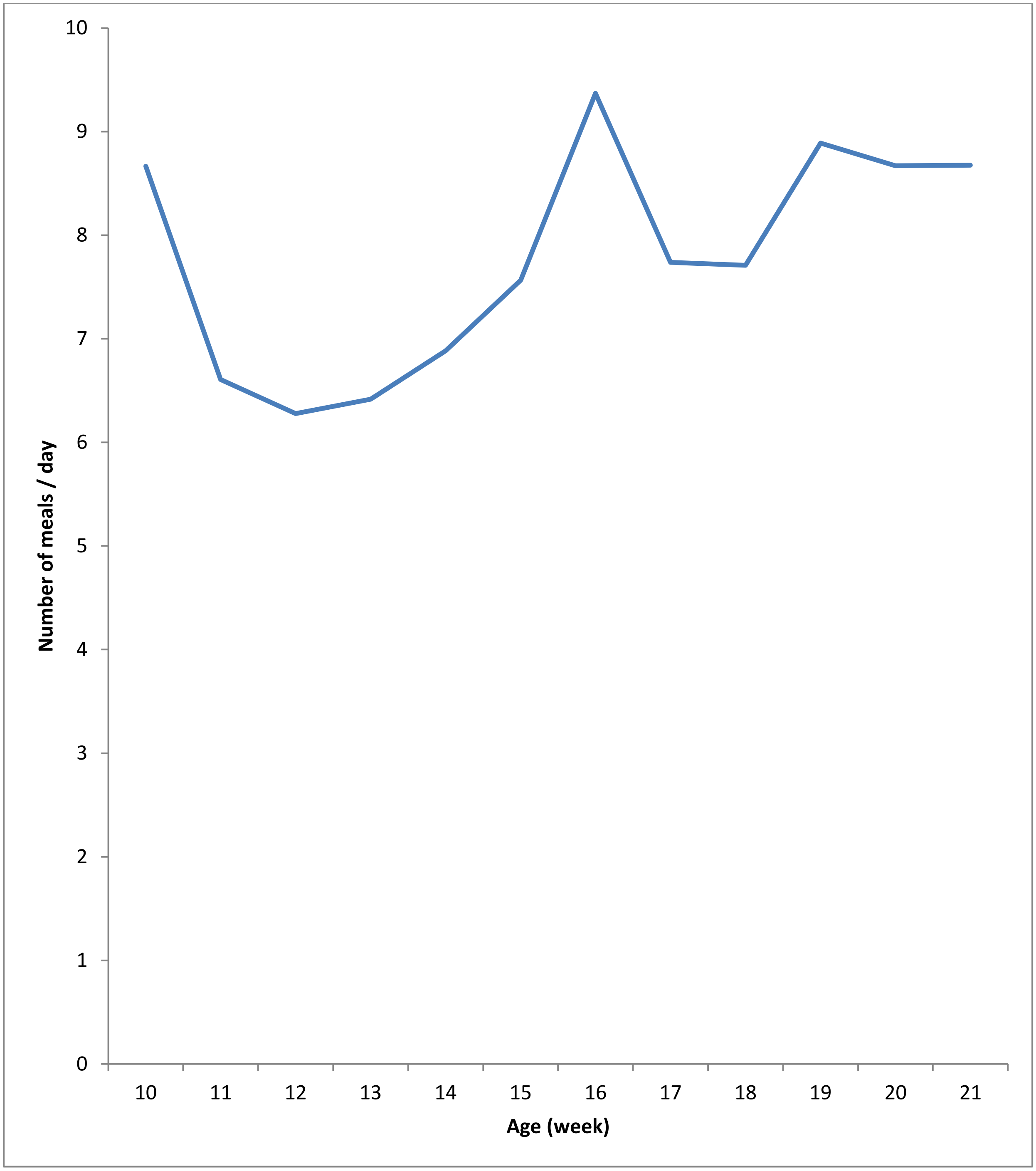

Figure 3.3. Average number of meals per day per pullet provided to precision-fed pullets by age (week). Precision feeding was the allocation of multiple small meals from a computerized feeding station (n = 6). If the bird was under the target BW, it was provided access to 25 g of feed for one minute before ejection from the station. Once the bird was ejected, the amount of feed in the feeder was topped up to 25 g for the next pullet. The average meal size was 10.32 g/meal and the average number of meals per day was 8 for precision-fed pullets from 10 to 21 weeks of age.

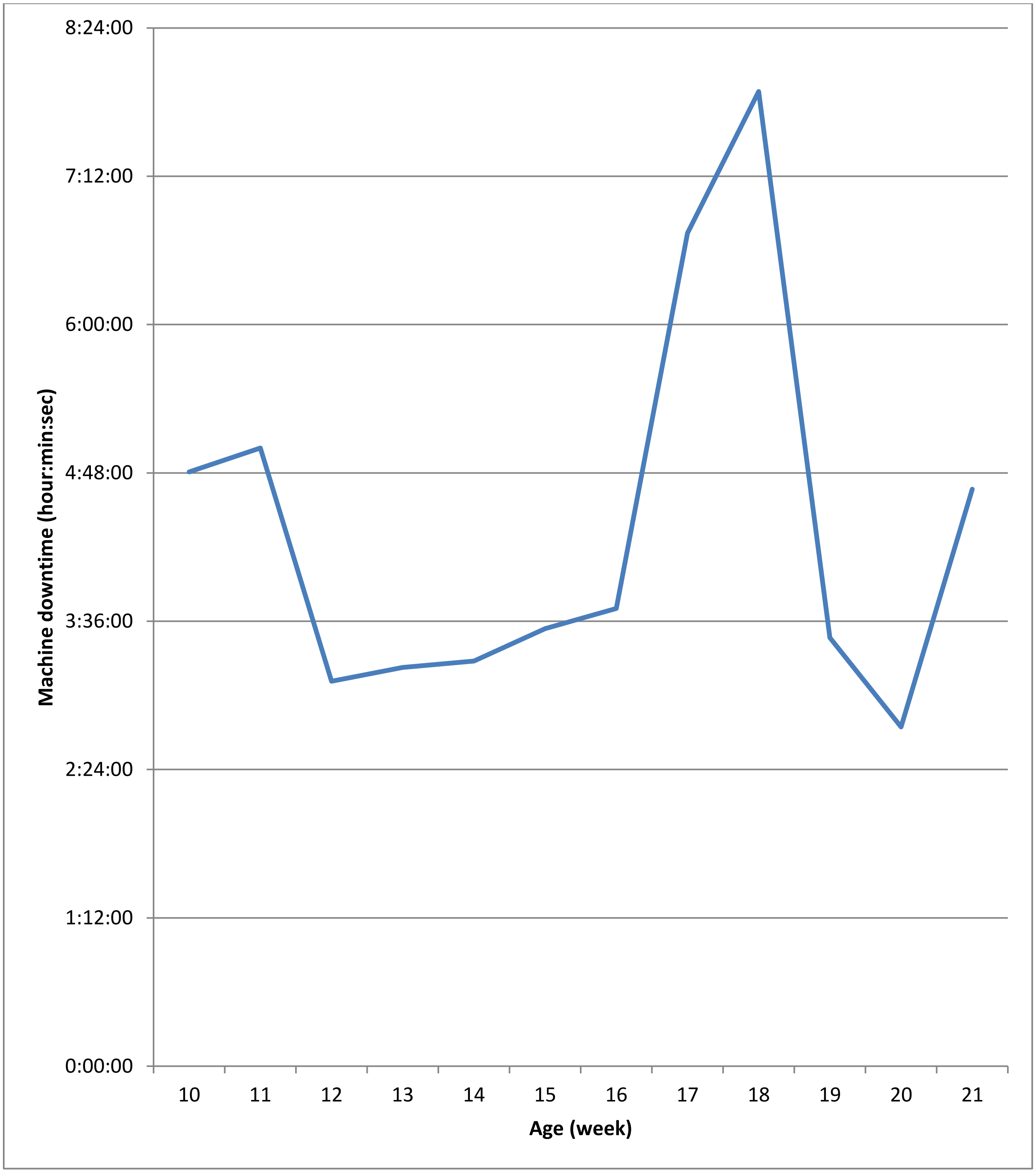

Figure 3.4. Average amount of machine downtime of precision feeding stations per pen by age. Machine downtime data was calculated for each pen (n= 6) by summing the number of minutes each precision feeding station was non-operational within each week. On average, there was 4:47:07 minutes of machine downtime per day per pen and 18:35:34 minutes of machine downtime per pen per week.

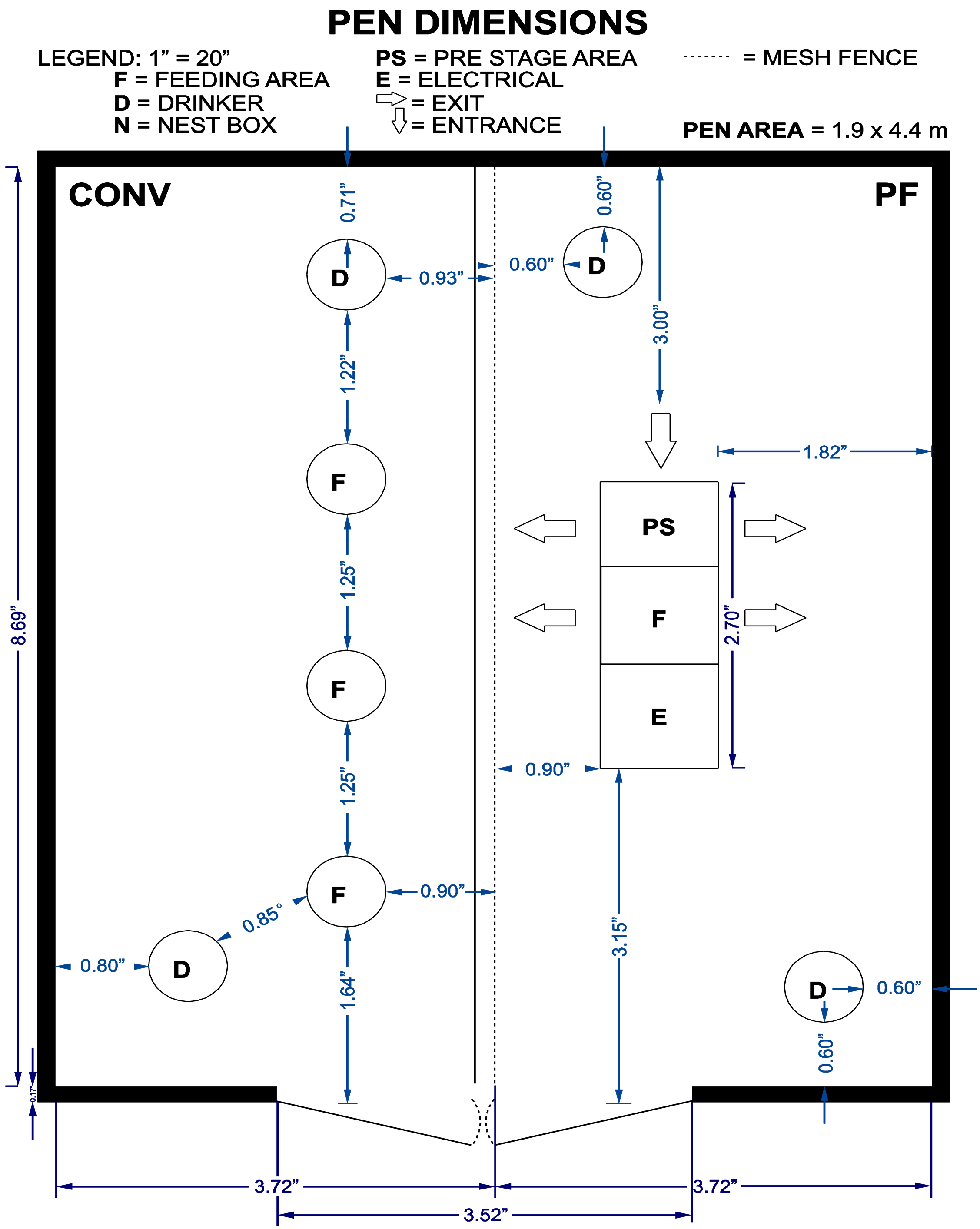

Figure 3.5. Diagram representation of one environmentally controlled chamber (block), with a CONV pen (skip-a-day feeding treatment) and a PF pen (precision feeding treatment). Drawn by P. Carneiro.

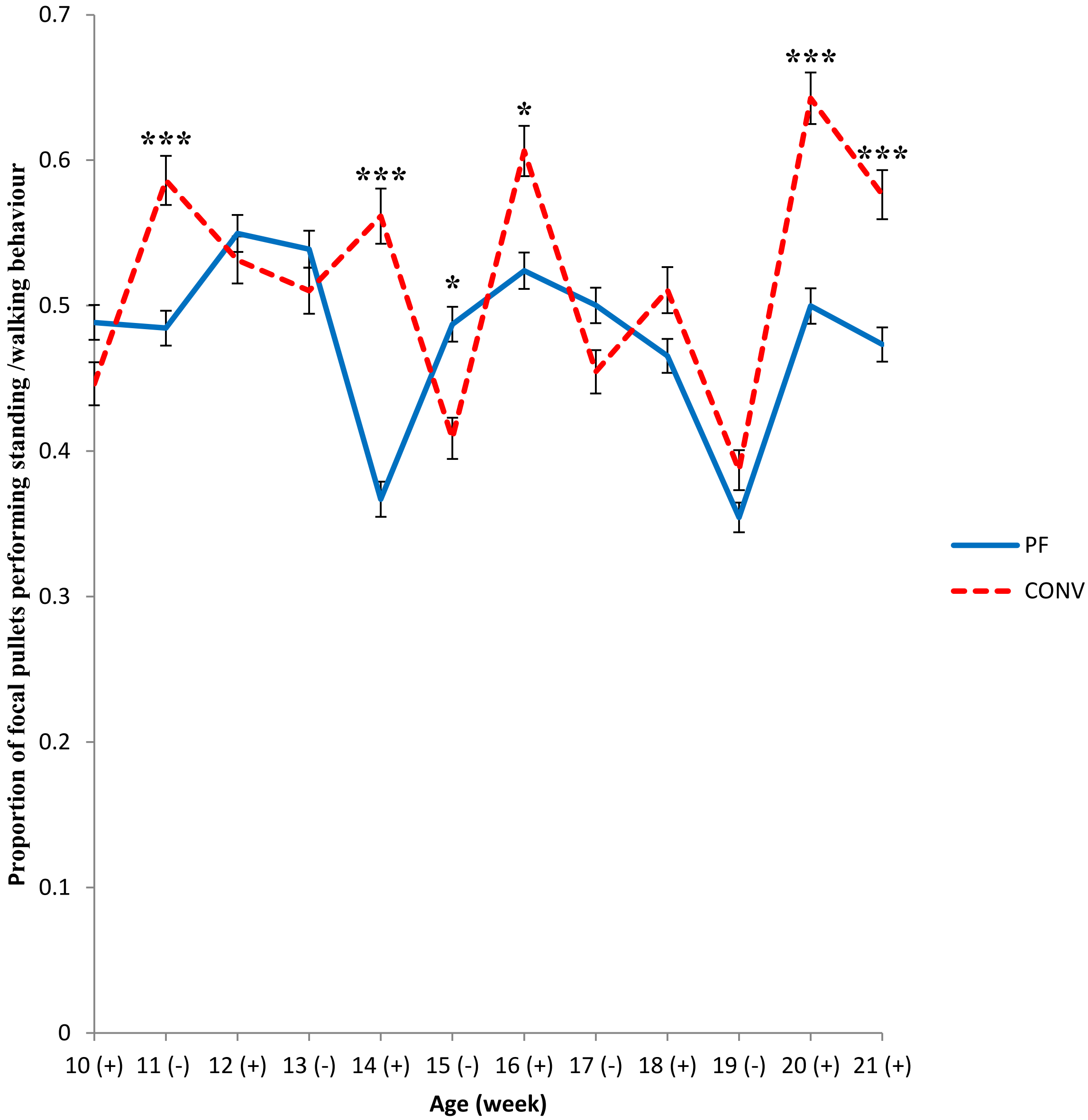

Figure 3.6. Age (week) and treatment (skip-a-day (CONV) or precision feeding (PF)) effect on the proportion of focal birds performing standing and walking behaviours. Data was collected from 12 focal birds per 6 CONV and 6 PF pens. (+) indicates observations of fed-days and (-) indicates observations of non-fed days of CONV pullets. Statistical analysis was performed on original count data, while data in the figure reflects proportion of focal birds (least squares means divided by 12 focal birds). Treatment had a significant effect on standing and walking behaviour ($P < 0.001$) as did treatment x age ($P < 0.001$). A Bonferonni means separation test was used. Treatment differences within age are indicated by (*): $P < 0.05$; (***): $P < 0.001$.

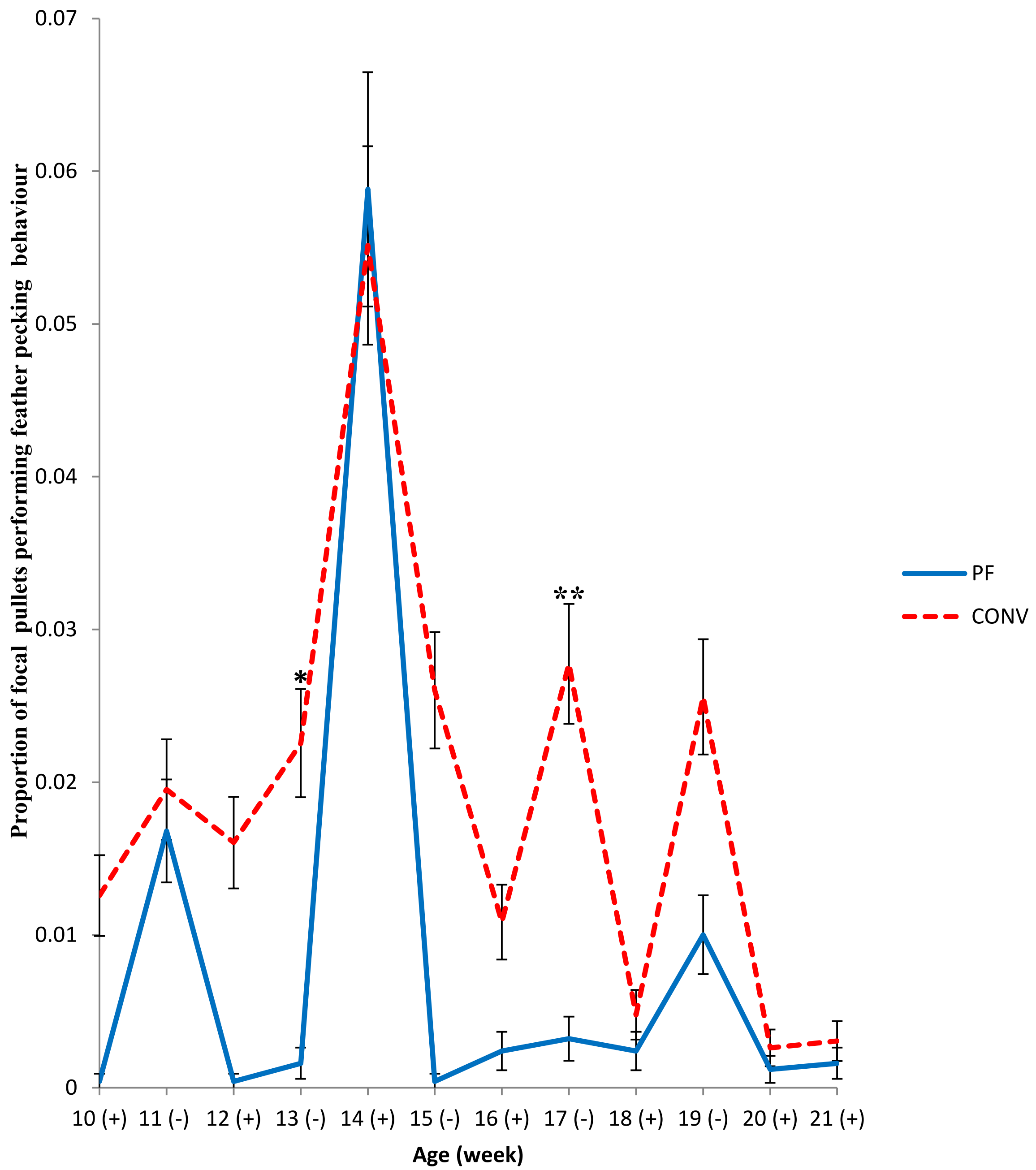

Figure 3.7. Age (week) and treatment (skip-a-day (CONV) or precision feeding (PF)) effect on the proportion of focal birds performing feather pecking behaviours. Data was collected from 12 focal birds per 6 CONV and 6 PF pens. (+) indicates observations of fed-days and (-) indicates observations of non-fed days of CONV pullets. Statistical analysis was performed on original count data, while data in the figure reflects proportion of focal birds (least squares means divided by 12 focal birds). Treatment had a significant effect on feather pecking behaviour ($P < 0.001$) as did treatment x age ($P < 0.001$). A Bonferonni means separation test was used. Treatment differences within age are indicated by (*): $P < 0.05$; (**): $P < 0.01$.

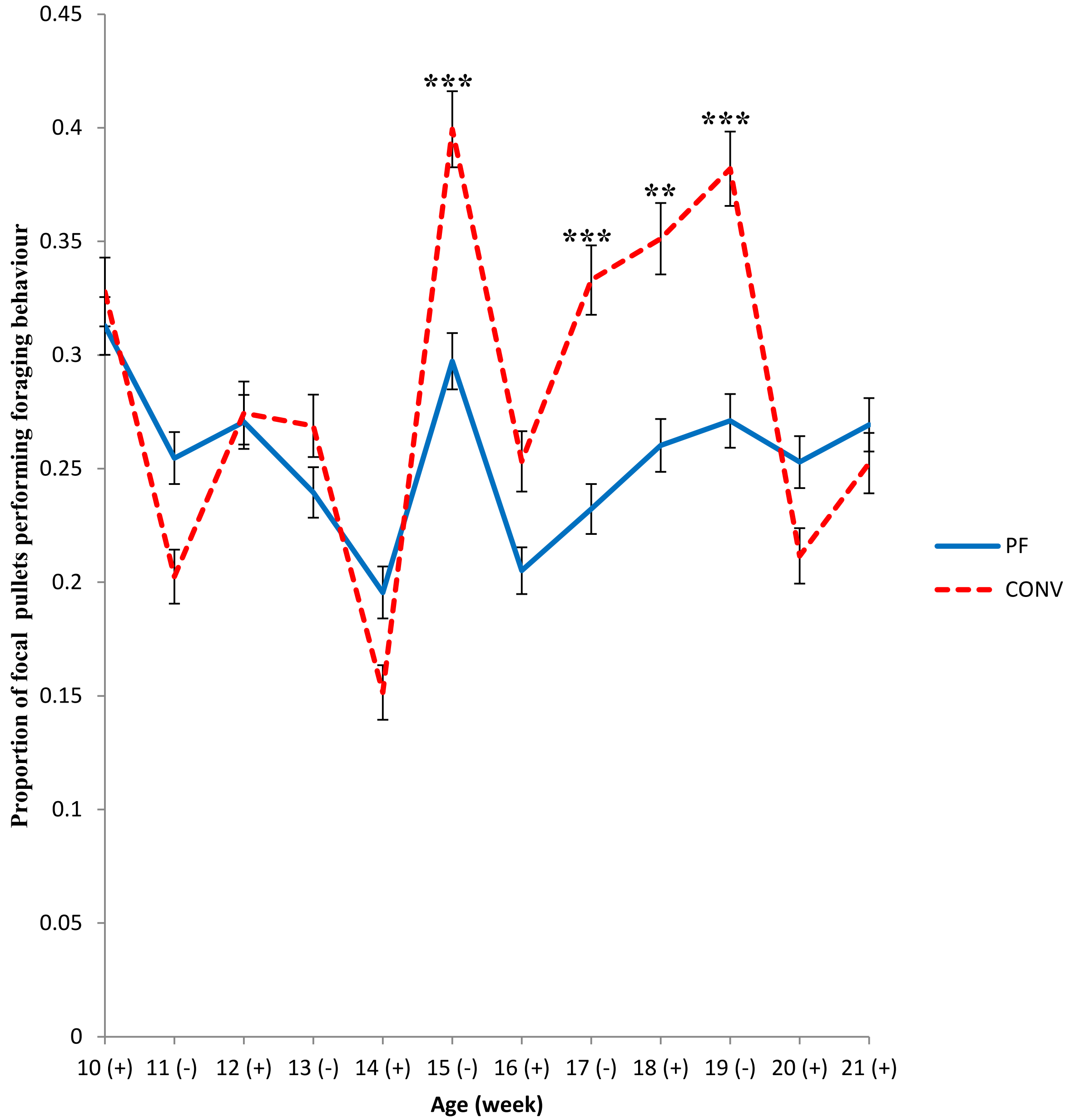

Figure 3.8. Age (week) and treatment (skip-a-day (CONV) or precision feeding (PF)) effect on the proportion of focal birds performing foraging behaviours. Data was collected from 12 focal birds per 6 CONV and 6 PF pens. Data was collected from 12 focal birds per 6 CONV and 6 PF pens. (+) indicates observations of fed-days and (-) indicates observations of non-fed days of CONV pullets. Statistical analysis was performed on original count data, while data in the figure reflects proportion of focal birds (least squares means divided by 12 focal birds). Treatment had a significant effect on foraging behaviour ($P < 0.001$) as did treatment x age ($P < 0.001$). A Bonferonni means separation test was used. Treatment differences within age are indicated by (**): $P < 0.01$; (***): $P < 0.001$.

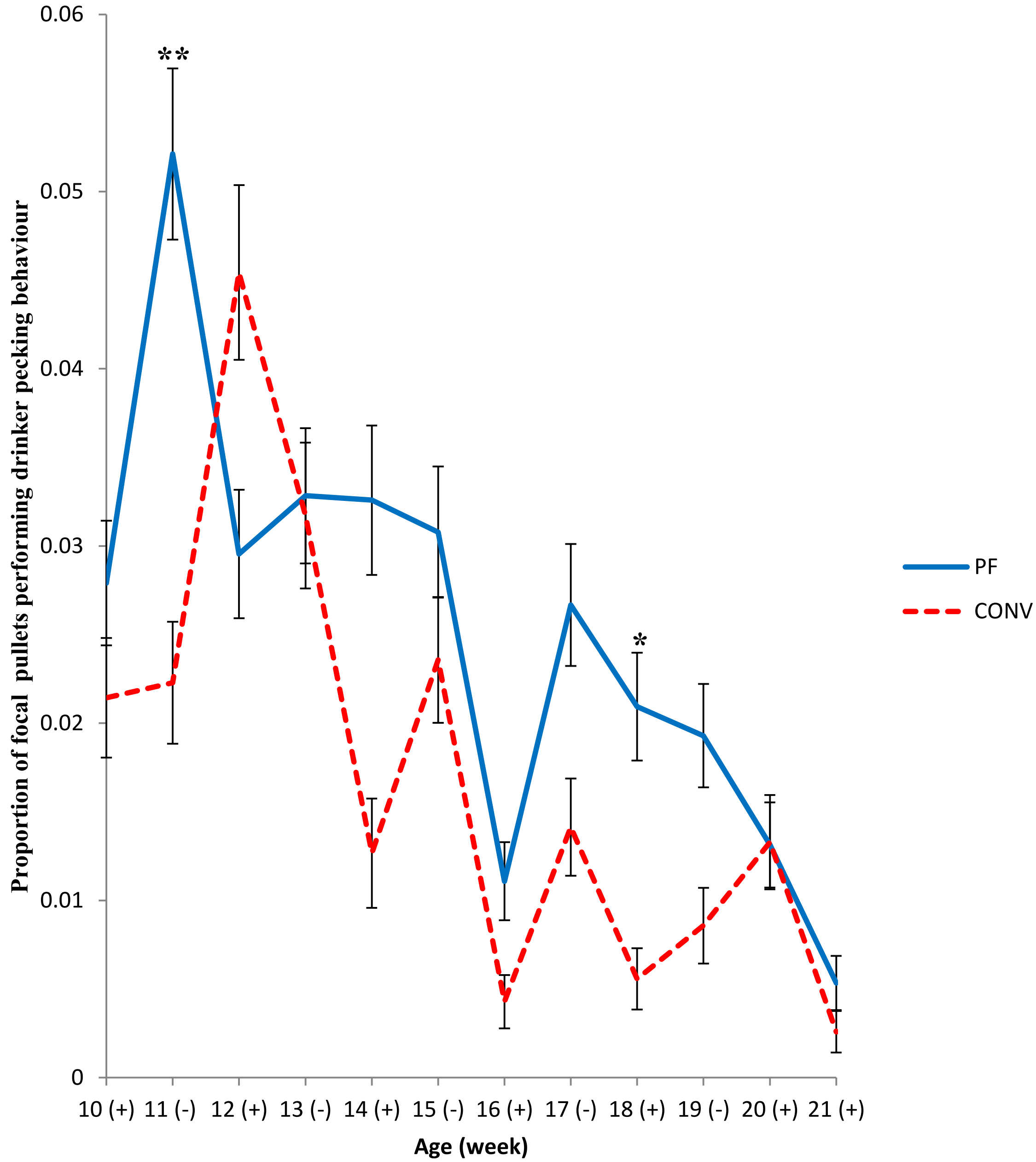

Figure 3.9. Age (week) and treatment (skip-a-day (CONV) or precision feeding (PF)) effect on the proportion of focal birds performing drinker pecking behaviours. Data was collected from 12 focal birds per 6 CONV and 6 PF pens. Data was collected from 12 focal birds per 6 CONV and 6 PF pens. (+) indicates observations of fed-days and (-) indicates observations of non-fed days of CONV pullets. Statistical analysis was performed on original count data, while data in the figure reflects proportion of focal birds (least squares means divided by 12 focal birds). Treatment had a significant effect on drinker pecking behaviour ($P < 0.001$) as did treatment x age ($P < 0.001$). A Bonferonni means separation test was used. Treatment differences within age are indicated by (*): $P < 0.05$; (**): $P < 0.01$.

4.0 Aggression and social rank fluctuations in precision-fed and skip-a-day-fed broiler breeders[1]

4.1 Abstract

Broiler breeders are feed-restricted to maximize reproductive output. The severity of feed restriction, conventionally managed during rearing through skip-a-day feeding, creates welfare concerns as broiler breeders exhibit aggression due to hunger. A precision broiler breeder feeding system was developed to provide individual broiler breeders protection while feeding. The precision feeding system provided small individual meals to each bird multiple times throughout a day each time their BW was less than a target BW. The objectives of the current study were to investigate whether precision feeding affected: 1) aggression among pullets in comparison to skip-a-day feeding; and, 2) the number of social rank fluctuations; in comparison to skip-a-day feeding. Using a randomized complete block design, precision feeding and skip-a-day feeding pens were represented in each of 6 blocks (45 Ross 308 pullets per pen; 6 pens per treatment), with pen as the experimental unit. Continuous behaviour observations (15 min per pen) were conducted twice weekly from 10 to 21 weeks of age and all instances of aggressive pecks, fights, and threats were recorded. Birds not involved in any aggressive pecks, fights, and threats were determined as 'non-participants' for that week and aggressive pecks and fights were categorized as 'aggressive encounters'. Data were reported as least squares mean of the number of observed behaviours or non-participants per 15 minutes per pen ± standard error. An aggressive rank index was used to rank pullets. Rank fluctuations were when a high ranking pullet became a low ranking pullet and vice versa. Data were reported as least squares mean of

[1] This chapter will be submitted for potential publication Applied Animal Behaviour Science and is formatted in accordance with its conventions and instructions to authors

the number of rank fluctuations per 2 week period ± standard error. Treatment differences in rank fluctuations, aggressive encounters, threats, and non-participants were analyzed using a generalized linear mixed model. Precision-fed pullets were more aggressive than skip-a-day-fed pullets (12.73 ± 0.61 vs. 8.02 ± 0.48. P = 0.0001; respectively). Skip-a-day-fed pullets displayed the greatest aggression during the afternoon on days they were fed. Skip-a-day-fed pullets tended to display more social rank fluctuations (4.45 ± 0.37 vs. 3.50 ± 0.37; P = 0.08; respectively) compared with precision-fed pullets. In conclusion, precision feeding increased aggression within a flock but did not increase social rank fluctuations when compared with skip-a-day feeding.

4.2 Introduction

Broiler breeders, the parents of broiler chickens, are feed-restricted to 25-35% of what they would consume *ad libitum* during the rearing period, to maintain optimal health and reproductive performance (de Jong et al., 2002). Broiler chickens have been selected for rapid growth rates and increased appetites (Siegel and Wisman, 1966). This increased appetite is undesirable in broiler breeders as *ad libitum* feeding increases the incidence of obesity-related diseases in broiler breeders (Whitehead, 2000) and decreases production rates (Hocking et al., 1987). However, feed restriction causes broiler breeders to experience chronic hunger (de Jong et al., 2005) which may increase aggression among broiler breeders (Shea et al., 1990).

Aggression between birds is used to determine social order in a domesticated poultry flock (Estevez et al., 2002). Once a stable social hierarchy within a domestic poultry flock is formed, aggression decreases as threat behaviours increase (Queiroz and Cromberg, 2006). Threats allow birds to maintain social order while minimizing the risk of injury due to aggression

(Queiroz and Cromberg, 2006). However, when feed is restricted the prevalence of aggression in broiler breeders increases and can destabilize or delay the formation of a social order (Shea et al., 1990). For example, a stable social order is often established in *ad libitum* and feed-restricted male broiler breeder flocks by approximately 7 and 10 weeks, respectively (Shea et al., 1990). Although aggressive behaviour of male broiler breeders is likely different from female broiler breeders, research regarding aggression among broiler breeder pullets is minimal. Morrissey et al. (2014) found that aggression among pullets during or immediately after feeding bouts occurred too infrequently to analyze with scan sampling in both daily- and skip-a-day-fed broiler breeder pullets. Thus, the current study utilized continuous observation sampling of aggression among broiler breeder pullets.

Methods of feed restriction may affect prevalence of aggression, social stability, and broiler breeder welfare within a flock. Competitive feeding systems allocate feed to animals simultaneously in an unprotected environment while non-competitive systems allocate feed to individually protected animals either in a simultaneous or sequential manner (Bench et al., 2013). In North America, competitive, simultaneous feeding of broiler breeders is the conventional practice, typically in a skip-a-day (CONV) fashion during the rearing period. During CONV feeding, broiler breeders are fed approximately twice the daily restricted feed allotment on alternate days in communal feeders (Morrissey et al., 2014). Both skip-a-day-fed male broilers and broiler breeders were reported as more aggressive during the days they were not fed compared with days on which they were fed (Mench, 1988; Shea et al., 1990, respectively). Thus, as a simultaneous, competitive feeding system, CONV may create welfare concerns due to increased aggression caused by prolonged periods without feed.

In contrast to competitive, simultaneous feeding systems, non-competitive, sequential feeding systems allocate feed to individuals in a protected environment and require animals to enter serially. Research regarding sequential feeding in broiler breeders has not yet been documented. However, sequential feeding has been utilized and investigated in gestating sows, which are also feed-restricted to optimize reproductive performance (Lawrence and Terlouw, 1993). For example, electronic sow feeders (ESF) allow individual gestating sows to eat pre-allocated amounts of feed in a protected stall. Sequential feeding of sows only partially alleviated aggression related to feed restriction (Bench et al., 2013). Although competition at the feed trough is eliminated, space around the entrance to the ESF often becomes the site for competition, resulting in aggression among sows at the ESF entrance (Spoolder et al., 1997).

A Precision Broiler Breeder Feeding system (PFS) designed at the University of Alberta, is a novel, non-competitive, sequential feeding system for broiler breeders (Zuidhof et al., 2014). Individual precision-fed (PF) birds can be fed multiple small meals each day if the bird's BW is less than a target BW. The objectives of the current study were: 1) to investigate whether precision feeding affected aggression in broiler breeders by comparing the number of aggressive encounters in PF and CONV pens; and, 2) to investigate whether PF affects social rank fluctuations of broiler breeders by comparing the number of pullets which switched from high ranking to low ranking and vice versa in CONV and PF pens. We sought to test the hypothesis that prevalence of aggression and social rank fluctuations would differ between PF and CONV flocks. Specifically, we hypothesized that due to shorter periods between meals, PF broiler breeder pullets may experience decreased aggression and social rank fluctuations, compared with CONV pullets.

4.3 Materials and methods

The animal protocol for this study was approved by the University of Alberta Animal Care and Use Committee for Livestock and followed animal care principles established by the Canadian Council on Animal Care (CCAC, 2009).

4.3.1 Animals, housing, and diets

Broiler breeder pullets (n=540, Ross 308; Aviagen, Huntsville, AL, USA) were raised at the University of Alberta's Poultry Research Centre (Edmonton, Alberta, Canada) from 0 to 22 weeks of age. Prior to 9 weeks of age, the floor pressure of all pens was 4.084 kg/m^2. Pullets began feed restriction at 3 weeks of age. Until 9 weeks of age, CONV pullets were fed on alternating mornings in round hanging feeders while CONV pullets were fed daily in floor troughs. At 9 weeks of age (week 0 of study) pullets were individually weighed and then randomly allocated into one of 12 pens, resulting in an initial floor pressure of 9.081 kg/m^2 per pullet at 9 weeks of age (week 0 of the study). Floor pressure increased and at 15 weeks of age (week 6 of the study) was reduced to 11.60 kg/m^2 in all pens to maintain consistent floor pressure. All pullets were reared on a mash starter diet (AME: 2,900 kcal/kg, CP:19%,) from d 0 to 3 weeks of age and then were placed on a grower diet (AME: 2,865 kcal/kg, CP: 15%) in mash form for the remainder of the experiment. The pullets were exposed to a photoschedule of 23L:1D (d 0 to d 2), 19L:5D (d 3), 16L:8D (d 4), 14L:10D (d 5), 12L:12D (d 6), 11L:13D (d 7). Light intensity decreased from 80 lux at d 0 to 30 lux at d 6. On d 9, a photoperiod of 10L:14D at 10 lux was applied to each pen for the duration of the trial. A standard temperature schedule was used that began at 28°C on d 0 and decreased in a linear fashion to 21°C until d 9. The set temperature was 21°C for the entire study. Each pen contained a depth of approximately 5.0 cm of pine shavings and two suspended nipple drinkers with 3.2 pullets per nipple.

At 9 weeks of age (week 0 of the study), for individual identification purposes, each pullet was wing banded with a radio frequency identification tag on its left wing. Additionally, to allow for identification of individual birds during behaviour observations, also at 9 weeks of age, an individually, numbered laminated card (5.08 x 8.89; 05371, Avery®, CA, USA) was attached to the wings of every pullet with a Swifttack fastener (Swifttack, Heartland Animal Health, Fair Play, Missouri, USA).

4.3.2 Treatments and Experimental Design

Two feeding systems were compared: a competitive, simultaneous feeding environment with a CONV schedule and a non-competitive, sequential feeding environment with a PF station. Pullets were fed at 10:30 on alternating mornings in CONV pens. Each PF pen contained one feeding station (4.78 cm of feeder space) while each CONV pen contained three round hanging feeders, providing 10 cm of feeder space per pullet (Figure 4.). Feed allocation for the CONV treatment was based on breeder recommended BW (Aviagen, 2011; Figure 4.2). The PF treatment was composed of three BW curves: Ross 708 (Aviagen, 2013), Ross 308 (Aviagen, 2013), and 'Step'. Interpolated Ross 308 and 708 target BW were updated hourly. The Step BW target followed the Ross 308 target (Aviagen, 2013) but increased BW targets only every 3 weeks, simulating over- and under-feeding of broiler breeders that may occur in industry. Therefore, the Step BW target was identical to Ross 308 BW targets every 1.5 weeks. In spite of the focal birds being on three target BW curves, there was less variation in BW in the PF treatment compared with the CONV treatment. Average body weight of PF pens followed the Ross 308 BW target curve (Figure 4.2). Therefore, the PF target BW curves were not considered in further analyses.

Each PF station contained a pre-stage area, where the bird was initially weighed and a feeding area, where the bird was given feed. A door separated the pre stage area and the feeding area (Appendix A). Precision feeding station use began when an individual broiler breeder entered the pre-stage area of the feeding system and the bird's BW was measured, recorded, and compared to the bird's target BW**.** If the BW of a broiler breeder exceeded or was equal to the target BW, the bird was ejected from the pre-stage area. If the BW of a broiler breeder was below the target BW, the bird could enter the feeding area and was given free access to 25 g of feed for 1 min and then was ejected from the station. Broiler breeders ate an average of 10.32 g per meal (Figure 4.3) and consumed approximately 8 meals per day (Figure 4.4). Once a broiler breeder was ejected from the station, the remaining feed was weighed and recorded. The required amount of feed was then added to remaining feed to equal 25 g for the meal of the next pullet. Broiler breeder pullets under their individual target BW by more than 250 g were given three feeding bouts prior to ejection and the feeder was topped up to 25 g prior to each bout.

If a bird BW was at least 250 g below the target BW it was given three minutes to ingest 75g of feed, prior to ejection. Precision-fed pullets that weighed less than 70% of the breeder-recommended weekly BW were identified as in need of PFS training. Training involved manually guiding each identified bird to the station entrance daily. At 15 weeks of age, training shifted to every second day to encourage birds to enter the PFS on their own. Training was discontinued when a pullet entered the station on its own more than four times over a period of two days or when a pullet weighed at least 70% of the breeder recommended BW.

Each feeding system treatment appeared once in each block in a randomized complete block design with 6 replicate pens per treatment (Appendix C). Each block consisted of a climate-controlled environmental chamber containing both a PF pen and a CONV pen separated by a mesh fence (Figure 4.). Pen was used as the experimental unit. For data relating to number of observed behaviours, pen was the sampling unit. Individual birds were the sampling unit for social rank data.

4.3.3 Observation techniques

Behaviour observations began when the pullets were 10 weeks of age and focused on feeding areas around the three communal feeders and the PF station in the CONV and PF pens, respectively (Figure 4.). Observers were trained to identify the specified behaviours and were evaluated throughout the trial to ensure 90% inter-observer reliability. Aggressive pecks, fights, and threats (Table 4.1) were recorded, as were the identities of each aggressor and recipient per encounter. The winner and loser of each encounter were also identified. The pullet that moved away from the encounter first was categorized as the 'loser' of that encounter. A tie was defined as when neither bird left the encounter (and performed behaviours outside of the encounter) or when both birds left the encounter simultaneously. Continuous behaviour observations were conducted on a weekly basis for two 15 min sessions per each pen per day, once in the morning (between 08:00 to 09:55) and once in the afternoon (between 13:45 to 15:40). Each pen was observed for a total of 6 hr over the 12 week trial (30 observation min/pen per week; 360 observation min/pen; 4,320 observation min total for all pens over the 12 week study). Because fights occurred too infrequently to analyze, fights and aggressive pecks were combined into the category of aggressive encounters.

Four trained observers, two per pen, rotated through chambers during each observation session (eg. AM and PM). Behaviour observers were randomly assigned observation pens to ensure random combinations of behaviour observers per each pen. Five minutes between each chamber observation was used to allow for observer travel between chambers and broiler breeder habituation to observer presence. The order of pen observations per week was randomly determined. However, it was ensured that each pen was observed twice during each 15 min observation session (between 08:00 to 09:55 and 13:45 to 15:40) throughout the 12 week trial. Observations occurred on the same day each week, except during 21 weeks of age, in which observations occurred one day earlier due to the beginning of photostimulation. Because CONV pullets were fed on alternating days, observation days captured five days CONV pullets were fed (fed-days) and seven days they were not fed (non-fed days).

4.3.4 Measurements

Any pullet not involved in an aggressive encounter or a threat during each week was defined as a 'non-participant' for that week. The number of aggressive encounters, threats, and non-participants were summed for each observation session per pen. Precision feeding systems were considered non-operational when any error mode of the PFS rendered the station inactive. Machine downtime data was calculated for each pen by summing the number of minutes each PFS was non-operational within each week. On average, there was 4:47:07 minutes of machine downtime per day and 18:35:34 minutes of machine downtime per week (Figure 4.5). Training data was determined by summing the number of individual PF pullets that required PF station training for each week. The average number of birds trained per pen per week was 3.78 pullets.

Because the low weekly numbers of birds involved in aggressive encounters and threats did not allow for the majority of the birds to be socially ranked from 10 to 21 weeks of age, two consecutive weeks of social rank data were combined into each age group. Combining weeks into age groups resulted in one hour of behaviour observation, six distinct ages, and five age group comparisons.

Dominance ($DI_{ai;}$ Bowen and Brooks, 1978**)**, agonistic (AGI; Puppe and Tuchscherer, 1994; reviewed by Langbein and Puppe, 2004), and aggressive (ARI; Barroso et al., 2000) rank indices were used to investigate social rank of pullets per age group and treatment.

$$DI_{ai} = \frac{\text{number of wins per individual pullet}}{\text{total number of aggressive encounters and threats in which that pullet was involved}}$$

$$AGI = \frac{\text{number of aggressive encounters and threats an individual pullet was involved in}}{\text{total number of aggressive encounters and threats per pen}}$$

$$ARI = \frac{\text{number of aggressive encounters and threats initiated by a pullet}}{\text{total number of aggressive encounters and threats in that pullet was involved in}}$$

Rank indices ranged from 0 to 1 and then were divided into high, low, medium, or high rankings (Table 4.2), Table All pullets were then ranked according to their individual rank score, per age group and pen. Medium-ranked pullets were not analyzed in order to focus on larger rank fluctuations only when a bird changed from a rank of high to low or vice versa (between two consecutive age groups).

The CORR procedure in SAS statistical software v9.4 (SAS Institute; Cary, NC) was used to create a Spearman's rank correlation matrix to determine the correlations between DI_{ai}, AGI, and ARI (Table 4.3). AGI did not provide information regarding wins or losses in aggressive encounters and thus was not used for further analysis. Because L and H ranked birds of DI_{ai} (measure of wins) and ARI (measure of initiation of aggression) were strongly and significantly correlated (r^2 =, 0.715, P < 0.001; r^2 =, 0.950, P < 0.001, respectively), it was determined that the initiator of an aggressive encounter was usually the winner. However, because ARI accounted for wins, ties, and losses, ARI was deemed better able to capture all information related to aggressive encounters and threats within the data set compared with DI_{ai}.

4.3.5 Statistical Analysis

Data were analyzed as generalized linear mixed models using the GLIMMIX procedure of SAS v9.4 (SAS Institute; Cary, NC). All models specified a Poisson distribution with a log link function (Kaps and Lamberson, 2004). Type 3 tests were requested and the inverse line (ilink) option specified to return least-squares means on the same scale as the original data. The random term in all models included chamber (block). Time of day (AM, PM) was also considered a block. Block effects and their first order interactions were presented where significant ($P < 0.05$). A Bonferroni means separation test was used and results were considered significant if $P < 0.05$. A tendency was defined as $0.05 \leq P \leq 0.10$ and P-values greater than $P > 0.10$ were considered not significant. Non-significant independent variables were removed from models. For example, the number of pullets per pen was used as a covariate when analyzing count data, and was removed from final models once determined to be not significant.

Model of behaviour data over the entire 12 week trial (which included fed- and non-fed days of CONV pullets) included fixed effects of treatment (CONV, PF) and age. In contrast, model of behaviour data for CONV and PF pullets (fed-days only) included the fixed effects of treatment. Model of CONV pullet behaviour on fed- and non-fed days included the fixed effect of feed schedule (fed-days, non-fed days). Data from PF pens were excluded from this analysis. The CORR procedure in SAS v9.4 (SAS Institute; Cary, NC) was used to create Spearman's rank correlation matrices to determine: 1) the correlation between aggressive encounters, threats, and non-participants; and, 2) the correlation between machine downtime, training, aggressive encounters, threats and non-participants in PF pullets only, since CONV pullets did not experience machine downtime or require training. The CORR procedure in SAS v9.4 (SAS Institute; Cary, NC) was also used to create a Spearman's rank to investigate the correlation between high and low ARI-ranked pullets with machine downtime and number of birds trained in PF pullets only.

Statistical analysis was performed for the number of behaviours on both a per pen and per pullet per pen basis. Results in tables were presented as least squares mean of the number of observed behaviours per pen per 15 minute observation session ± standard error and as least squares mean of number of observed behaviours per pullet per pen per 15 minute observation session. Results are displayed as the number of observed behaviours per pullet or as proportion data.

4.4 Results

4.4.1 PF vs. CONV (fed- and non-fed days)

The interaction of age by treatment significantly affected aggressive encounters ($P < 0.01$) and non-participants ($P < 0.01$) but did not significantly affect threats ($P = 0.7299$). After 12 weeks of age, PF pullets displayed a consistently higher number of aggressive encounters compared with CONV pullets (Figure 4.6). Non-participant data displayed an inverse relationship with the number of aggressive encounters in both treatments. Both CONV and PF treatments had the highest number of non-participants at 10 weeks of age (CONV: 36.99 ± 1.69, PF: 36.82 ± 1.68), although neither were significantly lower than non-participants at 11 weeks of age. Aggressive encounters peaked in PF pullets at 17 weeks of age (18.75 ± 2.44), which was significantly different from all other ages ($P < 0.05$). Precision-fed and CONV pullets had the lowest number of non-participants during 17 weeks of age (CONV: 23.49 ± 1.34, PF: 23.16 ±

1.33), however, neither of these counts were significantly different from 16 or 18 weeks-of-age (P > 0.10). Threats were not significantly affected by the interaction of treatment x age (P = 0.7319).

Precision-fed pullets were more aggressive compared with CONV pullets (CONV: 8.02, PF: 12.73; P = 0.0001; Table 4.4). There were 10% less non-participants in PF pens compared with CONV pens (CONV: 29.08, PF: 27.07; P = 0.0071). Precision-fed pullets tended to display more threats compared with CONV pullets (CONV: 1.96, PF: 2.52; P = 0.0597). In both treatments, more than half the birds were non-participants.

The number of aggressive encounters was not affected by time of day (P = 0.8738). However, the number of threats were significantly affected by time of day as there were more threats were displayed in the mornings compared with the afternoons (AM: 2.69, PM: 1.84; P = 0.0045). A higher number of non-participants tended to occur in the afternoons compared with the mornings (AM: 28.67, PM: 27.44; P = 0.0622). The interaction of time of day x treatment did not have a significant effect on aggressive encounters (P = 0.6276), threats (P = 0.7707), or non-participants (P = 0.7885; data not shown).

The relationships between aggressive encounters, threats, and non-participants (birds not involved in aggressive encounters or threats) were each significantly correlated, with the correlation between aggressive encounters and non-participants being the strongest (*r* : -0.78, P < 0.0001; Table 4.5). Machine downtime and number of birds trained had a significant, but weak positive correlation of *r* : 0.27 (P = 0.0226; Table 4.6). Machine downtime tended to be weakly negatively correlated with aggressive encounters (*r* : -0.23, P = 0.0544) and threats (*r* : -0.20, P = 0.0894).

4.4.2 PF vs. CONV (fed-days only)

There was no significant difference in the number of aggressive encounters (P = 0.3761), threats (P = 0.3233), or non-participants (P = 0.3582) between treatments (Table 4.7) only during days CONV pullets were fed.

4.4.3 Fed- vs. non-fed days within CONV treatment

The interaction of time of day and feed schedule was significant on aggressive encounters (P = 0.0022), threats (P = 0.0051), and non-participants (P = 0.0060; Table 4.8). The numbers of aggressive encounters, threats, and non-participants were not significantly different between the morning and afternoon of fed-days (P > 0.10). On non-fed days, CONV pullets exhibited a two-fold increase in aggressive encounters (AM: 8.12, PM: 3.60; P = 0.0329) and a three-fold increase in threats (AM: 2.95, PM: 0.91; P = 0.0323) in the mornings compared with the afternoons. There tended to more non-participants during the afternoon compared with the morning of non-fed days (AM: 28.52, PM: 33.81; P = 0.0630).

The number of aggressive encounters (P = 1.0000), threats (P = 0.9152), and non-participants (P = 0.7453) during the mornings of fed-days and non-fed days were not significantly different. However, during the afternoons of fed-days, there was a four-fold increase in aggressive encounters (Fed: 15.63, Non-fed: 3.60; P = 0.0019) and a three-fold increase in threats (Fed: 3.13, Non-fed: 0.91; P = 0.0306) compared with the afternoons of non-fed days. Also during afternoons, there were more non-participants during non-fed days compared with fed-days (Fed: 24.77, Non-fed: 33.81; P = 0.0088).

There was a two-fold increase of aggressive encounters (Fed: 12.48, Non-fed: 5.09; P = 0.0006; Table 4.9) in CONV pullets on fed-days compared with non-fed days. Additionally, there were more threats (Fed: 2.54, Non-fed: 1.63; P = 0.0463) between CONV pullets on fed-days compared with non-fed days. Also during fed-days, there were 20% less non-participants compared with non-fed days (Fed: 26.65, Non-fed: 31.05; P = 0.0069).

4.4.4 Social rank fluctuations

There tended to be more rank fluctuations among pullets in the CONV treatment compared with the PF treatment (4.44 ± 0.38; vs. 3.46 ± 0.37, respectively; P = 0.0819). Age also tended to affect the number if social rank fluctuations (P = 0.0640; Figure 4.). The number of social rank fluctuations increased amongst CONV pullet until 16 weeks of age and then markedly decreased. Social rank fluctuations among PF pullets increased and decreased with age, exhibiting no temporal pattern.

The number of low ARI-ranked pullets was negatively (r : -37; P = 0.0244) correlated to machine downtime (Table 4.10). However, the number of high ARI ranked pullets was not significantly correlated with machine downtime. The number of high or low ARI ranked pullets was not significantly correlated with the number of trained birds.

4.5 Discussion

Increased aggression observed in the PF treatment compared with the CONV treatment is likely due to sequential feeding, which created aggression around the station entrance in gestating sows (Edwards et al., 1988). Although each broiler breeder was protected from displacement while eating in the PF station, each pullet had to compete to enter the station in order to access feed. Further, as the number of aggressive encounters in a pen increased, the number of non-participants decreased, potentially compromising the welfare of more birds through increased aggression. Individual feeding of pullets may create welfare concerns as dominant pullets displace subordinate pullets in the vicinity of the station, as observed in ESF-fed sows (Bressers et al., 1993). As there were more pullets involved in aggressive encounters in the PF treatment compared with the CONV treatment, it appears that sequential feeding required more pullets to engage in aggressive activity compared with simultaneous feeding. When attempting to decrease the aggression around ESF, researches determined the importance of equipment layout, building lay out, and individual meal sizes (Brooks, 2003). Therefore, further research into pens containing PFS and appropriate meal sizes and durations are likely appropriate methods of reducing the amount of aggression in PF pullets.

Aggression in broiler breeders is due to hunger motivation (Jones et al., 2004) and a competitive feeding environment due to a limited feed resource (Shea et al., 1990). Pullets in the CONV treatment displayed increased aggression during fed-days compared with non-fed days. Thus, PF pullets exhibited chronic aggression, whereas CONV pullets exhibited acute levels of aggression every other day. The expectation of feed, likely due to environmental cues, appears to have increased aggression in broiler breeders in this study. Cues related to feeding in CONV pens may have been pen doors opening and closing or the presence of a feed pail. However, in PF pens feeding-cues may have been associated with the ejection doors of the PF station. As birds received a cue prior to feeding, they may have exhibited increased aggression due to feeding competition. Thus, the chronic level of aggression in the PF treatment may be due to the consistent presence of a feeding-cue stimulating competition between birds to enter the PF station.

Due to feeding competition and hunger, aggression can be mitigated, but not completely eliminated in a feed-restricted broiler breeder flock. Possible solutions to mitigating aggression in PF pens may be to reduce feed-cues or incorporate barriers into pens. Reducing feed-cues, through quieter machinery, may decrease stimulation of aggression in PF pens. The incorporation of barriers could change bird traffic patterns to decrease the number of birds waiting at the station entrance. Another possible solution to mitigate aggression in PF pens is to conduct further research into station settings (e.g. meal size and duration) to decrease feeding competition. Although birds were provided 25 g of feed, they did not consume the entirety of this meal within one minute. It is possible that the one minute duration used in this study was too short to allow PF pullets an amount of feed which would decrease (but not eliminate) a PF bird's hunger motivation. Like aggression, hunger due to feed restriction may only be reduced, but not eliminated. Providing birds with more time in the PF station (and subsequently larger meal sizes) may aid in reducing hunger in pullets. If hunger is decreased, pullets may wait at the PF station less or exhibit less aggressive behaviours.

Skip-a-day-fed pullets displayed an increase in the number of aggressive encounters during the afternoons of fed-days, compared with the mornings, although this was not significantly different from the morning. An increase in aggression during the afternoons of fed-days may be because CONV pullets were still hungry after meal consumption (de Jong et al., 2005). Thus, aggression in CONV pullets may be increased due to a lack of satiety and prolonged periods with no access to feed. However, a distinction between competitive and hunger aggression cannot be made in the PF pens due to the lack of distinct pre-and post-consummatory phase since pullets ate throughout each day. Nonetheless, this study has identified different potential causes of aggression in CONV and PF flocks (Jones et al., 2004; Shea et al., 1990).

A negative relationship between threats and aggressive encounters in the current study supports the theory that once social order is formed, threats are used instead of aggression to maintain dominance (Quieroz and Cromberg, 2006). As PF pullets displayed slightly more threats than CONV pullets, this may suggest a more stable social order. Further, fewer social rank fluctuations occurred in the PF treatment compared with the CONV treatment. As these results (threats and social order fluctuations) were only tendencies, no firm conclusion can be made regarding the differences in threats or social rank fluctuations between treatments. However, it is possible that the chronic level of aggression among PF pullets enabled pullets to better maintain their dominant and subordinate relationships compared with CONV pullets. Acute levels of aggression, every other day, may not have allowed for dominant and subordinate relationships to be recognized or solidified among CONV pullets.

Although aggression within a domesticated poultry flock is related to social order, aggressive acts among pullets are dependent on individual bird decisions made according to the relative costs and benefits of different strategies, (e.g. aggression or non-aggression; Estevez et al., 2002). Findings from the current study may suggest CONV pullets exhibited aggressive strategies due to increased hunger motivation during the morning on fed-days. Further, Shea et al. (1990) found that 'peck-order violations', aggressive acts which do not conform to the social order (e.g. a bird initiating aggression with a more dominant bird), increased in a skip-a-day-fed flock compared with an *ad libitum* flock. Increased social rank fluctuations in skip-a-day-fed flocks may be due to aggressive strategies which do not conform to social order. Thus, aggression within the PF flock may have similarly caused less shifts in social rank as pullets competed within appropriate social order ranks (e.g. a bird initiating aggression with a more subordinate bird) when trying to enter the PFS.

The positive correlation between PF station downtime and number of PF trained birds identifies the importance of a consistently functioning PF station. As machine downtime increased, more birds may have endured longer periods without feed. Extended periods without feed may have resulted in a greater number of birds severely under the target BW that require PF station training. Thus, machine downtime can become a welfare concern due to prolonged periods without feed in addition to pullets not receiving their breeder recommended nutrient intake. Unexpectedly, machine downtime tended to be negatively correlated with aggressive encounters and threats. It was expected that aggression would increase with increasing periods of machine downtime as pullets would no long have access to feed and therefore may have exhibited more frustration or aggression. However, the lack of cues associated with feeding, such as the ejection doors of the PF station, were likely reduced when the feeding station was not functional. Thus, fewer aggressive encounters and threats may have been initiated when the machine was not working. Machine downtime was also significantly positively correlated with low ARI-ranked pullets. Thus, as the periods of machine downtime increased, PF pullets became less aggressive. An increase in less aggressive pullets may support the negative relationship between machine downtime and aggressive encounters and threats. Therefore, development of future precision broiler breeder feeding systems should not only focus on decreasing the amount of machine downtime but also minimizing any possible ‘feed-cues’ a station may create.

4.6 Conclusion

The precision feeding system used in this study was found to significantly increase aggression compared with a skip-a-day feeding. These findings were despite the PFS being a non-competitive sequential feeding method and CONV being a competitive simultaneous feeding method. Despite a significant difference in aggression, CONV and PF pullets did not exhibit significantly different social rank fluctuations. However, PF pullets tended to display more threats and less social rank fluctuations compared with CONV pullets. Research into the cause of social rank fluctuations in feed-restricted broiler breeders is needed to further the understanding of aggression in precision-fed broiler breeders and to determine whether increased aggression better stabilizes social order.

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Table 4.1. Ethogram detailing the behavioural measurements[1].

Behaviour	Definition
Aggressive Peck	Thrusting motion where beak makes contact with the head or neck of another bird in a rapid and forceful fashion
Threat	Bird positions itself in an elevated manner and looks downward at another bird and remains still
Fight	Face-to-face encounter in which both birds attempt to or successfully peck at the head or neck of the other bird

[1]Modified from Estevez et al., 1997

Table 4.2. Categorization of three rank indexes (dominance, agonistic, aggressive) into high, medium, or low socially ranked pullets[1].

Rank Index	High (H)	Medium (M)	Low (L)
		Proportion	
Dominance (DI_{ai})[2]	H > 0.668	0.333 ≤ M ≤ 0.668	L < 0.333
Agonistic (AGI)[3]	H > 0.068	0.032 ≤ M ≤ 0.068	L < 0.032
Aggressive (ARI)[4]	H > 0.668	0.333 ≤ M ≤ 0.668	L < 0.333

[1] Three methods of social rank were initially investigated by determining general hierarchy positions (high, medium, or low) within each rank type

[2] DI_{ai} was determined by dividing the number of wins per individual pullet by the number of aggressive encounters that pullet was involved in; ranged from 0 to 1 (Bowen and Brooks, 1978)

[3] AGI was determined by dividing the number of aggressive encounters an individual pullet was involved in by the total number of aggressive encounters per pen for that age; ranged from 0 to 1 (Puppe Tuchscherer, 1994)

[4] ARI was determined by dividing the number of aggressive encounters initiated by an individual pullet by the number of aggressive encounters that pullet was involved in; ranged from 0 to 1 (Barosso et al., 2010)

Table 4.3. Correlation coefficients (*r*) for the relationships between high (H) and low (L)[1] ranked pullets according to three rank indices: dominance index (DI_{ai})[2], agonistic index (AGI)[3], and an aggressive index (ARI)[4]. Pullets were fed with skip-a-day or precision feeding systems and were 10 to 21 weeks of age.

Ranking	DI_{ai}-H	DI_{ai}-L	AGI-H	AGI-L	ARI-H	ARI-L
DI_{ai}-H	1.00	-0.05	-0.07	0.31 **	0.72 ***	-0.02
DI_{ai}-L		1.00	-0.27 *	0.68 ***	-0.06	0.95 ***
AGI-H			1.00	-0.15	0.05	-0.28 *
AGI-L				1.00	0.21 §	0.68 ***
ARI-H					1.00	-0.08
ARI-L						1.00

[1] DI_{ai}-H and ARI-H: > 0.668; DI_{ai}-L and ARI-L: < 0.33; AGI-H: > 0.068; AGI-L: <0.032
[2] DI_{ai} was determined by dividing the number of wins per individual pullet by the number of aggressive encounters that pullet was involved in; ranged from 0 to 1 (Bowen and Brooks, 1978)
[3] AGI was determined by dividing the number of aggressive encounters an individual pullet was involved in by the total number of aggressive encounters per pen for that age; ranged from 0 to 1 (Puppe Tuchscherer, 1994)
[4] ARI was determined by dividing the number of aggressive encounters initiated by an individual pullet by the number of aggressive encounters that pullet was involved in; ranged from 0 to 1 (Barosso et al., 2010)
§ $0.10 < P < 0.05$; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

Table 4.4. Effects of feeding system (skip-a-day (CONV) or precision feeding (PF)) on the numbers of behaviours exhibited by pullets. Behaviour observations of pullets occurred from 10 to 21 weeks of age and included fed- and non-fed days. Skip-a-day-fed pullets were fed at 10:30 AM on alternating mornings in communal feed troughs and PF pullets were individually fed multiple small meals per day from a computerized feeding station.

Behaviour	CONV[4]	PF	**P-value**
Aggressive Encounters[1]	8.02 ± 0.48 [0.19]	12.73 ± 0.61 [0.30]	0.0001
Threats[2]	1.96 ± 0.18 [0.05]	2.52 ± 0.20 [0.06]	0.0597
Non-participants[3]	29.08 ± 0.43 [0.68]	27.05 ± 0.42 [0.64]	0.0071

[1]Aggressive encounters included aggressive pecks (beak forward motion that makes contact with the head or neck of another bird in a rapid and forceful fashion) and fights (dyadic face-to-face encounter in which both birds attempt to or successfully peck at the head or neck of the other bird)

[2]Threats were defined as when a bird positioned itself in an elevated manner and looked downward at another bird and remained fixed in position

[3] Non-participants were birds that were not involved in threats or aggressive encounters

[4] Results depict least squares means ± standard error of the number of observed behaviours per 15 minute (AM or PM) observation per pen [least squares mean of the number of observed behaviours per pullet per pen in a 15 minute period]

Table 4.5. Correlation coefficients (*r*) for the relationships between the numbers of aggressive encounters[1], threats[2], and non-participants[3] exhibited by pullets fed with skip-a-day or precision feeding systems. Pullets were 10 to 21 weeks of age.

Variable	Aggressive Encounter	Threat	Non-Participants
Aggressive Encounter	1.00	0.39 ***	-0.78 ***
Threat		1.00	-0.59 ***
Non-Participants			1.00

[1]Aggressive encounters included aggressive pecks (thrusting motion where beak makes contact with the head or neck of another bird in a rapid and forceful fashion) and fights (face-to-face encounter in which both birds attempt to or successfully peck at the head or neck of the other bird)

[2]Threats were defined as when a bird positioned itself in an elevated manner and looked downward at another bird and remained fixed in position

[3] Non-participants were birds that were not involved in threats or aggressive encounters

*** $P < 0.001$

Table 4.6. Correlation coefficients (*r*) for the relationships between machine down time[1] and the numbers of aggressive encounters[2], threats[3], non-participants[4] and trained birds[5] in precision-fed pullets. Pullets were 10 to 21 weeks of age.

Variable	Aggressive encounters	Threats	Non-participants	Trained Birds
Machine downtime	-0.23[§]	-0.20[§]	0.13	0.27 [*]

[1]Machine downtime was defined as the sum of the number of minutes a precision broiler breeder feeding system per pen was not operational for each week

[2] Aggressive encounters included aggressive pecks (thrusting motion where beak makes contact with the head or neck of another bird in a rapid and forceful fashion) and fights (face-to-face encounter in which both birds attempt to or successfully peck at the head or neck of the other bird)

[3] Threats were defined as when a bird positioned itself in an elevated manner and looked downward at another bird and remained fixed in position

[4] Non-participants were birds that were not involved in threats or aggressive encounters

[5] Number of trained birds was defined as the total number of individual pullets that required personnel help to enter the precision broiler breeder feeding system in each week

[§] $0.10 < P < 0.05$; [*] $P < 0.05$

Table 4.7. Effects of feeding system (skip-a-day (CONV) or precision feeding (PF)) on the numbers of observed behaviours exhibited by pullets during fed-days. Behaviour observations of pullets occurred when pullets were 11, 13, 15, 17, and 19 weeks of age. Skip-a-day-fed pullets were fed at 10:30 AM on alternating mornings in communal feed troughs and PF pullets were individually fed multiple small meals per day from a computerized feeding station.

Behaviour	CONV[4]	PF	**P-value**
Aggressive Encounters[1]	12.80 ± 0.97 [0.30]	14.12 ± 1.01 [0.33]	0.3761[5]
Threats[2]	2.60 ± 0.33 [0.06]	3.13 ± 0.36 [0.07]	0.3233[5]
Non-participants[3]	26.72 ± 0.81 [0.62]	27.80 ± 0.80 [0.65]	0.3582[5]

[1]Aggressive encounters included aggressive pecks (beak forward motion that makes contact with the head or neck of another bird in a rapid and forceful fashion) and fights (dyadic face-to-face encounter in which both birds attempt to or successfully peck at the head or neck of the other bird)

[2]Threats were defined as when a bird positioned itself in an elevated manner and looked downward at another bird and remained fixed in position

[3] Non-participants were birds that were not involved in threats or aggressive encounters

[4] Results depict least squares means ± standard error of the number of observed behaviours per 15 minute (AM or PM) observation per pen [least squares mean of the number of observed behaviours per pullet per pen in a 15 minute period]

[5] P > 0.10 were considered not significant

Table 4.8. Block effect (time of day; AM vs. PM) and effect of feed schedule (fed- (FY) vs. non-fed (FN) days) on the number of observed behaviours exhibited by skip-a-day-fed pullets. Behaviour observations occurred from 10 to 21 weeks of age. Pullets were fed at 10:30 AM on alternating mornings in communal feed troughs.

Behaviour	Fed-AM[4, 5]	Fed-PM	Non-fed-AM	Non-fed-PM	Time of day x Feed schedule **P-value**
Aggressive Encounters[1]	9.97^{ab} ± 1.03 [0.23]	15.63^{a} ± 1.29 [0.37]	8.12^{a} ± 0.78 [0.19]	3.60^{b} ± 0.52 [0.09]	0.0022
Threats[2]	2.07^{ab} ± 0.36 [0.05]	3.13^{a} ± 0.44 [0.07]	2.95^{b} ± 0.36 [0.07]	0.91^{c} ± 0.20 [0.02]	0.0051
Non-participants[3]	28.67^{ab} ± 1.06 [0.67]	24.77^{b} ± 0.99 [0.58]	28.52^{ab} ± 0.90 [0.67]	33.81^{a} ± 0.98 [0.80]	0.0060

[1] Aggressive encounters included aggressive pecks (thrusting motion where beak makes contact with the head or neck of another bird in a rapid and forceful fashion) and fights (face-to-face encounter in which both birds attempt to or successfully peck at the head or neck of the other bird)
[2]Threats were defined as when a bird positioned itself in an elevated manner and looked downward at another bird and remained fixed in position.
[3] Non-participants were birds that were not involved in threats or aggressive encounters
[4] Results depict least squares means ± standard error of the number of observed behaviours per 15 minute (AM or PM) observation per pen [least squares mean of the number of observed behaviours per pullet per pen in a 15 minute period]
[5] a-c means within rows with no common superscript differ significantly (at least P < 0.05), as per Bonferroni means separation results

Table 4.9. Effects of feeding schedule (fed- vs. non-fed days) on the numbers of observed behaviours exhibited by skip-a-day-fed pullets. Behaviour observations of pullets occurred from 10 to 21 weeks of age. Pullets were fed at 10:30 AM on alternating mornings in communal feed troughs.

Behaviour	Fed[4]	Non-fed	**P-value**
Aggressive [1] Encounters	12.48 ± 0.82 [0.29]	5.09 ± 0.47 [0.13]	0.0006
Threats[2]	2.54 ± 0.30 [0.06]	1.63 ± 0.20 [0.04]	0.0463
Non-participants[3]	26.65 ± 0.74 [0.62]	31.05 ± 0.75 [0.73]	0.0069

[1]Aggressive encounters included aggressive pecks (thrusting motion where beak makes contact with the head or neck of another bird in a rapid and forceful fashion) and fights (face-to-face encounter in which both birds attempt to or successfully peck at the head or neck of the other bird)
[2]Threats were defined as when a bird positioned itself in an elevated manner and looked downward at another bird and remained fixed in position
[3] Non-participants were birds that were not involved in threats or aggressive encounters
[4] Results depict least squares means ± standard error of the number of observed behaviours per 15 minute (AM or PM) observation per pen [least squares mean of the number of observed behaviours per pullet per pen in a 15 minute period

Table 4.10. Correlation coefficients (*r*) for the relationships between high (H) and low (L) ranked precision pullets[1] according to an aggressive index (ARI)[2], machine downtime[3], and number of trained birds (train)[4] during 10 to 21 weeks of age. Precision pullets were individually fed multiple small meals per day from a computerized feeding station.

Variable	ARI-H	ARI-L	Machine downtime	Train
ARI-H	1.00	-0.05	0.13	0.18
ARI-L		1.00	-0.37 *	-0.18
Machine downtime			1.00	0.40 *
Train				1.00

[1] ARI-H: > 0.668; ARI-L: < 0.33
[2]ARI was determined by dividing the number of aggressive encounters initiated by an individual pullet by the number of aggressive encounters that pullet was involved in (Barroso et al., 2010)
[3] Machine downtime was determined by summing the number of minutes each Precision feed system per pen was not operational in a two week period that corresponded to the rank categorization
[4] Number of trained birds was determined by summing the number if individual precision-fed pullets that required precision feeding station training in a two week period that corresponded to the rank categorization
[*] $P < 0.05$; [* *] $P < 0.01$

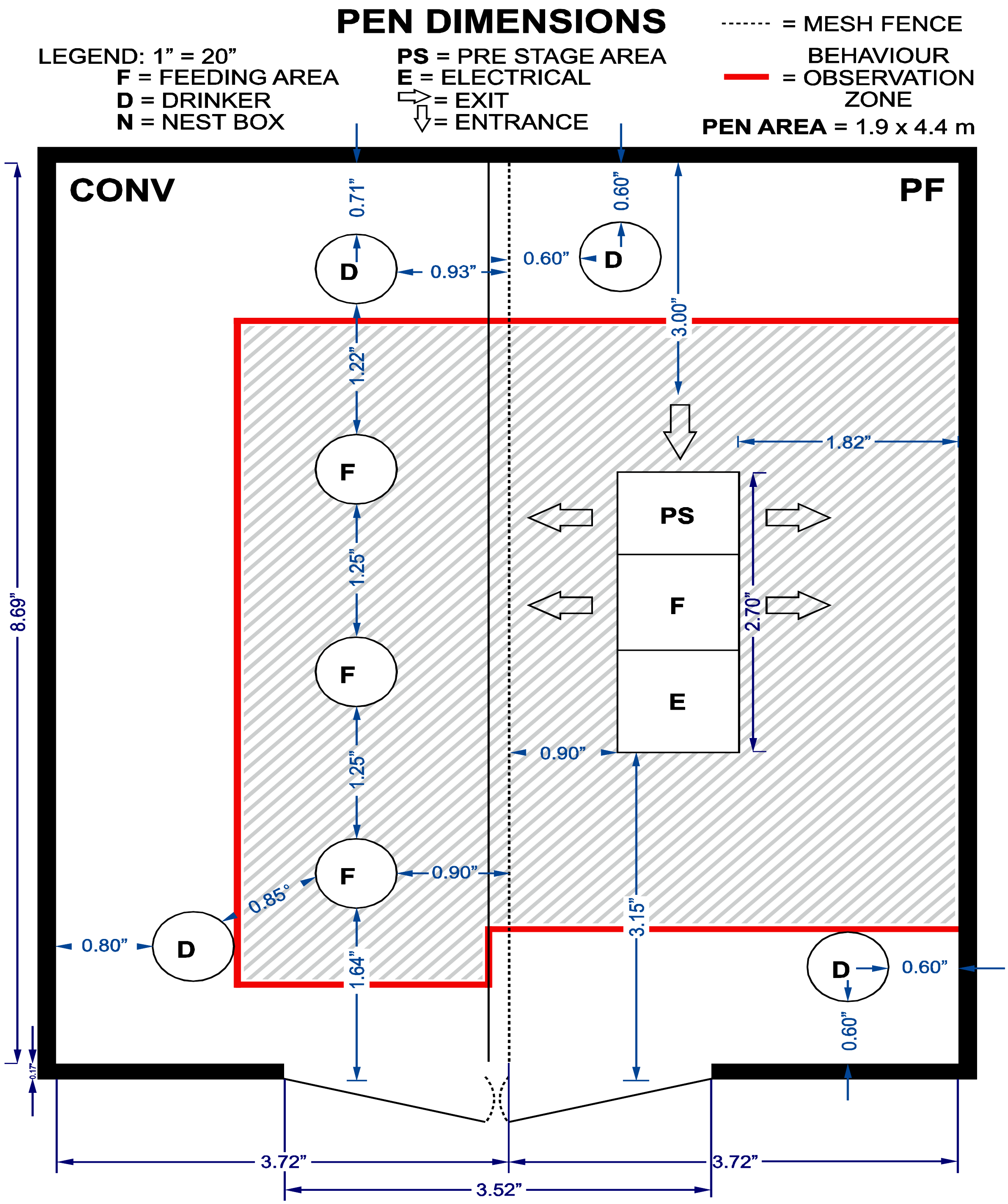

Figure 4.1. Diagram representation of one environmentally controlled chamber (block), with a CONV pen (skip-a-day feeding treatment) and a PF pen (precision feeding treatment). Behaviour observation zone denotes the feeding area where all aggressive pecks, fights, and threats were noted in a 15 minute observational session. (Drawn by: P.R. Carneiro).

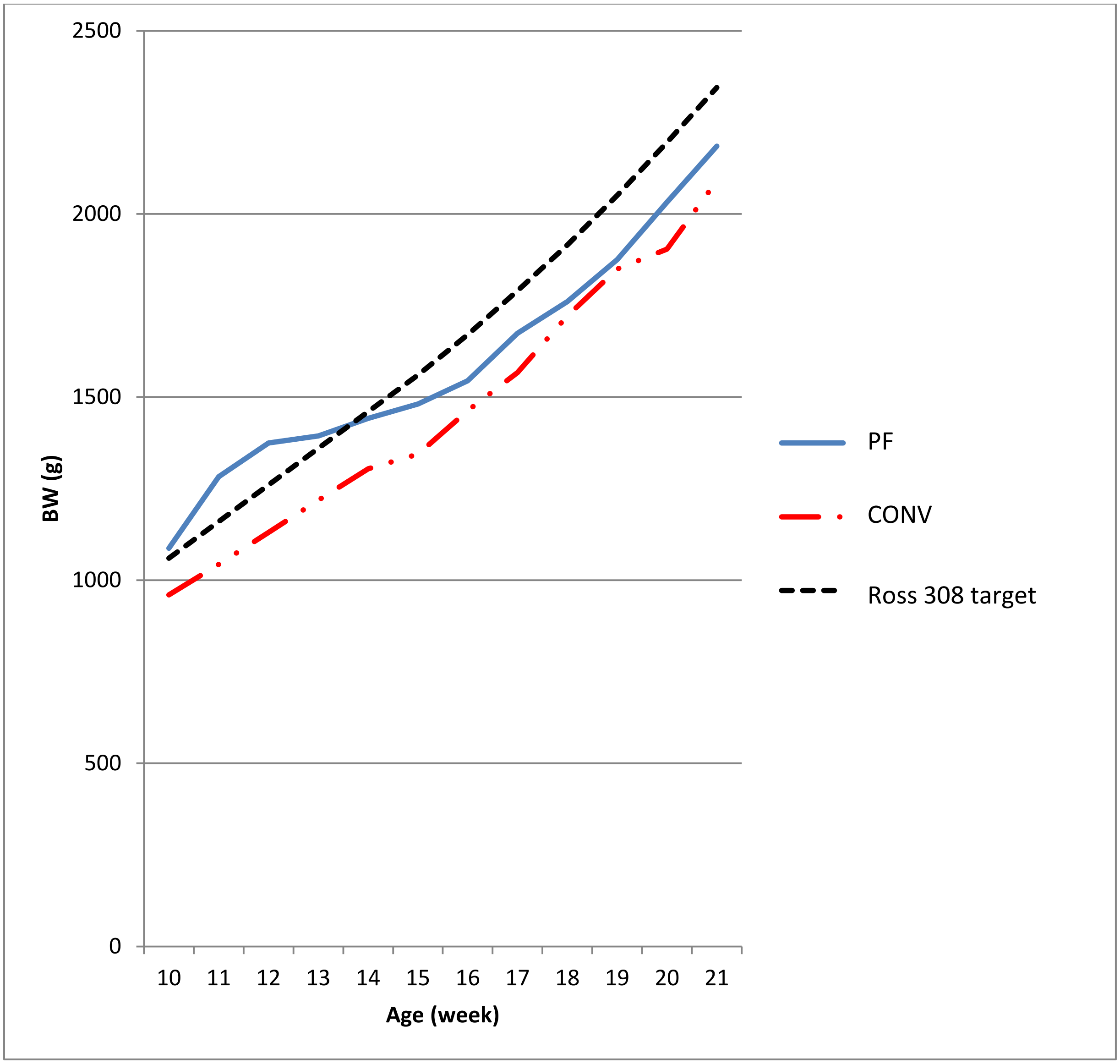

Figure 4.2. Average BW of precision-fed (PF) and skip-a-day-fed (CONV) pullets by week in comparison to weekly Ross 308 target BW (Aviagen, 2011). Feed allocation for the CONV treatment was based on Ross 308 target BW (Aviagen, 2011). The PF treatment was composed of BW targets of three body curves: Ross 708 (Aviagen, 2013), Ross 308 (Aviagen, 2013), and 'Step'. Because BW curves in the PF treatment had no significant effect on any observed behaviour or social rank fluctuations, behaviour information pertaining to BW curves was not used in any statistical analysis and were combined to form an average weekly BW. Skip-a-day-fed pullets were fed at 10:30 AM on alternating mornings in communal feed troughs and PF pullets were individually fed multiple small meals per day from a computerized feeding station.

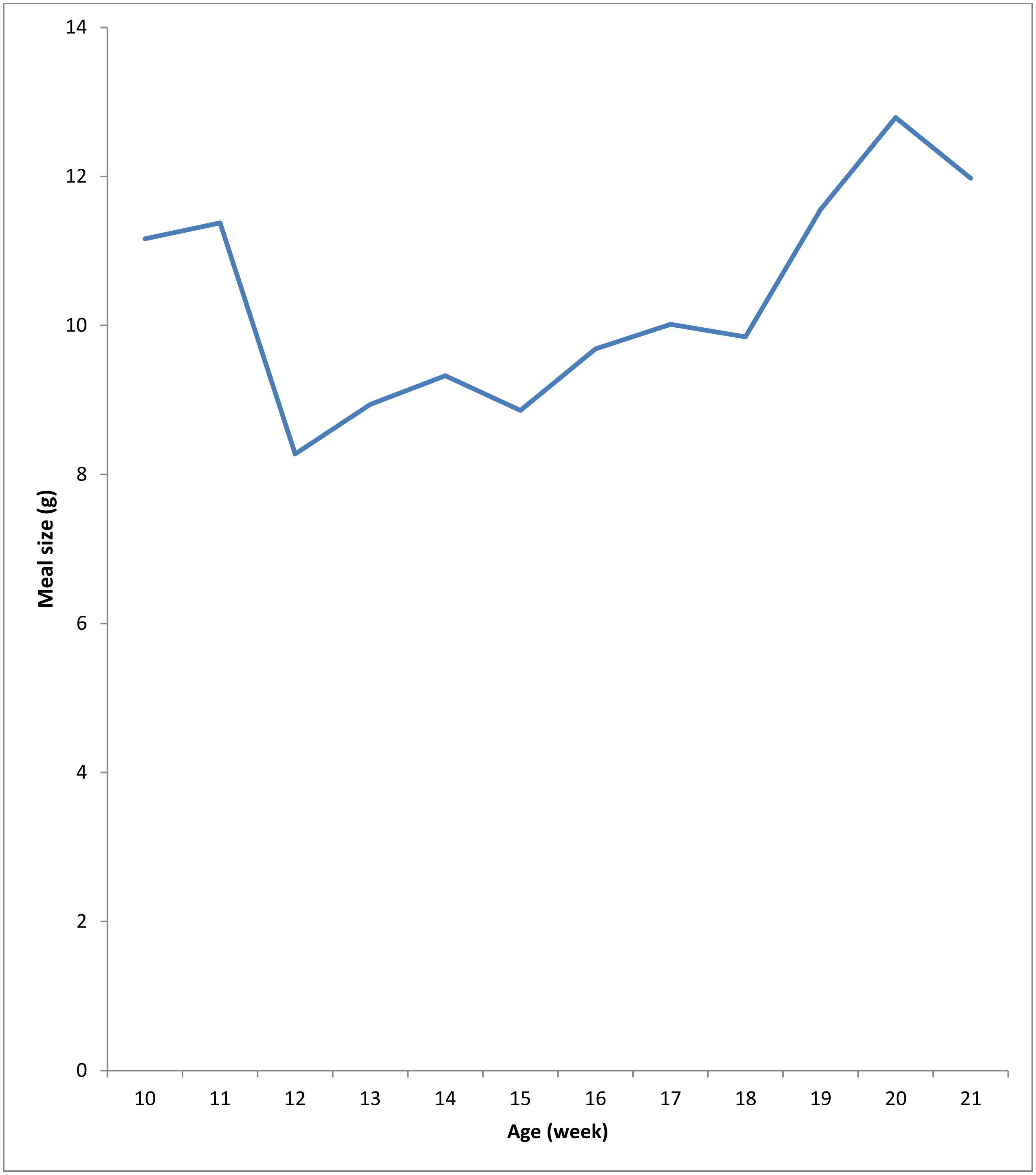

Figure 4.3. Average meal size of precision-fed pullets by age (week). Precision feeding was the continuous allocation of multiple small meals from a computerized feeding station (n = 6). If the bird was under the target BW, it was provided access to 25 g of feed for one minute before ejection from the station. Once the bird was ejected, the amount of feed in the feeder was topped up to 25 g for the next pullet. The average meal size was 10.32 g/meal and the average number of meals per day was 8 for precision-fed pullets from 10 to 21 weeks of age.

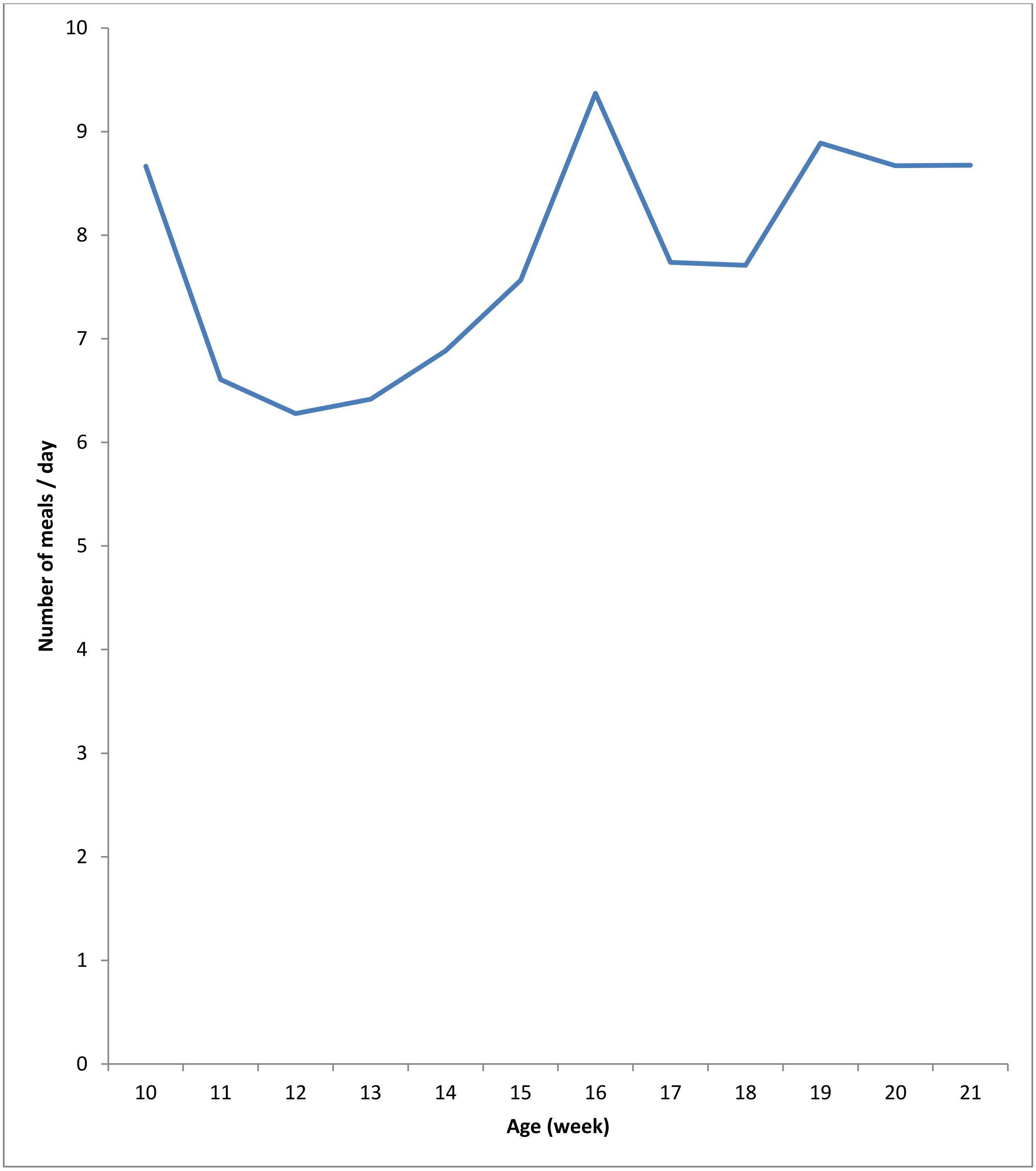

Figure 4.4. Average number of meals per day per bird provided to precision-fed pullets by age (week). Precision feeding was the allocation of multiple small meals from a computerized feeding station (n = 6). If the bird was under the target BW, it was provided access to 25 g of feed for one minute before ejection from the station. Once the bird was ejected, the amount of feed in the feeder was topped up to 25 g for the next pullet. The average meal size was 10.32 g/meal and the average number of meals per day was 8 for precision-fed pullets from 10 to 21 weeks of age.

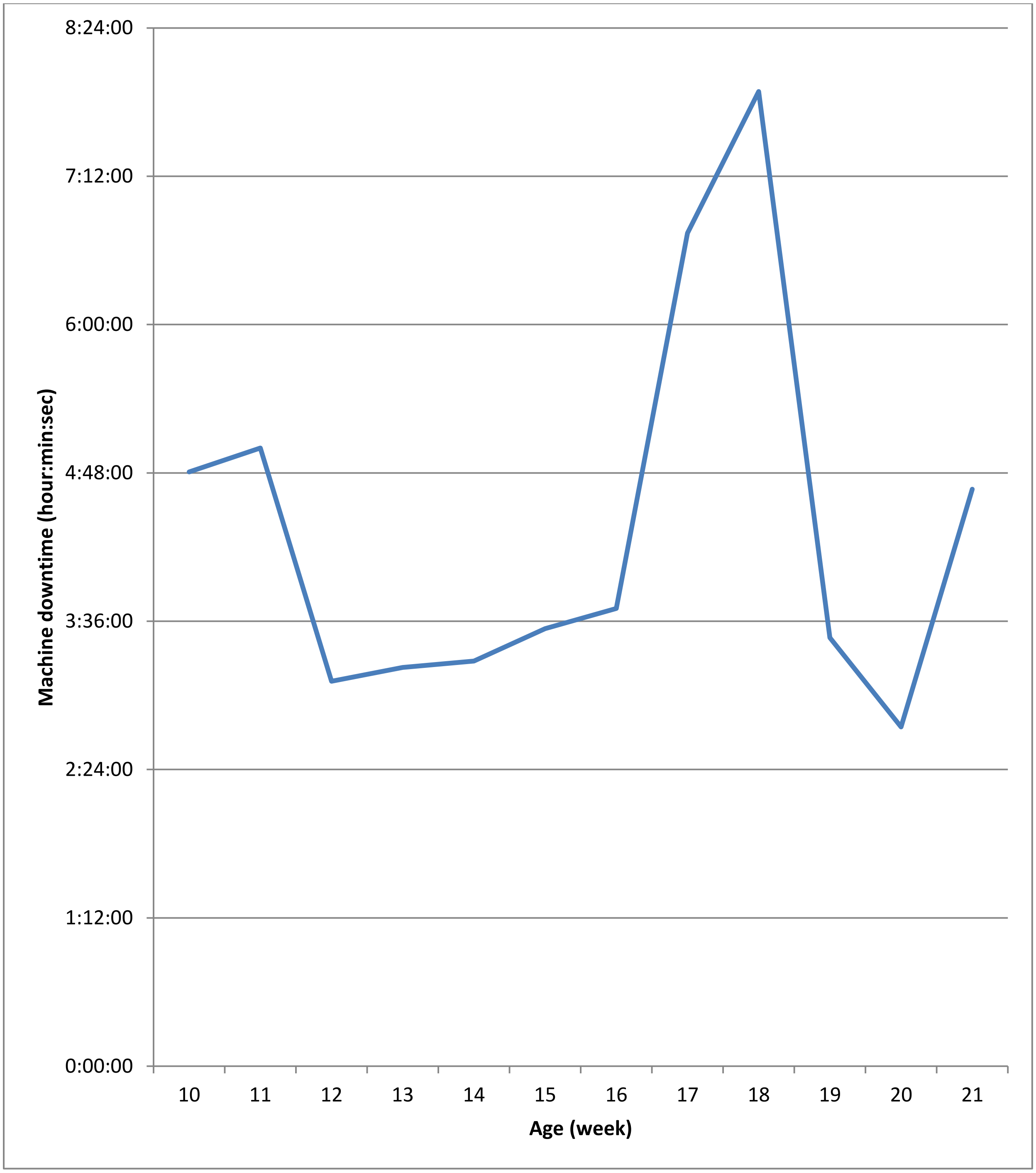

Figure 4.5. Average amount of machine downtime of precision feeding stations per pen by age. Machine downtime data was calculated for each pen (n= 6) by summing the number of minutes each precision feeding station was non-operational within each week. On average, there was 4:47:07 minutes of machine downtime per day per pen and 18:35:34 minutes of machine downtime per pen per week.

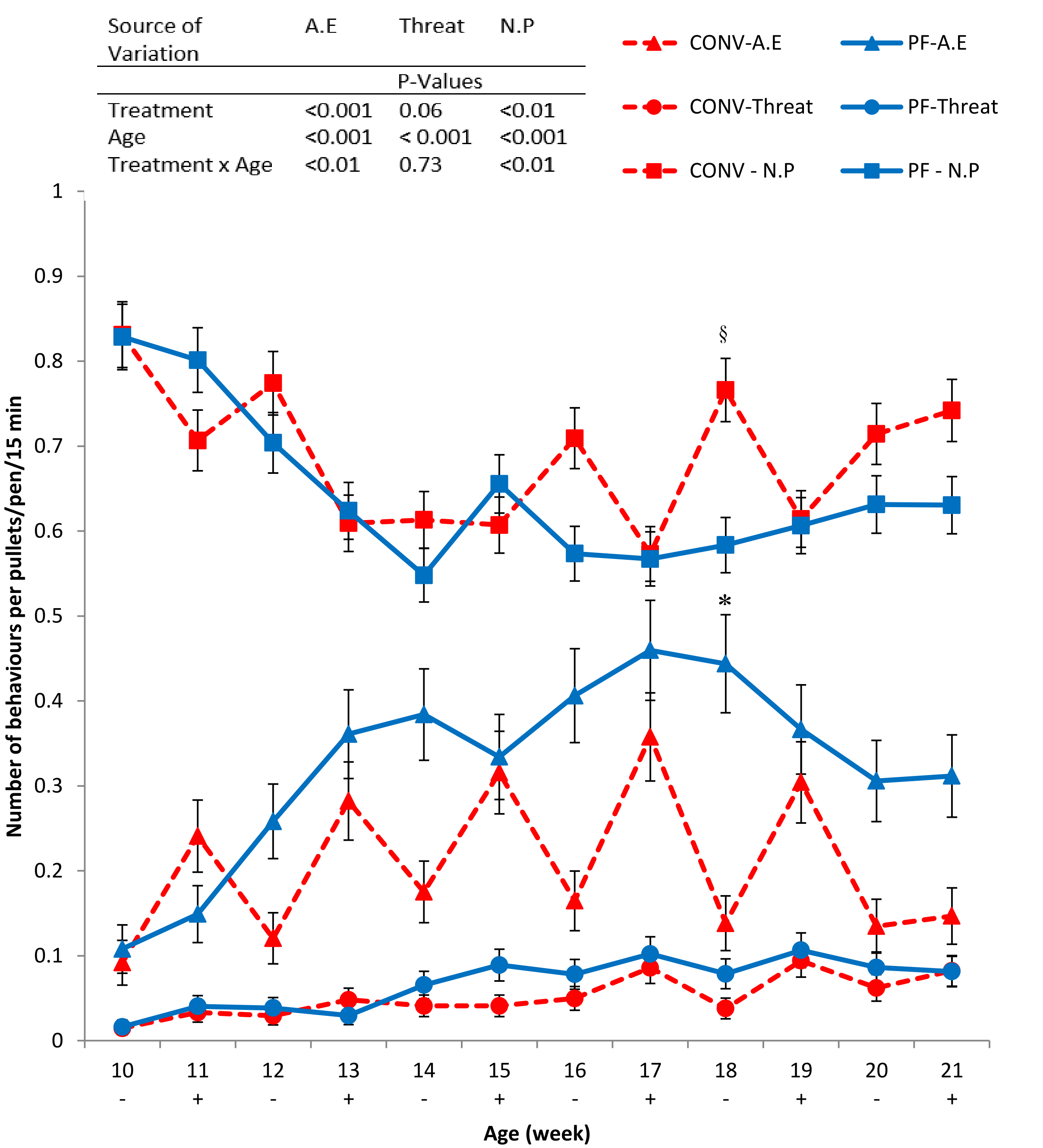

Figure 4.6. Age (week) and feeding system treatment (skip-a-day (CONV) or precision feeding (PF)) on the number of aggressive encounters (A.E), threats, and non-participants (N.P) per pullet per 15 minutes. Behaviour observations occurred when pullets were 10 to 12 weeks of age. (+) indicates observations of fed-days and (-) indicates observations of non-fed days of CONV pullets. Figure depicts the least squares mean of the number of specified behaviour per pullet per 15 minutes per pen. A Bonferonni means separation test was used. Treatment differences in the specified behaviour category within age are indicated by (§) 0.10< P < 0.05, (*) P < 0.05.

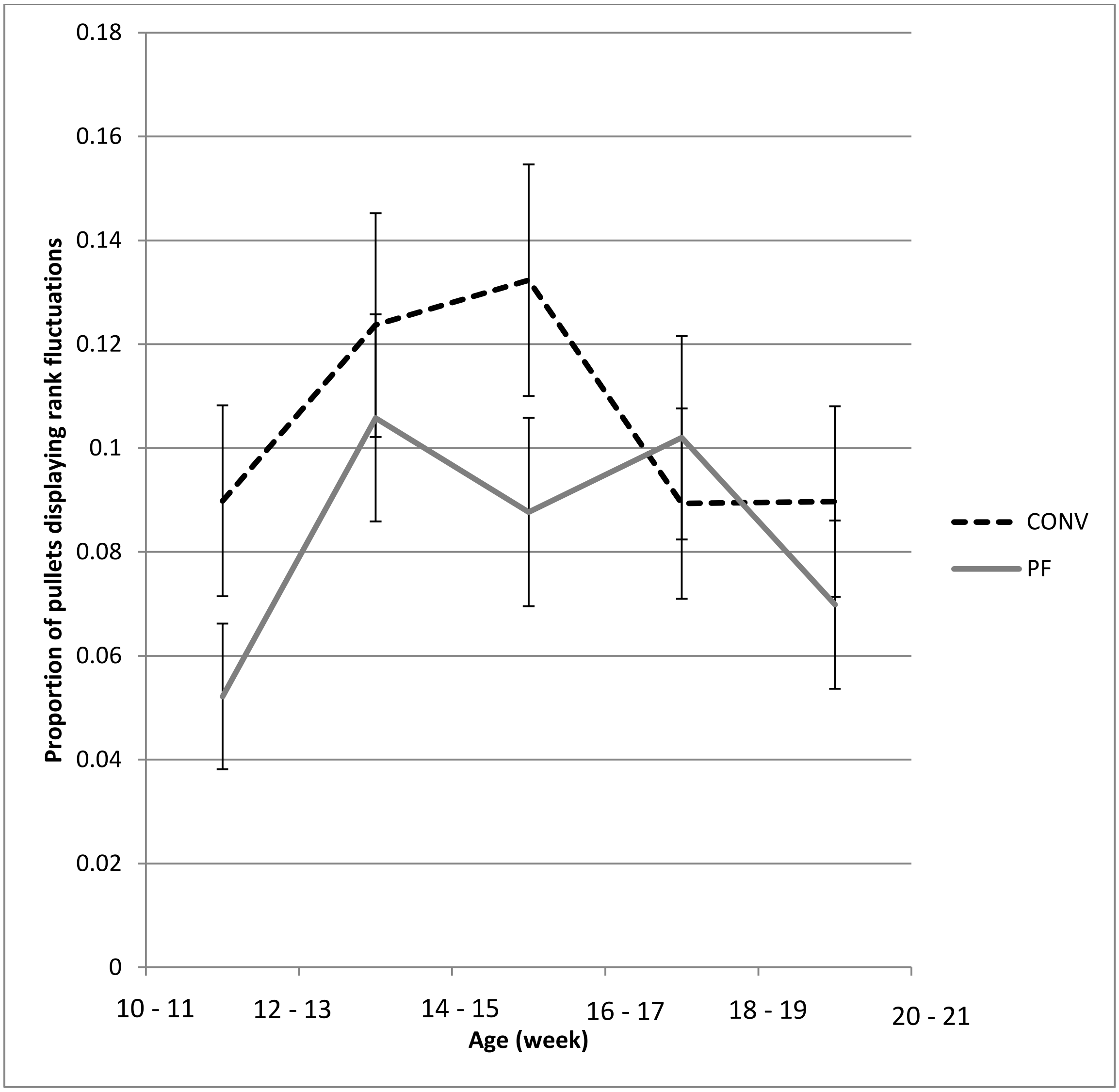

Figure 4.7. Effect of feeding system (skip-a-day (CONV) or precision feeding (PF)) and age on proportion of pullets displaying aggressive rank fluctuations between age groups. Age had a tendency to affect number of rank fluctuations (P = 0.0640) as did treatment (P = 0.08). Age group was determined by grouping weeks into combinations of 2, from 10 to 21 weeks of age.[1] Aggressive rank index was determined by dividing the number of aggressive encounters initiated by an individual pullet by the number of aggressive encounters that pullet was involved in. Ranks were then categorized as high (> 0.668; the top third of ranked pullets) or low (< 0.33; the bottom third of ranked pullets). Fluctuations were determined by counting the number of pullets that changed from H to L rank indices between consecutive age groups. Proportion of birds exhibiting fluctuations was determined by dividing the number of birds that fluctuated in rank by the average number of birds per pen at the beginning of the age group. Observations of fed-days of CONV pullets were during weeks 11, 13, 15, 17, 19. Observations of non-fed days were during weeks 10, 12, 14, 16, 18, 20, 21. A Bonferonni means separation test was used. Figure depicts the least squares mean of the proportion of pullets displaying social rank fluctuations between two consecutive age groups. There were no treatment differences in rank fluctuations within age.

5.0 Synthesis

Although feed restriction of broiler breeders creates welfare concerns (e.g. chronic hunger and inhibition of natural behaviours), feed restriction is required to decrease obesity-related disease and subsequent losses in production. Thus, the concern regarding broiler breeder welfare presented in this thesis was not whether to utilize feed restriction, but how to best manage broiler breeder feed allocation in order to decrease hunger motivation. This thesis focused on determining the behavioural consequences of precision feeding broiler breeders in comparison to a conventional, skip-a-day feeding schedule. As such, this thesis did not measure physiological indicators of hunger as a result of feed restriction nor did it focus on internal factors (e.g. genetics) that impact hunger motivation in broiler breeders. Instead, this thesis focused on the external factors (i.e. allocation of restricted feed) related to broiler breeder hunger motivation as measured through behavioural indicators of perceived hunger. Precision feeding was the automated allocation of multiple small individual meals throughout a day, whereas skip-a-day feeding was the allocation of one large meal, at the group level, every second day. Two experimental studies were run concurrently to examine and measure hunger perception: restlessness, dust-bathing, foraging, object pecking, feather pecking, aggression, and social order fluctuations were measured and compared in precision-fed and skip-a-day-fed broiler breeder pullets.

5.1 Objective 1. Restlessness

The first objective was to determine whether precision feeding reduced the broiler breeder's perception of hunger by comparing levels of restlessness (standing and walking) of precision-fed to skip-a-day-fed broiler breeders. There have been no previous studies comparing precision and skip-a-day feeding systems. It was reported in Chapter 3 that precision-fed pullets exhibited less standing and walking compared with conventional skip-a-day-fed pullets. Previous research has characterized 'activity' of broiler breeders to include behaviours such as: object pecking, standing, walking (Kostal et al., 1992; Savory and Maros, 1993; Savory et al., 1996), preening (Savory et al., 1992) foraging, feather pecking, aggressive pecking, and dust-bathing (Sandilands et al., 2006). In the current study, feather pecking and object pecking were investigated as aberrant behaviours in objective 3. Foraging and aggressive feather pecking were investigated in objectives 2 and 4, respectively. Preening was not investigated as it was confounded by individual bird identification methods. Sitting was used as an indication of inactivity and dust-bathing occurred too infrequently to analyze. Therefore, this objective focused on standing and walking behaviours as indicative of restlessness and therefore increased perceived hunger. Recently, Morrissey et al. (2014a) studied skip-a-day-fed broiler breeder pullets and defined activity as 'walking'. Standing and walking behaviour was less prevalent in precision feeding pens with 7% fewer precision-fed pullets observed standing and walking compared with CONV pullets (Chapter 3). Interestingly, although precision-fed pullets exhibited less restlessness compared with skip-a-day-fed pullets, precision-fed pullets were more aggressive compared with skip-a-day-fed pullets (Chapter 4). Further, precision-fed pullets consistently displayed more 'other' behaviours compared with conventional skip-a-day-fed pullets. 'Other' behaviours captured all behaviours not defined in the ethogram such as dust-bathing, pecking at wing-tags, preening, system entries, drinking, feeding, and aggression. Thus, the category of 'other' behaviours in Chapter 3 captured the increased aggressive behaviour in precision-fed pullets. Therefore, although precision-fed pullets appeared to experience decreased hunger motivation compared with skip-a-day-fed pullets, precision feeding may not entirely benefit broiler breeder welfare as it also created greater levels of aggressive activity compared with skip-a-day feeding.

5.2 Objective 2. Foraging

The second objective of this thesis was to identify whether the behavioural need to forage was better satisfied in a broiler breeder flock fed with precision feeding or a skip-a-day system. Conventional skip-a-day-fed pullets exhibited more foraging behaviour compared with precision-fed pullets. Although domestic broiler breeders and Red Jungle Fowl are genetically distinct, broiler breeders still possess the same behavioural repertoire as Red Jungle Fowl (Price, 1999). Foraging is displayed by Red Jungle Fowl for approximately 95% of the time between dawn and dusk (Dawkins, 1989) and is a behavioural need of chickens (Duncan, 1998). Thus, an environment which increases foraging behaviour quantitatively would be beneficial to a broiler breeder if the intent is to satisfy the behavioural need of foraging. Foraging has been defined as ground scratching and ground pecking (Chapter 3; Dawkins, 1989; Dixon et al., 2014; Sandilands et al., 2006). As 8% fewer precision-fed pullets foraged compared with skip-a-day-fed pullets, it appears that skip-a-day-fed feeding better satisfied the broiler breeders' need to forage. However, skip-a-day-fed pullets only exhibited a significant increase in foraging behaviours during days they were not fed. Thus, although foraging is a natural behaviour, the presence of foraging as a feed-seeking behaviour may indicate increased hunger (Morrissey et al., 2014a). Further, as entering the precision feeding station is a feed seeking behaviour, the ability of pullets to enter the precision feeding station numerous times a day may better satisfy the behavioural need to forage. Thus, ground pecking and ground scratching may not be the best measure of whether broiler breeders are satisfying their need to forage in precision feeding pens as there are likely additional feed seeking behaviours occurring. Therefore, for completeness, future measurements of foraging behaviour in precision feeding pens should include ground pecking, ground scratching, feather pecking, and the number of times a precision-fed pullet attempted to enter the feeding area of the station.

5.3 Objective 3. Aberrant behaviours

The third objective was to determine whether use of the precision feeding system resulted in broiler breeders exhibiting a different number of oral behaviours compared to skip-a-day feeding. True stereotypic behaviours are repetitive, serve no obvious goal or function, and have fixed and abbreviated action patterns (Ödberg, 1978). It was hypothesized that precision-fed pullets would exhibit fewer oral stereotypic behaviours as precision feeding would better satisfy the birds' behavioural need to forage. When the need to forage is unsatisfied, frustration results in re-directed vice or problematic behaviours. If this frustration is chronic and profound enough (e.g. frequent prolonged periods without feed such as those in a skip-a-day schedule), behavioural vices can develop into fixed and/or abbreviated stereotypies over time. It was Precision-fed pullets exhibited more object pecking but less feather pecking compared with conventional skip-a-day-fed pullets (Chapter 3). While there was no evidence in Chapter 3 of true stereotypic oral behaviours, feather pecking and object pecking behavioural vices still indicate a welfare concern due to an unsatisfied hunger motivation or foraging frustration (Jensen and Toates, 1993).

Skip-a-day-fed pullets performed more feather pecking behaviours compared with precision-fed pullets on both fed and non-fed days. Both gentle and severe pecking behaviours have been used in the definition of feather pecking in previous literature (Morrissey et al., 2014b) and were included in the definition of feather pecking in Chapter 3. Morrissey et al. (2014b) observed that feather pecking was prevalent in skip-a-day-fed broiler breeders 2.46% of observational time (08:00 to 11:00). 1% of skip-a-day-fed pullets feather pecked throughout observation sessions, while precision-fed pullets rarely (less than 1% of focal birds) exhibited the behaviour (Chapter 3). Severe feather pecking is believed to be a re-directed foraging behaviour (de Haas et al., 2010), therefore exhibition of foraging and feather pecking behaviours would be expected to be inversely related. However, skip-a-day-fed pullets were found to display more foraging and feather pecking compared with precision-fed pullets. These findings are not consistent with previous observations that feather pecking is due to re-directed foraging behaviours. As such, the inclusion of gentle feather pecking in the definition of feather pecking may have compromised the interpretation of the relationship between foraging and feather pecking. Further, CONV pullets displayed increased feather pecking during non-fed days compared with fed-days. Therefore, increased feather pecking in CONV pullets may be more due to prolonged periods without feed.

Object pecking (Hocking et al., 1993; Kostal et al., 1992; Savory and Kostal, 2006; Savory and Maros, 1993; Sandilands et al., 2005; Savory et al., 1992) has been identified as both a behavioural vice and a stereotypic behaviour in broiler breeders. Further, object pecking can include a variety of behaviours such as pen wall, drinker, and feeder pecking. Previous studies have found feed-restricted broiler breeders display more drinker pecking (Kostal et al., 1992; Savory et al., 1992), empty feeder pecking (Kostal et al., 1992; Savory and Maros, 1993), and pen wall pecking (Savory and Kostal, 2006) compared with *ad libitum* broiler breeders. Precision-fed pullets exhibited more drinker pecking compared with conventional skip-a-day-fed pullets. Increased drinker pecking was likely due to one drinker in close proximity to a feeding station entrance in each pen. As precision-fed pullets waited to gain access to the feeding station, there was an opportunity to re-direct foraging behaviours into drinker pecking. Therefore, management of precision feeding stations may benefit from providing pecking enrichment and moving drinkers away from the station's entrance.

5.4 Objective 4. Aggression

Objective four was to identify whether broiler breeders fed with a precision feeding system exhibited increased aggression compared with skip-a-day-fed broiler breeders. It was precision-fed pullets were involved in more aggressive encounters compared with conventional skip-a-day-fed pullets (Chapter 4). In Chapter 3, this aggression was captured in the 'other' behaviour category. Previous literature has defined broiler breeder aggression during rearing as aggressive pecking (Hocking and Jones, 2006; Morrissey et al., 2014a) or aggressive pecking and threats (Shea et al., 1990). Specifically, Morrissey et al. (2014a) studied the prevalence of aggression in broiler breeder pullets fed daily or on a skip-a-day schedule. However, due to scan sampling methodology and the rapid action of aggressive pecks, Morrissey et al. (2014a) did not reach a solid conclusion. In Chapter 4, aggressive encounters were defined as aggressive pecks and fights. Each pen was observed continuously for 15 minutes. Threats were investigated as part of social rank stability in objective 5.

Aggression in broiler breeders is due to hunger (Jones et al., 2004) and competition for a limited feed resource (Shea et al., 1990). In addition, for all intents and purposes, feed delivery acts as a cue for competition and aggression. Aggression was higher in conventional skip-a-day-fed pullets on days they were fed compared to non-fed days, and thus the pattern of acute aggression observed coincided with feed presentation. However, precision feeding frequently emitted a 'feed-cue' from the station and accordingly, precision-fed pullets exhibited chronic levels of aggression. Due to feeding competition and hunger, aggression can not completely eliminated in a feed-restricted broiler breeder flock. However, there are three potential solutions which may decrease aggression in precision-fed pullets. The first solution is to change the bird traffic pattern in the pen, through the use of partitions or perches, to decrease the number of birds waiting to enter the station. The second solution is to provide pen enrichment, such as hanging and shiny objects, to re-direct aggression around the station entrance. The third solution is to conduct further research into station settings, in particular meal size and duration, to determine the amount of feed required to all broiler breeders multiple meals a day while still decreasing competition and hunger motivation.

5.5 Objective 5. Social rank fluctuations

The fifth objective was to identify whether broiler breeders fed with a precision feeding system exhibited increased social order fluctuations in comparison to skip-a-day-fed broiler breeders. Rank fluctuations were defined as when a high ranking pullet became a low ranking pullet and vice versa. Precision-fed pullets tended to exhibit more threat behaviours, but fewer social rank fluctuations compared with conventional skip-a-day-fed pullets. Literature regarding variations in social rank of broiler breeder pullets is lacking. However, Shea et al. (1990) observed that when feed was restricted, the prevalence of aggression in male broiler breeders increased, which then destabilized and delayed the formation of a social order (Shea et al., 1990). In Chapter 4, the number of threats and an Aggressive Rank Index (ARI; Barossa et al., 2000) was used to investigate social order fluctuations within pullets which participated in aggressive encounters. The establishment of a social order within a flock depends on encounter outcomes (e.g. winners and losers in fights and threats; Estevez et al., 2002). Further, as social order becomes more stable, the number of aggressive behaviours is expected to decrease as the number of threats increases (Estevez et al., 2002). A decrease in aggressive acts and increase in threat behaviours is due to posturing, which maintains previously established social rank without more intense aggressive encounters (eg. pecks and fights). As precision-fed pullets experienced chronic aggression, one possible explanation for the decreased social order fluctuation observed is that there were numerous opportunities for birds to resolve conflicts. Therefore, through chronic prevalence of aggression and threats, a more stable social order may have been maintained amongst precision-fed pullets. In contrast, skip-a-day-fed pullets encountered acute periods of aggression during fed days, which did not allow for social order to stabilize (to the same degree as observed in precision-fed pullets). Therefore, chronic aggression in precision feeding appeared to stabilize social order to some extent, as observed in decreased ARI fluctuations. However, as the results concerning threats and social rank fluctuations were only tendencies, future research should investigate whether these findings hold under different precision feeding settings (meal size and meal duration) and using other social rank indexes. Furthermore, as aggression in domestic poultry is thought to be dependent on individual bird strategies (e.g. aggression or non-aggression; Estevez et al., 2002), further research is warranted into specific strategies pullets adopt to successfully access feed in a precision system and how these strategies correlate to social rank.

5.6 Novelty of research

Previous studies have attempted to increase broiler breeder welfare through implementing various feeding schedules (e.g. daily feeding, skip-a-day feeding), increasing meal durations (e.g. qualitative restriction), or altering the method of feed allocation (e.g. scatter-feeding). However, none of these methods have been successful in eliminating the welfare concerns of feed restriction (Mench, 2002). It had been suggested that more frequent feeding of broiler breeders may improve welfare (Mench, 2002). This thesis was the first investigation into the behavioural implications of broiler breeder precision feeding.

5.7 Study limitations

As the precision feeding station in the current trial was an early prototype, there were still areas where the station could be improved. Periods of machine downtime may have influenced study results by creating periods during which pullets could not obtain feed or enter the station. Additionally, while waiting at the entrance of the feeding station, pullets may have experienced an increase in frustration due to not entering the feeding station. The location of a drinker in close proximity to the station entrance may have influenced drinker pecking results as precision-fed pullets may have been more inclined to peck at the drinker while waiting to enter the feeding station.

The use of environmental chambers constrained behaviour observations as instead of observing side by side pens, observers had to remain in chambers while conducting observations. Because of distinct observation periods for each pen, live observations of each pen could only occur for 15 minutes. Instantaneous scan sampling for fifteen minutes did not allow us to conclude whether object pecking and feather pecking behaviours had become completely 'fixed' as per the definition of a stereotypy. Further, 15 minutes was not long enough to observe all of the birds in aggressive encounters. Alternatively, video cameras or longer periods of live observations would have been needed however we chose not to use video cameras as they labour and time intensive. Instead, training of observers occurred over 4 months prior to the project and ensured an inter-observer reliability of 90%. Video cameras or longer periods of live observations also would have helped us to apply our results to larger portions of the day. Additionally, due to station development, this study did not begin until the pullets were 10 weeks of age. The delay in study commencement appeared to result in a greater number of precision-fed pullets requiring station training. By beginning precision feeding station use at a later age, birds have already learnt to expect feed or forage for feed in and around the floor troughs. Thus, precision feeding station use was likely not completely intuitive to the pullets at 10 weeks of age. Ideally, a trial investigating methods of feed restriction should begin at the beginning of feed restriction (e.g. 3 weeks of age).

5.8 Future research

This study provided only foundational knowledge of the behaviour and welfare implications of broiler breeder precision feeding. Therefore, further investigative studies are warranted into precision feeding of broiler breeders. Future research into the behavioural consequences of different precision feeding system settings (e.g. meal size and duration) are required to determine effects on aberrant behaviours. For example, providing precision-fed pullets with a longer duration and therefore, increased meal size, may decrease the prevalence of object pecking. Use of different system settings (e.g. meal size and duration) may also provide information regarding individual bird strategies and whether they conform to optimal foraging theory when using the precision feeding system. For example, smaller meal sizes may require more subordinate pullets to enter the precision feed station at night, due to a potential increased competition and therefore energetic cost, during the day.. Further, pen management factors such as enrichment and bird traffic patterns should be investigated when attempting to decrease aggression amongst precision-fed pullets around the feeding station.

Finally, as scatter-feeding increases duration of foraging and feeding behaviour (van Middelkoop et al., 2000), scatter-feeding may be better able to improve broiler breeder welfare compared with skip-a-day feeding. Thus, if the hypothesis that precision feeding station entries may simulate foraging behaviours in broiler breeders is true, an interesting experiment would be to compare to the behavioural and welfare implication of scatter compared to precision feeding.

Specifically, scatter-feeding has decreased object pecking in broiler breeder pullets during rearing (de Jong et al., 2005) while precision feeding has increased object pecking compared to skip-a-day (Chapter 3). Scatter-feeding is becoming a common practice in the Netherlands and Canada (van Middlekoop et al., 2000) while skip-a-day feeding has been banned in the United Kingdom due to welfare concerns of prolonged periods without feed (DEFRA, 2007). Thus, a comparison between scatter and precision feeding systems may benefit broiler breeder feed restriction management

5.9 Overall Implications

Our results supported previous evidence that increased restlessness (standing and walking) is indicative of increased hunger motivation (Savory and Lariviere, 2000). Increased standing and walking subsequently results in less sitting and resting. However, we found increased sitting was not directly related to comfort or satiety (Chapter 3), as previous reports have suggested (Sandilands et al., 2005). We also found that increased exhibition of foraging behaviours does not always indicate a reduction in broiler breeder hunger motivation. Instead, an increase in foraging behaviour appeared to indicate increased hunger motivation, rather than satisfying the behavioural need to forage in a feed-restricted environment. Further, an increase in both foraging and feather pecking behaviours was observed in skip-a-day-fed pullets which did not support the theory that a decrease in foraging behaviours results in an increase in feather pecking behaviour (de Haas et al., 2010). Thus, this study did not find a clear, inverse relationship between re-directed foraging and feather pecking in broiler breeders. Therefore, it is theorized that there may be different causes of feather pecking in broiler breeders (e.g. hunger motivation) compared with laying hens (e.g. re-directed ground foraging).

This study may aid in management guidelines for automated poultry production methods. Results provided in Chapter 3 and 4 provided information regarding management of broiler breeder hunger motivation and behavioural needs. Future animal care policies concerning broiler breeder precision feeding should include pen enrichment and appropriate meal sizes and durations in order to reduce aggression and aberrant behaviours such as object pecking and feather pecking in precision-fed pullets.

5.10 Conclusion

Although precision-fed pullets exhibited less restlessness compared with skip-a-day-fed pullets, precision-fed pullets exhibited more aggression compared to skip-a-day-fed pullets. Simulation of foraging behaviour by the precision feeding station may be achieved by allowing birds to search for feed within the station and thereby preventing the experience of prolonged periods without feed. Thus, ground pecking and ground scratching may not be the best measure of whether broiler breeders are satisfying their behavioural need to forage in precision feeding pens and may require the addition of precision feeding station entry data. There was no evidence of true stereotypic oral behaviours in either feeding system, however pullets in each treatment did exhibit what could be considered behavioural vices. In precision-fed pullets, object pecking was a prominent behavioural vice. Object pecking may have been augmented due to drinker placement in close proximity to where birds waited to enter stations. Overall, precision feeding resulted in decreased feather pecking compared to skip-a-day feeding. Future research investigations and possible solutions to decrease behavioural vices should include changing bird traffic pattern in the pen, re-directing aggression towards specific enrichment, or changing precision feeding meal sizes and durations to help mitigate aggression around the feeding station.

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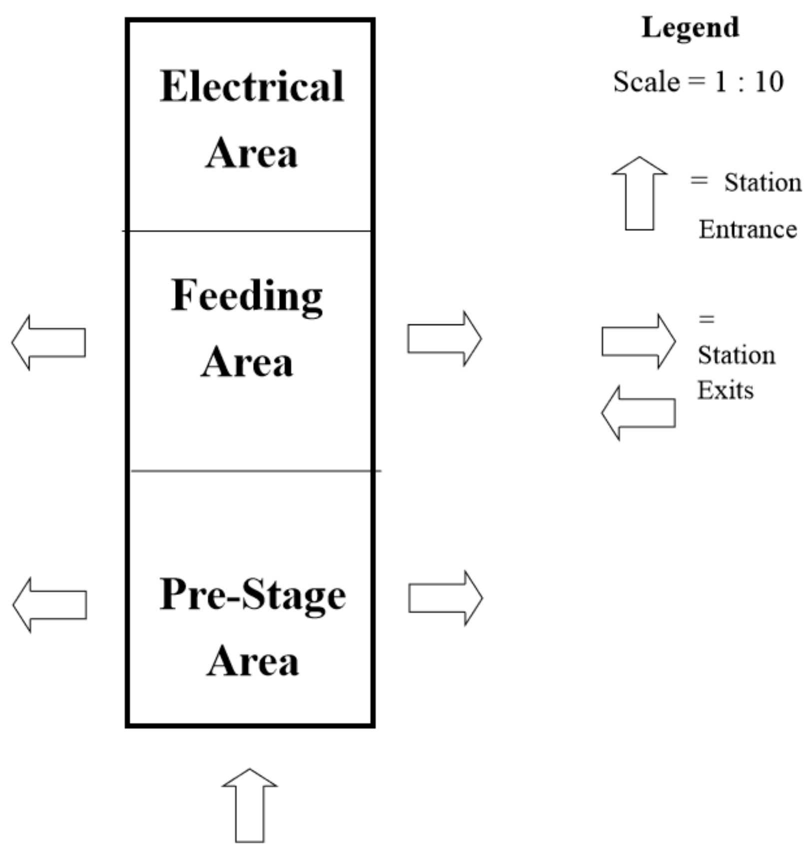
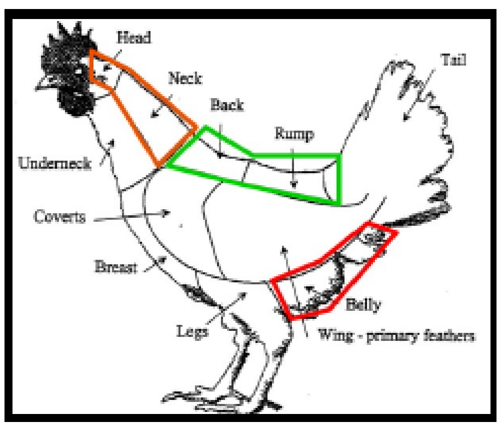
Appendix A. Diagram representation of the precision broiler breeder feeding station. The precision broiler breeder feeding station is a computerized feeding station which allocates individual small meals to birds throughout a day. The pre-stage area is where a bird was initially weighed in order to determine whether the bird would receive a meal. The feeding area is where a bird was provided feed. The electrical area included the computerized portion of the feeding station. Feeding bouts began when an individual broiler breeder entered the pre-stage area of the feeding station. The broiler breeder's BW was then measured and compared to its target weight. If the broiler breeder BW exceeded or was equal to the target weight, that broiler breeder was ejected from the pre-stage area. If the BW of a broiler breeder was below the target BW, it could enter the feeding area where it was given free access to 25 g of feed for 1 min before ejection.

PRECISION BROILER BREEDER FEEDING SYSTEM



Appendix B. Welfare Quality® Assessment protocol for poultry: Plumage damage in laying hens (Welfare Quality®, 2009).

Title	**Plumage damage**
Scope	Animal-based measure: laying hens
Method description	The feathers of normal birds should be smooth with no signs of disturbance. All feather shafts then usually point in one direction resulting in a protective and insulating cover to the skin. Due to abrasion against wire, feather shafts can be broken. Due to pecking behaviour feathers can be disturbed, broken or even torn out. Areas where feather damage usually starts are the tail, neck and cloacal region. Birds are visually inspected individually. Score each animal according to three individual body parts (see photographic reference). For each bird 3 scores are given (i.e. 1 for each body part): being the back and rump together, around the cloacae (belly) and head and neck together. The 3 body parts are chosen to give information regarding the cause of feather damage: damage to feathers of the back and rump usually indicate feather pecking, damage to the feathers of head and neck can be caused by abrasion, and feather damage to the belly can be seen in high productive animals. (However, the latter can also be caused by vent pecking.).



For each body part a score is given on a 3-point scale

a - no or slight wear, (nearly) complete feathering (only single feathers lacking);
b - moderate wear, i.e. damaged feathers (worn, deformed) or one or more featherless areas < 5 cm in diameter at the largest extent
c - at least one featherless area ≥ 5 cm in diameter at the largest extent

To achieve a single general score per bird the scores of the 3 body parts are combined according to the following classification.

Individual level:
0 - All body parts have score 'a'
c - One or more body parts have score 'b', but no body part has score 'c'
c - One or more body parts have score 'c'

Classification: **Percentage** of birds with scoring categories of 0,1,2

Appendix C. Diagram representation of the complete randomized block experimental design used in the current trial. 'PF' and 'CONV' represent treatment pens within the block (chamber). Entrance arrow depicts the entrance to the barn and position of a hallway situated between the six blocks.