The impact of infrared beak treatment on the production, behaviour, and welfare of layer pullets and hens

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Overall Abstract

Two experiments were conducted to determine the effects of infrared beak treatments (IRBT) on the productivity and welfare of Lohmann LSL-Lite and Lohmann Brown pullets and hens. Birds were treated on day of hatch and IRBT equipment settings were adjusted to create 4 specific beaks shapes: shovel (SHV), step (STP), standard (STAN), and an untreated sham control (C). Experiment 1 pullets were housed in cages from 1 to 29 d of age. Data collected included body weight (BW), feed intake (FI), feed efficiency (FE), water disappearance (WD), pecking force (PF), beak length, age of beak sloughing, behavioural expression, and mortality. Experiment 2 pullets were housed in floor pens from 1 d to 18 wk of age. Data collected included BW, behavioural expression, and mortality. At 18 wk, pullets were transferred to layer barn. Experiment 2 hens were housed in cages until 60 wk of age. Data collected included BW, FI, egg production (EP) and quality (EQ), behavioural expression, feather cover, comb damage, and mortality. During early life, IRBT treatments did not negatively affect FI, FE, or BW. STP and STAN pullets had lower WD than C pullets when given access to water via nipple drinkers but this did not result in reduced growth. The IRBT treatments did not affect PF, suggesting that pullets were not in pain. During the first 5 wk of the rearing period, STAN pullets were more active but performed less exploratory pecking than C pullets. There was no effect of IRBT treatments on mortality during early life. Throughout the laying period, there was no effect of IRBT treatments on production. At 23 wk of age, SHV and STP hens preened more in comparison to C hens; no effect of IRBT treatments on behaviour was seen after this time. The IRBT treatments reduced feather loss, comb damage, and mortality from cannibalism. During both the rearing and laying periods, strain appeared to have more of an effect than the IRBT treatments on production and behaviour. In conclusion, the IRBT treatments and subsequent beak shapes had minor effects on the productivity and behaviour of the pullets and hens while simultaneously improving welfare by improving feather cover and reducing mortality.

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IRBT	infrared beak treatment
HBT	hot-blade trimming
HDP	hen-day egg production
HHP	hen-housed egg production
$F{:}G^m$	feed-to-gain ratio, corrected for mortality
PSP	Poultry Service Processor
LB	Lohmann Brown
LW	Lohmann LSL-Lite
SHV	shovel beak treatment
STP	step beak treatment
STAN	standard beak treatment
C	sham control treatment
L	light
D	dark
d	day
wk	week
h	hour
cm	centimetre
mm	millimetre
kg	kilogram
g	gram
N	newton

1.0 Chapter 1. Literature review: the effects of infrared beak treatment on the production, behaviour, and welfare of layer pullets and hens

1.1 Introduction

The practice of beak treatment for poultry was developed in the late 1930's by researchers at the Ohio Experiment Station (Kennard, 1937). The procedure was developed to help reduce and control cannibalistic behaviour in the birds. At its onset, beak treatment was conducted manually using a sharp knife and removed approximately 2.5 cm of the beak of adult laying hens (Kennard, 1937). At the time, it was believed that the beak had no blood or nerve supply and therefore the procedure would not cause any pain or loss of sensation (Kennard, 1937). It has since been shown that the chicken's beak is highly innervated, contains an extensive blood supply and that beak treatment may result in both short and long-term pain (Kuenzel, 2007). Presently, beak treatment involves the removal of one-quarter to one-third of a bird's upper mandible or both the upper and lower mandible (Gentle, 1986a) and is performed as a management strategy to reduce the damage and mortality that can result from cannibalism and severe feather pecking (Savory, 1995). Cannibalism and severe feather pecking can be socially transmitted in poultry (Zeltner et al., 2000), with 2 proposed mechanisms for its transmission: imitation and stimulus enhancement (Nicol, 1995). Imitation involves directly copying the actions of a bird displaying severe feather pecking, while stimulus enhancement involves the bird displaying the feather pecking behaviour drawing attention to specific features (feathers, blood, etc.) of the target bird causing other birds to peck at the same features (Zeltner et al., 2000). Severe feather pecking can cause feather loss as well as vocalizations and withdrawal by the recipient bird (Savory, 1995). As a result of feather loss, the skin is exposed and the presence of blood may serve as an attractant to other birds and result in increased pecking, which can then cause tissue damage, cannibalism and death (Savory, 1995).

There are currently 2 predominant methods of beak treatment used in the commercial poultry industry. The first is hot-blade trimming (HBT). This process involves using a heated blade (approximately 750°C) to cut and cauterize the beak tissue (Jendral and Robinson, 2004). HBT is performed at a commercial hatchery on the day of hatch, or on farm, usually between 7 and 10 d of age and birds are often re-trimmed when adults (Jendral and Robinson, 2004). However, research has shown that HBT results in acute pain and may result in neuroma formation and chronic pain, depending on the age of the bird at treatment and the severity of the treatment (Breward and Gentle, 1985; Gentle, 1991). For example, Lunam et al. (1996) found that the beaks of hens that had been severely treated (two-thirds upper beak removed and one-half lower beak removed) using HBT at hatch developed trauma-associated neuromas while the beaks of hens that had been moderately treated (one-half upper beak removed and one-third lower beak removed) using HBT at hatch did not. Gentle et al. (1997) also found that birds treated at either 1 or 10 d of age with HBT and were moderately treated (one-third of their upper and lower beak removed) did not have neuromas present in their beak tips.

The second method is infrared beak treatment (IRBT). This process involves the beak tip being exposed to an infrared energy source. The treated beak tissue is killed and gradually sloughs off after 7 to 10 d (Glatz, 2005). This treatment is performed at the hatchery on day of hatch chicks. IRBT is thought to have less of a negative impact on production, behaviour, and welfare as compared to HBT (Marchant-Forde et al., 2008; Dennis et al., 2009). Treatment settings or configurations can be adjusted for different bird strains, species, beak pigmentation, hydration level, and future housing system (Schwean-Lardner, 2018). Typically, the treatment settings that are used based on these factors result in a standard or symmetrical beak shape (top and bottom are of approximately equal length). However, some variation from this standard shape can occur post-IRBT and it has been suggested that any beak shape that does not fit the standard description may be a welfare concern (Kajlich et al., 2016; Yamauchi et al., 2017). It is important to understand how IRBT, the sloughing of the beak tissue, and the variations in beak shape that can occur post-IRBT impact the physiology and behaviour of egg production birds so it can be determined whether or not IRBT is an acceptable method of beak treatment.

Despite increasing evidence that IRBT is less detrimental to the welfare of egg production birds than more traditional forms of beak treatment such as HBT, consumer concern (valid or not) still exists for any form of beak manipulation. The main objections to beak treatment are that the practice may cause acute and/or chronic pain in the birds and that beak treatment can result in diminished function and sensory feedback of the beak (Glatz, 2000). Regardless of these objections, beak treatment remains one of the most effective methods of controlling cannibalism. Therefore, the overall objective of this research is to determine the effects of different IRBT treatments on Lohmann LSL-Lite (LW) and Lohmann Brown (LB) pullet and hen production, behaviour, and welfare. This research will examine how various settings of the infrared equipment can be utilized to create specific beak shapes and how those beak shapes and the subsequent sloughing of the beak tissue affects production performance, behaviour, and welfare.

1.2 Welfare

The practice of beak treatment is a contentious issue, especially concerning animal welfare. Disagreement exists between poultry producers, poultry consumers, and animal welfare organizations as to whether or not the practice is beneficial and should be allowed. Research has demonstrated that while beak treatment may compromise some aspects of bird welfare, such as potential or perceived pain associated with the treatment procedure, it can simultaneously improve other aspects, such as reducing injuries and mortality due to severe feather pecking and cannibalism (Cunningham, 1992). In a review of the implications of beak treatment, Kuenzel (2007) highlighted 5 major welfare concerns.

1. The reduced ability of the bird to perform normal behaviours such as eating, drinking, and preening. Several studies have reported a drop in feed intake following HBT (Andrade and Carson, 1975; Gentle et al., 1982; Lee and Craig, 1990; Kuo et al., 1991; Glatz and Lunam, 1994; Gentle et al., 1997). Gentle et al. (1982), Lee and Craig (1990) and Kuo et al. (1991) attributed this drop in intake to an inability to grasp the feed. Gentle et al. (1982) found that Brown Leghorn hens that underwent HBT at 40 wk of age pecked 3 to 5 times more than intact birds to consume the same amount of feed up to 15 d post-treatment. These studies also suggested that the drop in feed intake could be a result of the bird experiencing pain or discomfort from the procedure. In terms of preening and other maintenance behaviours, studies have found either no differences between treated and intact birds (Sandilands and Savory, 2002) or an improvement in feather condition (Craig and Lee, 1990; Lee and Craig, 1991). This improvement in feather condition is thought to be due to a reduction in feather pecking rather than an increase in time spent preening (Jendral and Robinson, 2004).
2. Acute pain and stress following beak treatment. Kuenzel (2007) reported that regardless of the method, beak treatment causes short-term pain. However, studies since this review have shown that IRBT may not result in acute pain as the authors found no behaviour indicators of pain (Gentle and McKeegan, 2007) or reductions in pecking force (Freire et al., 2008). This may be true for HBT as well during the first d post-treatment. When birds are HBT shortly after hatch, there is less of an

immediate stress response in comparison to birds trimmed at 10 or 42 d of age (Glatz and Lunam, 1994). Glatz and Lunam (1994) found that birds that were HBT at 1 d of age showed no increase in heart rate post-treatment whereas birds that were HBT at 10 or 42 d of age had an increase of 15 to 35 beats per minute. The increase in heart rate is indicative of a stress and/or pain response (Glatz and Lunam, 1994). Because of this positive correlation between age at treatment and impact on bird welfare, it is recommended that beak treatment occur on day of hatch (Schwean-Lardner et al., 2016).

3. Damage to the bird's tongue and nostrils. This typically only occurs if greater than 75 percent of the beak is removed. This problem rarely occurs, as it is no longer common in the poultry industry to remove that much beak tissue (Kuenzel, 2007).
4. The formation of neuromas and scar tissue in remaining beak tissue after HBT. Breward and Gentle (1985) identified the presence of neuromas and scar tissue within the beak of birds that had been treated using HBT at 5 wk of age. Lunam et al. (1996) studied birds that had been treated using HBT at a younger age (1 d old) and found microneuromas in the beak tissue 10 wk post-trimming but when examined 70 wk post-treatment, no neuromas were found. In addition to age at treatment, the severity of treatment was also found to be related to the presence or absence of neuromas and scar tissue. Gentle et al. (1997) found that birds that had one-third of their beak removed at 1 or 10 d of age had no scar tissue or neuromas present whereas birds that had two-thirds of their beak removed had neuromas that persisted for 70 wk.
5. Chronic pain from HBT. The literature with respect to this is not consistent. Breward and Gentle (1985) reported the presence of neuromas and spontaneous neural discharges from the intramandibular nerve in HBT beaks and interpreted these as evidence of chronic pain. Later studies supported this with behavioural evidence of chronic pain in 16 wk old hens that had either one-half of their upper and lower beaks trimmed (Duncan et al., 1989) or one-third of their upper and lower beaks trimmed using HBT (Gentle et al., 1990). However, not all birds experience chronic pain as a result of beak treatment. The results of Dubbeldam et al. (1993) suggested that beak treatment does not make the beak more susceptible to pain and

both Gentle et al. (1997) and Schwean-Lardner et al. (2016) failed to find evidence of neuroma formation or chronic pain when birds were HBT at 1 d of age.

Beak treatment can vastly improve bird welfare; however, concerns regarding the practice still arise from animal rights groups and a growing number of consumers. Because of this, countries such as Switzerland, Finland, Norway, Sweden, Austria, Denmark, Germany, and parts of Australia have banned the practice of beak treatment. Other countries, such as the Netherlands, are in the process of phasing its use out by late 2018 (Burgin, 2015; World Poultry, 2015; Brockotter, 2016). This legislation bans not only the more traditional forms of beak treatment such as HBT, but IRBT as well, despite evidence that the latter has positive effects on bird welfare with no or little detrimental impact.

1.2.1 Methodologies for assessing welfare

Several parameters can be measured to assess bird welfare. These include, but are not limited to, health status, productivity, management practices, physiological responses, and behavioural responses (Moura et al., 2006). With regards to beak treatment, the parameters most often used to assess welfare are productivity (feed intake, feed efficiency, and egg production), health status (mortality and incidence of injuries), pain and stress responses (heterophil to lymphocyte ratio, corticosterone), and behavioural responses.

1.2.1.1 Behaviour

Welfare can be thought of as an animal’s affective and physiological state as it attempts to cope with its environment (Broom, 1993; Duncan, 1993) and an animal’s behaviour is reflective of these states (Dawkins, 1990). Understanding if an animal is in a positive state (e.g. pleasure or comfort) or a negative state (e.g. fear or pain) can help determine if its welfare is optimal or not (Duncan, 1998). Changes in behaviour can indicate that birds are experiencing negative states or that bird welfare or comfort is not optimal.

Comfort behaviours such as preening, dustbathing, stretching, and beak wiping were initially thought to be low priority in the ranking of bird behavioural patterns and the relationship between these behaviours and the physiological needs of the bird was not clear, other than being associated with maintaining plumage condition or stretching muscles (Black and Hughes, 1974).

However, the performance of comfort behaviours can be indicative of positive emotional states in poultry and may take up a greater proportion of a bird's time budget than previously thought (Delius, 1988; Zimmerman et al., 2011).

Preening. Preening, defined as birds grooming themselves by pecking or combing at their plumage (Black and Hughes, 1974; Hurnik et al., 1995), results in a state of relaxation or de-arousal as reported by Delius (1988) who observed slower electroencephalogram waves in wild birds that were preening. There is another distinct form of preening, known as displacement preening, which has been observed in circumstances where a bird may be experiencing frustration or stress (Duncan and Wood-Gush, 1972). Displacement preening is typically shorter in duration and the preening action is directed towards easily accessible areas of the body such as the neck and chest (Duncan and Wood-Gush, 1972).

Dustbathing. Dustbathing is defined as the act of a bird lying on its side in the floor material while head rubbing, wing shaking, and scratching at the floor (Hurnik et al., 1995). During the process, the bird throws particles of the floor material over its body (Hurnik et al., 1995). The function of dustbathing is to aid in maintaining good plumage condition and to remove lipids, parasites, and dead skin from the feathers (Olsson and Keeling, 2005).

Beak wiping. Beak wiping is the rapid stroking of alternate sides of the beak on the walls or floors of the bird's cage or pen (Marchant-Forde et al., 2008). The primary function of beak wiping is to clean the beak but a possible secondary function is the manipulation of beak growth by wiping the beak on abrasive surfaces as observed in captive European starlings (Cuthill et al., 1992).

Environmental pecking. Environment pecking, generally categorized as exploratory behaviour, is defined as pecking at inedible objects such as cage walls/floor, and the outside of the feeder (Gentle and McKeegan, 2007; Marchant-Forde et al., 2008). Exploratory behaviour indicates positive welfare because of its link to natural behaviour and positive affective states (Mellor, 2015). Chickens appear to have an intrinsic motivation (Wood-Gush and Vestergaard, 1989) to explore (i.e. exploring stimuli that has no biological value) (Newberry, 1999) and being deprived of this behaviour may lead to boredom, frustration, and aggression (Wood-Gush and Vestergaard, 1989).

Gentle pecking. Gentle pecking is defined as pecking directed at the plumage of other birds that does not cause damage or injury (Savory, 1995). Gentle pecking is typically aimed at particles on the plumage rather than the feathers themselves (Savory, 1995). It has been suggested that gentle pecking may be part of normal exploratory behaviour (Riedstra and Groothuis, 2002) or may serve as a precursor to aggressive pecking (Rodenburg et al., 2003).

Aggressive pecking. Aggressive pecking is used to maintain social dominance within a flock or group of birds (Savory, 1995). The head of subordinate birds is targeted and the pecks are often forceful enough to cause the recipient to vocalize and attempt escape (Savory, 1995). Aggressive pecking can cause damage to the comb and in cases of continuous pecking, severe injury or mortality (Savory, 1995).

Severe feather pecking. Severe feather pecking is more aggressive than gentle pecking. Unlike with gentle pecking, where pecking is directed towards particles on the plumage, severe feather pecking involves the pecking at and pulling of individual feathers. Often, these feathers will be completely removed and this results in bare areas of skin on the birds' body. Denuded areas can become a target of more pecking and can result in hemorrhage and cannibalism (Savory, 1995). Severe feather pecking can also be classified as feather pulling (Hartcher et al., 2015) but is distinct from aggressive pecking as aggressive pecking does not typically cause feather loss and is more often directed at the head rather than the body (Savory, 1995; Gilani et al., 2013; Hartcher et al., 2015).

Vent pecking. Vent pecking occurs most often after birds reach sexual maturity and enter the laying cycle. It is thought to be associated with hormonal changes in the bird during this time (Savory, 1995). Vent pecking can be stimulated by a prolapse of the uterus after oviposition (Savory, 1995). Prolapse is related to the laying of large eggs and/or the result of young hens entering the laying cycle (Rodenburg and Koene, 2004). With uterine prolapse, there is often blood or exposed tissue and this can be an attractant to other birds and stimulate pecking (Savory, 1995).

This initial investigatory pecking can result in severe damage to the skin and tissue, the removal of internal organs, and death (Savory, 1995).

1.2.1.2 Pecking force

Pecking force can be a tool to aid in determining if birds are experiencing pain, irritation, or a loss of sensation/sensory feedback from beak treatment. It is thought that if birds are experiencing pain at the site of treatment, pecking force will be reduced as to prevent further stimulation of the painful tissue (Jongman et al., 2008). Pecking force may be altered, not because of pain in the treated tissue, but rather because the bird has reduced sensory feedback from the beak to the central nervous system (Freire et al., 2008). Nerves within the beak are severed as a result of beak treatment and are not always found in regrown beak tissue post-treatment (Gentle et al., 1997). Because of this, birds that are beak treated may experience less sensory stimulation or sensation in their beak tips while performing beak or pecking related behaviours and may simply engage in less pecking as a result (Freire et al., 2008).

Pecking force is measured using a force plate apparatus that consists of a pecking stimulus, such as food or a novel object, which is connected to a force displacement or pressure transducer. After a bird has successfully pecked the stimulus, the force is registered and displayed on the transducer. Pecking force is most often reported in newtons (Freire et al., 2008) or grams (Jongman et al., 2008).

1.2.1.3 Feather and comb scoring

Feather cover or condition is commonly evaluated to assess the effects of feather pecking and to determine if beak treatment influences the level of damage inflicted towards the feathers and skin of other birds from feather pecking. There are numerous scoring methods that have been used for poultry. Two of the most common methods involve either evaluating the plumage of the entire body and giving one score (used, for example, by Hughes and Duncan, 1972) or evaluating several parts of the body separately and giving a score for each area (used, for example, by Tauson et al., 1984). When scoring the feather condition or cover of individual areas of the body, point scales (typically from 1 to 4) are used with each point or score representing a different level of damage to the plumage. For example, a score of 4 often indicates full, intact plumage whereas a score of 1 would indicate little to no feather cover (Davami et al., 1987; Sarica et al., 2008). The individual regions of the body that are commonly feather scored are the neck, breast, back, wings, tail, and vent (Tauson et al., 1984).

A less frequent method of assessing the degree of pecking damage is comb scoring. Comb damage often occurs due to aggressive pecking from dominant birds (Savory, 1995). As with feather cover, beak treatment helps reduce the amount of damage inflicted upon the comb from the beak of the aggressive bird. Similar to the feather scoring system described above, comb damage is scored using a point scale (typically 0 to 4). However, unlike the feather scoring system, the higher the score, the more extensive the damage. For example, a scoring method used by Ali and Cheng (1985) gave a 0 to birds with no signs of pecking damage, a 1 to birds with a single mark of pecking damage, a 2 to birds with 2 or 3 marks of damage, a 3 to birds with greater than 3 marks of pecking and a 4 to birds with severely damaged combs that included the presence of blood.

1.3 Anatomy and innervation of the chicken beak

1.3.1 Beak anatomy

The beak of the chicken is a complex structure and is involved in performing many important functions including feeding, drinking, grasping feed, grooming and aggressive actions (Lunam, 2005). The beak is highly innervated and has many anatomical features such as sensory receptors, blood vessels, taste buds, nerves, and salivary glands that help carry out these functions (Lunam, 2005). The external surface of the beak consists of a keratinized layer called the rhamphotheca. Underneath this surface lies the epidermis and several layers of epithelial cells. The dermis lies between the epidermis and the bone. The dermis layer consists of dense collagen and elastic fibres and is the primary location of several blood vessels, nerves fibres, and sensory receptors (Lunam, 2005). The trigeminal nerve runs the length of the beak and consists of both myelinated and unmyelinated nerve fibres that innervate the upper and lower beak. The upper beak is innervated by the ophthalmic branch of the trigeminal nerve and various ganglia of the facial nerve. The lower beak is innervated by the intramandibular branch of the trigeminal nerve and the chorda tympani branch of the facial nerve (Lunam, 2005).

1.3.2 Sensory receptors in the beak

The types of sensory receptors that have been identified in the beak include mechanoreceptors, thermoreceptors, magnetoreceptors, and nociceptors, which play important roles in the perception of heat, cold and noxious stimuli (Cheng, 2006). Mechanoreceptors are tactile sensory receptors that respond to mechanical stimuli and help the bird discriminate between various types of feed particles (Breward and Gentle, 1985). Two mechanoreceptors, Herbst and Grandry corpuscles, have been identified and both corpuscles are concentrated in the beak tip (Lunam, 2005). These corpuscles are innervated by large nerve fibers extending from the trigeminal nerve (Lunam, 2005). Nociceptors, otherwise known as free nerve endings, are receptors that are sensitive to noxious stimuli (Gentle, 1992). These are found predominantly in the upper beak and are the terminals of unmyelinated and myelinated nerve fibres that extend from the trigeminal nerve (Gentle et al., 1997; Lunam, 2005).

1.3.3 Effects of beak treatment

Microscopic examination has shown that after HBT, the nerves in the beak degenerate 2 to 3 millimetres past the site of treatment (Gentle, 1986a). Within 10 d post-treatment, these nerves regenerate and by 30 d post-treatment, the nerve fibres begin to sprout (Gentle, 1986a; Cheng, 2006). These regenerating sprouts can sometimes form neuromas, which are proliferative masses of swollen, tangled nerves that develop at the end of the severed nerve (Lunam et al., 1996; Kuenzel, 2007). Neuromas can form either as large masses or as small, scattered bundles known as microneuromas (Lunam et al., 1996). Regardless of the size, these neuromas can discharge action potentials and exhibit spontaneous neural activity that has been perceived as chronic pain (Breward and Gentle, 1985; Lunam, 2005). Neuromas consisting of sensory corpuscles and nociceptors have been identified in the beaks of hens that were treated using HBT as adults (Breward and Gentle, 1985). Neuroma formation following HBT depends largely on the age at trimming and the severity of trim. The severity of trim is determined by the amount of beak tissue that is removed starting from the beak tip and stopping at the nares. Schwean-Lardner et al. (2016) found that mild HBT (one-half upper beak and one-half lower beak) at 0, 10, and 35 d of age did not result in neuroma formation, although healing was faster in birds treated using HBT at 0 and 10 d of age. Lunam et al. (1996) found that microneuromas were present in the beaks 10 wk after moderate HBT (one-half upper beak and one-third lower beak) at hatch. However, they were not present at 70 wk of age, indicating that the neuromas resolved after 10 wk (Lunam et al., 1996). Severe HBT at hatch (two-thirds upper and one-third lower beak) resulted in the formation of neuromas that persisted for 70 wk (Lunam et al., 1996). In contrast to beaks that were severely trimmed, sensory receptors, Herbst corpuscles, or Grandry corpuscles were found in the beaks that had been moderately trimmed, indicating normal function (Lunam et al., 1996). The results of these studies indicate that that there is a critical amount of beak tissue that must remain intact to avoid persistent neuromas (Breward and Gentle, 1985; Lunam et al., 1996).

Following injury or exposure to noxious stimuli, nociceptors are reported to release substance P and/or calcitonin gene-related peptide (Lunam, 2005), both of which are neurotransmitters associated with pain transmission and inflammatory processes (Cheng, 2006). Iron deposits have been discovered in the nerves in the upper beak of chickens and are thought to play an important role in magnetoreception (Falkenberg et al., 2010). Magnetoreceptors are sensory receptors that enable the chicken to orient itself in small areas using Earth's magnetic field (Wiltschko et al., 2007). A study conducted by Freire et al. (2011) found that chicks with intact beaks stayed closer to a magnetic stimulus that was associated with food than birds whose beaks had been HBT. Freire et al. (2011) concluded that while minor HBT did not result in acute pain during early life, it did impair the function of mechanoreceptors and magnetoreceptors in the beak and results in a loss of sensitivity in the beak.

1.4 Pain and its relationship to beak treatment

Pain is defined as “an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage” (IASP, 1979). Many of the behavioural and physiological responses to pain are similar between humans and animals (Gentle, 1992). However, there are numerous challenges when trying to assess and study pain in animals. Pain is a subjective experience, meaning that the experience of undergoing beak treatment may vary drastically between birds (Gentle, 1992). Animals also cannot directly communicate what they are experiencing in regards to pain and stress (Gentle, 1992). Finally, there is no universal indicator of pain and it can be difficult to measure (Gentle, 1992).

There are 4 major processes in the pain pathway. Transduction begins when cells are injured and is the conversion of chemical information at the cellular level into electrical impulses.

Transmission is the phase in which the impulses are carried from the site of injury in the peripheral nervous system towards the brain. Perception is the conscious experience of pain and discomfort when the body's pain threshold is reached and finally, modulation occurs when the brain interacts with the spinal nerves to alter the pain experience. This is done through the release of neurochemicals to inhibit pain (Institute of Medicine, 1987). Pain activates the body's stress response and results in pupil dilation, tachycardia (increased heart rate), tachypnea (increased respiration), increased blood pressure, and increased metabolic rate (Molony and Kent, 1997). Other perceptible signs of pain include grimacing, guarding and/or restricted movement of the affected body part, attempting to withdraw from noxious stimuli, and vocalizing (Molony and Kent, 1997).

1.4.1 Response to pain

It has been proposed that there are 3 phases of the pain response in mammals and birds: immediate or "painless", acute, and chronic (Wall, 1979). These phases have been extensively studied with regards to HBT (Breward, 1984; Gentle, 1986b; Duncan et al., 1989; Craig and Lee, 1990; Gentle, 1991). The pain response with regards to IRBT may be different as it has been demonstrated that IRBT does not result in chronic pain (McKeegan and Philbey, 2012), however, there is still limited research directly examining the anatomical and neurological changes that occur in the beak tissue post-IRBT and how those changes, if any, correspond to pain.

Painless phase. The "painless phase" is the period immediately following HBT. This phase can last anywhere from a few hours to 24 h post-treatment (Gentle et al., 1991). Electrical activity recorded from the trigeminal nerve near the treatment site has shown no abnormal or spontaneous activity 4 and a half h post-treatment, with birds showing normal beak usage 6 h after HBT (Gentle et al., 1991). A study reported no differences in behaviour post-HBT between 1 d old and 10 d old birds that were provided an analgesic prior to beak treatment and birds that were not (Cho, 2008), providing further evidence that birds experience a pain free period after HBT. Gentle et al. (1990) found that after 24 h post-HBT, birds began to display pain-related behaviour such as guarding behaviour and reluctance to use their beak and by 30 h post-HBT, all birds were displaying pain-related behaviours. Abnormal neural activity has also been recorded from the trigeminal nerve 24 h post-HBT (Breward and Gentle, 1985). However, the mechanism for why these pain responses begin 24 to 30 h post-HBT is not fully understood (Duncan et al. 1989; Gentle et al., 1990).

Acute phase. The acute phase of pain is the period in which the bird transitions from coping with the injury to preparing for recovery (Cheng, 2006). When the beak tissue or nerves are damaged following HBT, nociceptors in the beak are activated and send signals to the central nervous system to trigger a pain response (Cheng, 2006). It has also been reported that the damaged cells at the treatment site release inflammatory mediators such as bradykinin, ATP and prostaglandins (Cheng, 2006). During this period, abnormal neural activity has been recorded in the beak stump and could be indicative of acute pain (Breward, 1984; Gentle, 1986b). Birds that have been treated using HBT have been shown to exhibit behavioural changes such as reduced walking, loss of appetite and increased sleep for up to 5 wk post-treatment (Eskeland, 1981; Duncan et al., 1989; Craig and Lee, 1990). There are also physiological changes associated with HBT such as increased heart rate. Glatz and Lunam (1994) found that birds treated using HBT at 10 and 42 d of age showed significant increases in heart rate as compared to birds that were trimmed at 1 d of age. This study provided evidence that the short-term pain and stress response of the bird to beak treatment can be reduced by performing HBT shortly after hatch (Glatz and Lunam, 1994). These behavioural and physiological changes are reliable indicators of acute pain and demonstrate that, regardless of method, beak treatment can result in acute pain (Cheng, 2006).

Chronic phase. The chronic phase of pain is defined as the phase in which the bird experiences pain extending for weeks or months beyond the expected healing time (Molony and Kent, 1997). Chronic pain has only been associated with HBT. It has been reported that IRBT does not result in chronic pain or neuroma formation (McKeegan and Philbey, 2012). One of the proposed reasons for why HBT may result in chronic pain is that the damage to the nerves and subsequent inflammation negatively affect membrane-bound ion channels and this leads to spontaneous activity in the nociceptors (Cheng, 2006). Beak treatment alters the functions of these receptors and can lead to sensitization of both the central and peripheral nervous systems (Cheng, 2006). The damaged nerve fibres are unable to return to their normal state, which may result in amplified nociception and neuroma formation (Cheng, 2006). Abnormal and spontaneous discharges have been recorded in intramandibular nerve fibres extending from the beak stump to the trigeminal nerve (Breward and Gentle, 1985). A comparison of behaviour between hens that were HBT (approximately half of the upper and lower mandible removed) at 16 wk of age and hens with intact beaks found that for at least 5 wk post-treatment, treated birds demonstrated behavioural changes that were indicative of long-term pain (Duncan et al., 1989).

1.5 Infrared beak treatment

Infrared beak treatment (IRBT) is performed using the Poultry Service Processor developed by Nova-Tech Engineering LLC (Willmar, MN, USA) (Figure 1.1). This system uses a non-contact high intensity infrared energy source to treat the beak tissue (Glatz, 2005). The infrared beam penetrates the hard outer layer of the beak (rhamphotheca) and damages the keratin-producing cells in the tissue layers directly underneath, thereby stopping regeneration of the rhamphotheca (Glatz, 2005). After 1 to 2 wk, the treated beak tissue softens and sloughs over a period of approximately 2 wk (Glatz, 2005). During treatment, birds are loaded into a head-holding fixture, which allows for better repeatability and accuracy as compared to manual HBT (Glatz, 2005). This head-holding fixture was created using the average head size of different bird species (Glatz, 2005). Once the birds are loaded in the fixture, they can also be vaccinated, sexed, and counted in addition to undergoing beak treatment (Glatz, 2005). Minimal handling during the process as compared to manual HBT reduces stress on the bird and automation of the process reduces variability (Dennis and Cheng, 2010a). The IRBT system can be programmed to apply specific treatments to chicks based on species, strain, parent flock age, beak pigmentation, hydration level, and housing system (Schwean-Lardner, 2018).

Because the infrared method does not physically cut the beak tissue, the procedure is bloodless and does not result in an open wound, reducing the chance of infection (Gentle et al., 1997; Glatz, 2005). Because the rhamphotheca layer remains intact immediately post-treatment and the loss of the beak tissue is gradual, the bird is able to continue to use its beak and adapt to the changing shape and size of the beak (Angevaare et al., 2012). The gradual loss of the beak tissue allows for normal feeding and drinking behaviour during the critical first few days of life (Glatz, 2005; Marchant-Forde et al., 2008). Some of the reported benefits of using the IRBT technique compared to the traditional method of HBT include improved feather condition, reduced aggression, higher feed intake, better flock uniformity, better feed efficiency, higher egg production and higher body weight gain (Dennis et al., 2009; Marchant-Forde and Cheng, 2010; Carruthers et al., 2012).

Figure 1. 1. Poultry Service Processor. Chicks are placed into head-holding fixtures on the machine and the beak tip is exposed to an infrared light. Source: Nova-Tech Engineering LLC.

1.5.1 Severity of treatment

There are 3 components of the IRBT equipment that determine the length and shape of the beak, and therefore the severity of the treatment: guard-plate (length and height), mirror design (shape and material), and infrared intensity. Guard-plate length and height determines how much of the top beak is exposed to the infrared light. Mirror design determines how much infrared light is reflected onto the bottom beak. Infrared intensity determines how deep the light wavelength penetrates the beak tissue. Infrared intensity can be adjusted for variations in bird size, species, breed, and age, allowing for a more reliable and precise procedure (Glatz, 2005). Since severity of treatment or the amount of beak tissue removed, has been identified as having a strong effect on potential pain experienced from HBT (Gentle et al., 1997; Lunam, 2005), it is important to understand the effects that different IRBT settings have on bird behaviour, welfare, physiology, and production.

One of the benefits of IRBT is that it may result in more symmetrical beak lengths (Dennis and Cheng, 2010a). Beak length symmetry is important as it may influence feed consumption

(Prescott and Bonser, 2004; Dennis and Cheng, 2010a). Dennis and Cheng (2012) studied the effects of different IRBT guard-plate and infrared intensity protocols on bird behaviour and production. Two different guard-plate sizes, 25/23C (more severe) or 27/23C (less severe), were used with each of 3 intensity settings: high (52), moderate (48), and low (44). Repeated measures analysis of body weight showed that birds treated with the 27/23C (48) protocol had the highest body weight at 5, 10, 20, and 30 wk of age and birds treated with the 25/23C (44) protocol were the lightest (Dennis and Cheng, 2012). The reduction in body weight that was observed with the more severe guard-plate and higher power protocols could be associated with pain or sensitivity from the IRBT procedure or from an alteration in the bird's ability to manipulate feed due to the change in beak shape and length (Gentle et al., 1982; Dennis and Cheng, 2012).

An increase in the percent of birds walking was seen in birds treated using the less severe guard-plate protocols as compared to birds treated using the more severe guard-plate protocols or HBT at 5 wk of age (Dennis and Cheng, 2012). An increase in time spent walking is indicative of improved well-being (Bizeray et al., 2002; Pohle and Cheng, 2009) and suggests that birds treated using the less severe IRBT protocols were not experiencing pain from the IRBT procedure. By 10 wk of age, the differences in time spent walking were no longer apparent (Dennis and Cheng, 2012). Dennis and Cheng (2012) also reported that with less severe IRBT protocols (increased guard-plate length and decreased infrared energy), the frequency of drinking at 5 wk of age increased. Birds treated using the 25/23C (52 intensity) protocol or HBT spent the least amount of time drinking, which the authors attributed to pain in the beak tip. This reduction in time spent drinking disappeared by 10 wk of age in birds treated using HBT, however, a reduction in time spent drinking was still seen at 10 wk for birds treated using the 25/23C (52) protocol. This may suggest that birds experience prolonged periods of sensitivity from IRBT with increasing infrared energy and therefore, are less motivated to peck at the drinker. Birds treated using the less severe guard-plate and the low and moderate power protocols also spent significantly more time pecking at a test feather and caused less damage to the feather than birds treated using HBT or the more severe guard-plate and high power protocols.

1.5.2 Pain and healing

It has been observed that beaks treated using the IRBT technique undergo healing and re-innervation. McKeegan and Philbey (2012) reported evidence of re-epithelialization, fibrovascular hyperplasia, and bone remodelling in IRBT treated beaks. Histopathological examination of beaks treated using the IRBT technique showed repopulation of sensory receptors (mechanoreceptors, thermoreceptors, and nociceptors) by 4 wk of age, suggesting that significant re-innervation occurs post-treatment. There was no evidence of neuroma formation or abnormal nerve fibre growth at 4, 10, 30, and 50 wk of age. Electrophysiological tests found that the lower beak responded to thermal and mechanical stimulus after 10 wk of age, suggesting that mechanical sensitivity was present in the regrown beak tissue. Nociceptor response did not differ between treated birds and control birds and there was no abnormal neural activity recorded. These findings suggest that IRBT is not associated with hyperalgesia (increased sensitivity to pain) or allodynia (painful response to non-painful stimulus) after 10 wk of age and is unlikely to result in chronic pain.

McKeegan and Philbey (2012) were unable to study the effects of IRBT on birds younger than 10 wk of age, as it was a challenge to obtain electrophysiological recordings. Therefore, it is difficult to determine if IRBT results in acute pain based on this specific study. Marchant-Forde et al. (2008) presented data indicating an increased time to initiate feeding, reduced beak-related behaviours and decreased feed intake as evidence of acute pain after IRBT. In regards to chronic pain, Gentle and McKeegan (2007) found no indication that broiler breeder chicks experienced any stress or pain because of IRBT. McKeegan and Philbey (2012) had similar results, finding no differences in pain receptor thresholds in the beaks of treated versus intact birds. In a recent review of beak treatment methods, Janczak and Riber (2015) noted that chronic pain due to IRBT has yet to be reported.

1.5.3 Beak growth

Reducing beak growth post-treatment is important as it reduces the need for re-trimming the bird at an older age, preventing further stress on the bird (Marchant-Forde and Cheng, 2010). It has been hypothesized that the infrared energy penetrates deep enough into the beak tissue to prevent further growth of the germ layer, reduce inflammation, and reduce scar formation (Marchant-Forde and Cheng, 2010), which has been previously documented in mammals (Oron et al., 2001; Capon and Mordon, 2003). It has also been suggested that both the guard-plate length and infrared intensity of the IRBT equipment may play an important role as to how much growth occurs (Dennis and Cheng, 2012). Dennis and Cheng (2012) found that birds trimmed using a shorter guard-plate length and higher infrared intensity had the least amount of beak growth from 5 to 30 wk of age.

Marchant-Forde and Cheng (2010) studied the effects of 3 different beak treatments (HBT, IRBT, and untreated control (C)) on beak length and growth. All beak treatments were applied to day of hatch chicks and pictures of the beaks were taken at 0, 2, and 4 d post-treatment. After 4 d, pictures were taken weekly until 10 wk of age. Immediately post-treatment, birds treated using HBT had shorter beaks than C and IRBT birds, with C birds having the longest beak lengths. This continued to be the pattern as the beak tissue began sloughing until 2 wk post-treatment, with beak growth being similar between HBT and IRBT birds from 3 to 8 wk of age. Starting at 7 wk of age, HBT birds had faster beak growth than IRBT birds that continued until the end of the study. Overall, C birds had the longest beak lengths over the 10 wk study. Beaks of birds treated with IRBT had the shortest beak lengths and the least amount of beak growth as compared to HBT birds, suggesting that the IRBT setting used in this study, although not specified, was more effective at suppressing beak growth than HBT reducing the need to re-trim birds in later life. However, because this study and previous findings (Marchant-Forde et al., 2008) only used one setting of IRBT, it is unclear whether using different IRBT settings will result in the same suppression of beak growth relative to HBT. Gentle et al. (1997) reported a similar growth trend for birds that had one-third of the upper beak trimmed using HBT at 1 and 10 d of age. Post-treatment, treated birds had shorter beak lengths than intact C birds. By 5 wk of age, HBT birds showed significant compensatory growth. As mentioned previously, compensatory beak growth, noted more often when birds are treated using HBT, may result in birds having to be subjected to further beak treatment later in life. Removing one-half of both the upper and lower beaks of 16 wk old birds using HBT resulted in long-term negative effects such as reduced growth and feed intake (Duncan et al., 1989).

Gentle and McKeegan (2007) also studied the effects of different beak treatments (C (intact), IRBT at 1 d, HBT at 1 d, and HBT at 7 d) on beak length and growth. They found that birds treated using HBT at 1 d of age had the shortest beak lengths as compared to C and IRBT birds, which is in agreement with Gentle et al. (1997) and Marchant-Forde and Cheng (2010). At 13 d post-treatment, there were still significant differences in beak lengths between treatments, with birds treated using HBT at 7 d continuing to have the shortest beak lengths. By 3 wk post-treatment, birds treated using HBT at 7 d still had significantly shorter beak lengths than control and IRBT birds, which contrasts with the results of Marchant-Forde and Cheng (2010). By 6 wk post-treatment, treated birds exhibited compensatory growth with birds treated using HBT at 7 d still having significantly shorter beaks, which again contrasts with the results found by Marchant-Forde and Cheng (2010). Dennis and Cheng (2010a) found that birds treated using IRBT at day of hatch had longer beaks compared to birds treated using HBT at 7 d, even up to 35 wk of age. They hypothesized that this may allow the bird more perception of the sensory receptors in the beak tissue and improve their ability to perform feeding behaviours. However, the authors did not provide details of the IRBT setting that was used in this study and depending on which setting is used, the beaks of birds treated using IRBT may not always be longer than those treated using HBT.

1.6 Brown vs. white strains

Very few studies have compared responses from various strains with differing feather colours (white and brown) concurrently but it has been suggested that different strains of chickens may respond differently to HBT (Marchant-Forde et al., 2008). Brown layer strains may be more susceptible to neuroma formation and may exhibit more pain-related behaviours post-HBT than white layer strains (Breward and Gentle, 1985; Lee and Craig, 1990; Kuo et al., 1991). These differences could be due to the genetics of the bird, the tissue types found within the beak, or the neuroanatomy of the beak itself. It is unclear if these same effects are noted between strains treated with IRBT. Damme and Urselmans (2013) studied the effects of IRBT on Lohmann Brown (LB) and Lohmann LSL-Classic (LWC) layer strains simultaneously. Birds were assigned 1 of 3 beak treatments: IRBT, HBT, or untreated C. IRBT was performed at the hatchery on day of hatch birds and HBT was performed on farm at 9 d of age. Unfortunately, the specifications of the different IRBT settings (if any) were not provided for each of the bird strains used, limiting the comparison between the bird strains.

Damme and Urselmans (2013) reported that body weight was higher in IRBT treated LB pullets than LWC pullets from 1 to 18 wk of age. There was no reduction in feed intake due to IRBT in LWC pullets but IRBT treated LB pullets had lower feed intake during the rearing period (1 d to 18 wk of age) as compared to C birds and IRBT treated LWC pullets. Mortality during the rearing period was numerically higher in LB pullets regardless of treatment (IRBT vs. HBT vs. untreated). During the egg production period, LWC hens had better feather scores, however, this may be because feather loss and denuded areas are easier to quantify in white strains than brown strains. Morrissey et al. (2016) also reported a minor interaction between strain and beak treatment for mortality related to injurious pecking between LB and Hy-Line Browns, with untreated LB hens having the highest mortality.

Vieira Filho et al. (2016) conducted a similar study. The authors studied the effects of IRBT and HBT on the production and egg quality in 3 strains of laying hens. They also evaluated if the different beak treatments warranted a second beak treatment at 10 wk of age. The 3 bird strains used in this experiment were LWC, LB, and Hy-Line W-36. Birds assigned to the IRBT group were treated on day of hatch using the following specifications provided by Nova-Tech Engineering LLC: beaks were treated to within 2 mm of the anterior end of the nares with a high infrared intensity (52) and a reflective mirror. It was not stated if IRBT settings varied between the strains. Birds assigned to the HBT group were treated at 7 d of age. If a second beak treatment was required, the procedure was performed at 10 wk of age using a Lyon hot-blade debeaker. At 10 wk of age, birds treated using IRBT were significantly heavier than birds treated using HBT, however by 63 wk of age, there were no differences between beak treatments. LB hens were also significantly heavier than the other 2 strains at 10 and 63 wk of age and no interactions between beak treatment and strain were observed. The authors found no differences in feed efficiency (feed to egg mass) between IRBT and HBT birds; although both strains of treated Lohmann birds (IRBT or HBT) had poorer feed efficiency than treated Hy-Line birds. In regards to days to reach sexual maturity, an interaction between beak treatment and strain was observed. LB hens reached sexual maturity first and Hy-Line hens reached sexual maturity last, regardless of beak treatment method. LWC hens treated using IRBT took 2 d longer to reach sexual maturity than LB hens treated using IRBT or HBT. This was attributed to LB hens having heavier body weights and therefore, earlier and more rapid development of the skeletal and reproductive systems.

1.7 Behaviour

1.7.1 Feeding behaviours

A reduction in feeding activity, in terms of both the amount of feed consumed and the amount of time spent at the feeder, in beak treated birds as compared to C birds, regardless of beak treatment method, has been observed in numerous studies (Andrade and Carson, 1975; Duncan et al., 1989; Lee and Craig, 1990; Kuo et al., 1991; Gentle et al., 1997; Marchant-Forde et al., 2008). This reduction in feeding activity suggests that beak treatment, regardless of method, may alter the bird's ability to grasp and consume feed (Gentle et al., 1982). It may also indicate a reduced motivation to eat due to pain or discomfort from the treatment procedure (Marchant-Forde et al., 2008); however, other studies measuring feeding activity have found no evidence of acute pain in broiler breeder chicks treated using IRBT (Gentle and McKeegan, 2007) or layer chicks treated using HBT (Sandilands and Savory, 2002). Differences in feed intake were not seen 3 to 4 wk post-treatment, regardless of beak treatment method (Gentle et al., 1997; Marchant-Forde et al., 2008).

There is a pattern of beak treated birds consuming less feed but having better feed conversion ratios than untreated C birds (Blokhuis et al., 1987; Lee and Craig, 1990; Gentle et al., 1997; Honaker and Ruszler, 2004). In a comparison between birds treated using IRBT or HBT, Dennis and Cheng (2010a) found that IRBT treated birds spent less time at the feeder than HBT treated birds but had heavier body weights at the end of the study. Although feed intake was not directly measured in this study, the results suggest that IRBT allowed for more efficient feeding behaviour (Dennis and Cheng, 2010a). Marchant-Forde et al. (2008) found that IRBT birds had lower feed intake than HBT birds and C birds. The duration of the depression in feed intake varies. Marchant-Forde et al. (2008) reported lower feed intake that continued for 4 wk in IRBT birds and 3 wk in HBT birds. Contrary to Dennis and Cheng (2010a), Marchant-Forde et al. (2008) found no effect of beak treatment method on feed conversion. A later study done by Marchant-Forde and Cheng (2010) found that IRBT birds had lower feed intake than C birds but higher feed intake than HBT birds. These differences were no longer apparent 5 wk post-IRBT and 6 wk post-HBT (Marchant-Forde and Cheng, 2010). A reason for this could be that by 5 wk, the birds had adapted to their shorter beak lengths and increased their time spent feeding (Gentle et al., 1982).

Feed wastage is lower in treated birds and may explain the improvement in feed efficiency, although earlier beak treatment studies did not quantify feed wastage (Lee and Reid, 1977; Blokhuis et al., 1987; Marchant-Forde et al., 2008). IRBT birds had numerically lower feed wastage as compared to HBT birds and C birds, throughout a 10 wk study and significantly lower wastage at 2, 5, 7, 8, and 9 wk of age (Marchant-Forde et al., 2008). It has been suggested that the lower feed wastage observed in treated birds is due to reduced feeding activity in treated birds

(Gentle et al., 1982; Lee and Craig, 1990; Marchant-Forde et al., 2008). The reduction in feed wastage could also be due to a change in how treated birds use their beaks in regards to feeding (Marchant-Forde et al., 2008). Blokhuis et al. (1987) observed that C birds wasted more feed than HBT birds from flicking or shaking their heads as they ate. Lee and Reid (1977) observed increased wastage from C birds who used their beaks to scoop feed out of the feeder and onto the floor. Craig and Lee (1990) suggested that feed wastage could be reduced in C birds by improving feeder design.

The results of Marchant-Forde et al. (2008), Dennis and Cheng (2010a), and Marchant-Forde and Cheng (2010) suggest that beak treatment, regardless of method, may reduce feed intake, however, IRBT appears to have less of a negative impact than HBT. The reasons for this could be the absence of open wounds and bleeding at the treatment site with IRBT (less potential for inflammation and pain), and better adaptation to the change in beak shape and length (due to the gradual loss of the beak tissue seen with IRBT) (Marchant-Forde and Cheng, 2010).

1.7.2 Drinking behaviours

There is concern in the poultry industry that birds treated using IRBT have difficulty drinking from nipple drinkers, which are common in the industry. Despite this concern, there have been very few studies studying the effects of IRBT on drinking behaviour, especially in terms of water consumption. Because the nipple drinkers require the bird to physically peck the nipple to obtain water, reductions in drinking behaviour could be related to pain or discomfort from IRBT or HBT (Dennis and Cheng, 2012) or could be a result of the bird having difficulty physically manipulating the nipple with its altered beak shape. Dennis and Cheng (2012) studied birds treated using various IRBT settings (less severe vs. more severe guard-plate length with high, moderate, or low infrared intensity) and HBT and the effects on beak-related behaviours such as eating, drinking, and pecking as well beak morphology and production measures. They found that the frequency of drinking increased as the infrared energy intensity decreased and guard-plate length increased. Birds treated using HBT or the most severe IRBT setting (25/23C guard-plate with high infrared intensity (52)) spent the least amount of time drinking. This pattern of drinking behaviour suggests that more severe IRBT settings and HBT may cause pain or sensitivity in the beak or that the alterations in the beak shape and length impede normal behaviours. The reduction in drinking was no longer apparent by 10 wk of age for HBT birds but persisted at 10 wk in birds treated using the more severe IRBT settings. The results of Dennis and Cheng (2012) provide evidence that the productivity and welfare of birds treated using IRBT can be optimized by adjusting guard-plate length and infrared intensity.

Swenson and van Gulijk (2014) studied how different drinker types affected drinking behaviour, mortality, body weight gain, and flock uniformity in layer chicks. Birds were assigned to 1 of 3 treatment groups: treated using IRBT on day of hatch, treated using HBT at 7 d of age, or C (intact beaks). The birds treated using IRBT or HBT were given access to water through either a vertical pin nipple drinker, a 360º nipple drinker, or a vertical pin nipple drinker plus a supplemental chick fount. The vertical pin nipple drinker system requires the bird to push the nipple up and down to produce a water droplet whereas with the 360º nipple drinker system, the nipple can be touched from any direction and produce a water droplet (Swenson and van Gulijk, 2014). Operation of the vertical pin nipple drinker requires a greater reliance on the sensory abilities of the beak (Swenson and van Gulijk, 2014). Because beak treatment may result in a loss of sensitivity in the beak tip (Breward and Gentle, 1985), successful operation of the vertical pin nipple drinker represents a challenge to the bird and may result in decreased water intake during the first few critical days post-treatment (Swenson and van Gulijk, 2014).

In the first experiment, Swenson and van Gulijk (2014) tested 3 groups: C birds given access to vertical nipple drinkers, IRBT birds given access to vertical nipple drinkers, and IRBT birds given access to vertical nipple drinkers plus a supplemental chick fount. The objective of this study was to determine if providing supplemental water to the treated birds would reduce mortality at 10 d of age. IRBT birds given access to vertical pin nipple drinkers as their sole water source had the highest mortality of the 3 treatment groups while IRBT birds given access to both vertical pin nipple drinkers and supplemental chick founts had the lowest mortality. These results suggest that the specific IRBT setting(s) used in this study caused treated birds to have difficulty manipulating the vertical pin nipple to produce a water droplet. Consequently, treated birds given access to water via vertical pin nipples may consume less water leading to poorer bird condition and higher mortality.

In a second experiment, the authors provided both IRBT and HBT birds with vertical pin nipple drinkers, 360º nipple drinkers, or vertical pin nipple drinkers plus supplemental founts and looked at the effect on body weight over an 11 wk period and mortality at 7 d of age (Swenson and van Gulijk, 2014). Similar to the first experiment, providing supplemental chick founts decreased mortality in IRBT treated birds. IRBT birds given access to 360º nipple drinkers only also had lower mortality as compared to HBT birds given access to either the vertical pin nipple drinker or the 360º nipple drinker. In regards to body weight gain, from 0 to 3 wk of age IRBT birds given access to 360º nipple drinkers had significantly higher weight gain as compared to HBT birds given access to 360º nipple drinkers. At 11 wk of age, birds given access to 360º nipple drinkers had higher body weights as compared to birds given access to the vertical pin nipple drinkers with or without supplemental founts, regardless of beak treatment method. Throughout the 11 wk study, IRBT birds given access to 360º nipple drinkers had the highest overall body weight gain and uniformity. Despite there being very little research studying IRBT and water consumption, it is evident that the format of water delivery plays an important role. Swenson and van Gulijk (2014) demonstrated that IRBT birds with access to 360º nipple drinkers had reduced mortality, higher body weight gain, and improved flock uniformity as compared to IRBT birds with access to vertical pin nipple drinkers and HBT birds with access to 360º nipple drinkers.

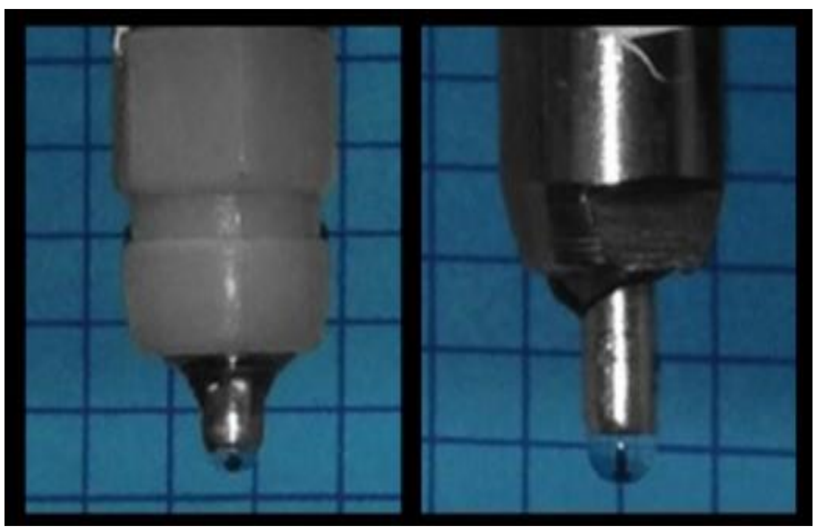

Figure 1. 2. From left to right: vertical pin nipple, 360º nipple. Source: Swenson and van Gulijk (2014).

1.7.3 Comfort behaviours

The effects of beak treatment on comfort behaviours such as preening are quite variable between studies. Older studies have reported that the percent of time spent preening decreases following HBT (Duncan et al., 1989; Gentle et al., 1997). Duncan et al. (1989) found that preening continued to be reduced in treated birds even after other behaviours (feeding, drinking) had returned to pre-treatment levels and interpreted this reduction as evidence of pain. Despite this, it is not clear why some behaviours were affected by HBT for a longer period of time. The authors suggested that, unlike feeding and drinking, preening is not essential for survival and may be more easily influenced by pain (Duncan et al., 1989). Gentle et al. (1997) found that in the first wk after HBT, treated birds spent a smaller percentage of time preening as compared to C birds; however, by 5 wk post-treatment, no differences were seen. This contrasts with Duncan et al. (1989) who found that the reduction in preening in treated birds lasted for the entire duration of their study. This difference in recovery time from HBT between these 2 studies is most likely due to the fact that birds were much older at the time of trimming in the Duncan et al. (1989) study and had a greater proportion of beak tissue removed than the birds used in the Gentle et al. (1997) study.

More recent studies have found that beak treatment does not affect or increases the time spent preening. Sandilands and Savory (2002) reported that HBT did not significantly affect the amount of time spent preening. However, the authors did see that HBT birds took longer to collect oil from their preen glands and directed more attention towards their preen glands than untreated birds. It has been suggested that preening may increase following beak treatment because the shortened beak is less effective at manipulating the plumage (Marchant-Forde et al., 2008). Marchant-Forde et al. (2008) saw that the effects of beak treatment on preening were most apparent during the first 2 d post-treatment. Immediately post-treatment, treated birds (IRBT or HBT) preened more compared to C birds but by 1 d post-treatment, birds treated using IRBT preened the least amount of time. After 2 d, there were no differences in time spent preening between the 3 treatment groups (HBT, IRBT, and control) (Marchant-Forde et al., 2008). For preening behaviour over the entire 9 wk study period, IRBT birds were not different from C birds in terms of total time spent preening, the number of bouts, or bout duration, although IRBT birds spent numerically more time preening than C birds (Marchant-Forde et al., 2008).

In a study examining the effects of beak trimming on aggression levels in laying hens, Shinmura et al. (2006) found that the proportion of birds displaying aggression significantly decreased following HBT and in relation to this, the proportion of birds preening significantly increased. Gabrush (2011) found varying effects of IRBT on preening behaviour. In one experiment, a decrease in preening was seen in IRBT birds 1 d post-treatment as compared to C birds, however, by 1 wk, IRBT birds preened more than C birds. During the laying period, percent of time spent preening was also higher in IRBT birds as compared to C birds. However, in other experiments, the author found that preening was either not affected or reduced. Due to this, Gabrush (2011) hypothesized that the increase in preening seen in IRBT birds was not due to beak treatment but rather a less aggressive environment. The results of this study also challenge the hypothesis that preening increases due to a reduced effectiveness of the beak as there were no effects of beak treatment (IRBT or HBT) on preening during the rearing period (Gabrush, 2011).

Other comfort behaviours such as beak wiping and feather ruffling were also performed more frequently post-HBT than before HBT (Shinmura et al., 2006). Gentle et al. (1990) reported that the occurrence of beak wiping was reduced in birds that were HBT as compared to intact C birds. However, more recent studies have shown that the occurrence of beak wiping is higher in HBT and IRBT birds than C birds (Shimura et al., 2006; Marchant-Forde et al., 2008).

1.7.4 Active behaviours

An increase in inactive standing or sitting is frequently observed in studies examining the effects of beak treatment on bird behaviour. Eskeland (1981) found that hens treated with HBT at 18 wk of age and had one-third of the upper beak removed had more frequent and longer periods of resting behaviour (inactive standing or crouching). This increased resting behaviour was seen for as long as 56 wk post-HBT (Eskeland, 1981). Similarly, Craig and Lee (1990) and Gentle et al. (1997) also found that immediately post-HBT, birds were less active and performed fewer feeding and comfort behaviours. A reduced activity level in beak treated birds is thought to be indicative of reduced welfare (Hughes and Gentle, 1995) and could be a sign of pain or discomfort associated with the beak treatment procedure (Marchant-Forde et al., 2008; Marchant-Forde and Cheng, 2010).

Gentle and McKeegan (2007) found that HBT and IRBT had no significant effects on sitting, standing, and sleeping in the first h post-treatment in broiler breeder chicks treated using IRBT on day of hatch or HBT at 1 or 7 d of age. The only behaviour that was affected by beak treatment during the 6 wk study was environmental pecking. At 3 and 4 wk of age, a greater proportion of C and sham-operated birds pecked at the environment than IRBT and HBT treated birds. No effects were seen on behaviour after 4 wk. Dennis and Cheng (2012) also reported an increase in walking behaviour at 5 wk post-treatment in birds treated using less severe IRBT protocols as compared to birds treated using HBT or more severe IRBT protocols. However, by 10 wk of age there were no significant differences in walking behaviour between the treatment groups (Dennis and Cheng, 2012). This suggests that birds may experience acute pain related to the beak treatment procedure for up to 5 wk but using less severe IRBT protocols may reduce or prevent this (Dennis and Cheng, 2012). Inactivity is higher in both HBT and IRBT treated birds relative to intact C birds but only until 4 d post-treatment (Marchant-Forde et al., 2008). Inactivity was highest in birds treated using HBT in the first 24 h post-treatment but highest in birds treated using IRBT on d 3 and 4 (Marchant-Forde et al., 2008). These results agree with several other studies that have reported a decrease in bird activity level post-beak treatment (Eskeland, 1981; Craig and Lee, 1990; Kuo et al., 1991).

1.7.5 Pecking behaviour

The amount of time birds spend performing pecking behaviours, the overall number of pecks, what the birds peck at, and pecking force can all be measured to help determine the relationship between beak treatment and the pain response. Using pecking force as a possible indicator of pain is discussed in the Methodologies section of this literature review. Marchant-Forde et al. (2008) investigated how IRBT affects pecking behaviour by recording the number of times birds pecked at the feeder, at the drinker, and at other birds. They found that birds treated using IRBT pecked at the feeder more frequently but had less inter-bird pecking when compared to C birds. Following beak treatment, the authors found that the proportion of birds with abnormal beak ratios (upper mandible shorter than lower mandible) was highest in birds treated using IRBT. Although this effect was transient and due to differences in tissue erosion rates between the upper and lower mandibles following IRBT, it may have affected their ability to eat and would cause them to peck at the feeder more often. The authors also found that birds treated using IRBT had fewer number of pecks at the drinker in comparison to C birds. The authors suggested this change in pecking behaviour in IRBT birds might be due to the alteration in beak shape from the IRBT procedure, reduced sensory feedback in the beak tip after IRBT or acute pain from the treatment procedure. Although it is still unclear whether IRBT results in acute pain, it is evident that IRBT affects the birds’ ability to grasp and manipulate feed, causing the bird to peck at the feeder more often (Gentle et al., 1982; Marchant-Forde et al., 2008).

Birds treated using HBT have also been observed to engage in more exploratory or investigative pecking than C birds (Jongman et al., 2008). Jongman et al. (2008) found no evidence that birds treated using HBT experienced severe chronic pain leading the authors to propose that the birds were potentially experiencing phantom sensations in their beaks. They suggested that because of the differences in sensation between an intact beak and a treated beak, treated birds might increase their investigative pecking. It is also possible that beak treatment results in an irritation of the treated beak tissue rather than pain, which in turn stimulates the beak resulting in an increase in investigative pecking (Broom and Johnson, 1993). A third explanation is that engaging in investigative pecking and therefore touching or rubbing the treated beak tissue may help mask the sensation of pain (Melzack and Wall, 1965).

1.7.5.1 Pecking force

It is thought that if birds are experiencing chronic pain, they will peck less and use less force (Jongman et al., 2008). Freire et al. (2008) investigated how beak treatment and the potential pain from the treatment method affected pecking force. They had 4 treatment groups: IRBT at 1 d of age, HBT at 1 d of age, C (untreated), and HBT at 10 wk of age. They hypothesized that if treated birds are in pain and express guarding behaviours, then they should also peck with less force as compared to C birds with intact beaks. They also predicted that the difference in pecking force between treated and C birds would no longer be apparent after the addition of an analgesic to the feed and that treated birds would consume more analgesic-treated feed than control birds. Birds treated using HBT at 10 wk of age pecked with the least amount of force among the treatment groups and there were no differences in pecking force between the IRBT, HBT (1 d) and control birds. Treated birds also did not consume more of the analgesic-treated feed as compared to C birds. From these results, the authors concluded that there was no evidence of pain from beak treatment at 11 wk of age. Despite observing a reduction in pecking force in birds treated using HBT at 10 wk of age, which could indicate that these birds were experiencing pain, they did not consume more analgesic-treated feed.

Dennis and Cheng (2010b) studied birds treated using HBT at 2 d of age to determine the effects of HBT on pecking force and feeding behaviour. They found that HBT birds spent significantly less time pecking at feed and used less force than intact C birds but only up to 3 wk post-HBT. This was also the trend for time spent pecking. The authors suggested this reduction could be attributed to pain or discomfort at the site of trimming, which would reduce the bird's motivation to peck at food. Since the differences in feeding behaviour disappeared by 3 wk post-HBT, it is thought that pain associated with HBT is also reduced by this time. The authors also found that beak treated birds pecked with consistent force over a 3 wk period but C birds pecked with more force during the first wk compared to the second and third wk. The reason for this was thought to be a difference in learning curves between C and treated birds. When learning a new task, there is a period during which the animal establishes the correct amount of force required to correctly complete the task (Vanswearingen, 2008). Beak treatment disrupts this process and may cause the bird to start with less force rather than peck with more force and slowly reduce its pecking force to the lowest necessary level (Swinnen, 1996).

In contrast to conclusions drawn by Dennis and Cheng (2010b), who found that pecking force was reduced for the first 3 wk post-treatment, Freire et al. (2011) found that pecking force was not affected by HBT at any age. They studied the pecking force of birds that had been beak treated with or without the application of an analgesic. Their objective was to determine whether differences in pecking force and behaviour were due to a loss of sensitivity in the beak or pain due to beak treatment. Within the first 24 h post-treatment, treated birds pecked with more force than intact birds. Within the first wk, treated birds were less motivated to peck at the provided stimulus but did not differ in pecking force, which suggests that although they may have been less interested in pecking, they were not experiencing pain.

Jongman et al. (2008) also found no evidence that birds were experiencing chronic pain based on pecking behaviour, as they found no difference in overall number of pecks between C and HBT treated birds. Although there was a consistent trend for C birds to use more force when pecking at stimuli than HBT birds, differences were only significant at 12 wk of age. They attributed this difference to reduced feedback from sensory receptors in the beak, rather than pain because if birds were experiencing severe chronic pain from the HBT procedure, they would be expected to peck less and use less force. Although previous studies have shown that reduced pecking and increased guarding behaviour may be indicative of pain in the beak (Gentle et al., 1990), it has also been proposed that these changes in behaviour are due to a loss of sensitivity in the beak rather than pain (Hughes and Gentle, 1995), thus making exploratory pecking less effective and rewarding (Workman and Rogers, 1990).

1.7.6 Aggressive behaviours

Birds use their beaks to peck at other birds and their surroundings in order to explore and better understand their environment. Typically, this behaviour is harmless but can become problematic if birds experience stress or fear (Vestergaard et al., 1993). Fear can be a predictor for the development of feather pecking behaviour (Rodenburg et al., 2004). Birds that had increased fearfulness as chicks showed more severe feather pecking as adults (Rodenburg et al., 2004). Feather pecking can result in denuded areas, bleeding, and cannibalism, thus increasing mortality and reducing welfare. One of the rationalizations for beak treatment in laying hens is the reduction of aggressive behaviours such as aggressive pecking, feather pulling, and vent pecking (Lee and Reid, 1977; Hester and Shea-Moore, 2003; Dennis and Cheng, 2012) as birds that are not beak treated have the potential to cause the most damage to the plumage, skin, and vents of other birds.

1.8 Production

1.8.1 Body weight and growth

There have been numerous studies examining the effect of beak treatment on body weight. However, there is still no clear consensus on what that effect is. Earlier studies comparing HBT and intact birds and more recent studies comparing IRBT, HBT, and C birds have found that beak treatment causes a reduction in body weight and feed intake in the period immediately following treatment, regardless of age or treatment method (Gentle et al. 1982; Gentle et al., 1997; Honaker and Ruszler, 2004; Marchant-Forde et al., 2008). However, after 3 wk post-treatment, the difference in body weight between C and IRBT birds was no longer apparent (Marchant-Forde and Cheng, 2010). The initial difference in body weight could be related to the change in beak shape and/or potential pain related to the procedure, which may impede the bird’s ability to eat (Gentle et al., 1982). Growth during the pullet phase was not affected by IRBT (Dennis and Cheng, 2010a) and as birds reach sexual maturity, the effects of beak treatment are no longer apparent (Honaker and Ruszler, 2004). Birds that have been treated using IRBT are shown to have heavier body weights and better feed efficiency in comparison to birds treated with HBT (Gentle and McKeegan, 2007; Marchant-Forde et al., 2008; Dennis and Cheng, 2010a).

1.8.2 Egg production

As with body weight, there are inconsistent reports as to what the effect of beak treatment is on egg production. Older studies, focusing on electric debeaking, have reported finding no significant effects of beak treatment on egg production (Bray et al., 1960; Beane et al., 1967; Andrade and Carson, 1975; Lee and Reid, 1977). These studies examined its' effect on a wide range of treatment ages from 1 d old to 1 year old. More recent studies show that birds that are HBT consistently have higher hen-day egg production (HDP) and hen-housed egg production (HHP) than intact birds (Craig and Lee, 1989; Davis et al., 2004; Guesdon et al., 2006). The improvement in egg production is most likely because of reduced injuries and mortalities due to cannibalism in treated birds (Cunningham, 1992). Age at trimming and the severity of treatment have also been studied in regards to their effects on egg production. Older studies have reported that treating younger birds using HBT results in better egg production as compared to C birds (Morgan, 1957; Bramhall and Little, 1966). Gabrush (2011) reported that HHP was higher in beak treated birds (regardless of HBT or IRBT) but HDP was unaffected compared to C birds. These results do not agree with the findings of Honaker and Ruszler (2004) who found that birds treated at 1 wk of age using HBT had higher HHP than birds treated at 1 d of age using IRBT but did not differ from birds that were not beak treated. The differences between these 2 studies could be due to higher rates of mortality seen in the IRBT treated birds and not C birds in the Honaker and Ruszler (2004) study.

In regards to severity of treatment, Morgan (1957) found that removing one-third to one-half of the beak resulted in better egg production as compared to intact C birds. Bramhall and Little (1966) had 3 groups of beak treated birds (two-thirds of both the upper and lower beak removed at 7 d of age; two-thirds of the upper beak removed and the bottom beak tipped at 12 wk of age; or one-half of the upper and lower beak removed at 12 wk of age). Kuo et al. (1991) found similar results to Morgan (1957) while Lee and Reid (1977) found that the removal of up to two-thirds of the beak had no effect on egg production. The severities used by Morgan (1957) and Kuo et al. (1991) are similar to what is used in the poultry industry currently whereas the ones used by Bramhall and Little (1966) are more severe than what is used today. In a study focusing on the effect of IRBT on egg production, Damme and Urselmans (2013) found that birds treated using IRBT consistently outperformed birds treated using HBT and C birds. Birds treated using IRBT had higher HHP and less production days lost due to mortality. These results contradict those of an earlier study done by Dennis et al. (2009), who reported no difference in egg production between birds treated using IRBT or HBT. As in most areas measured, the severity and age of treatment within various studies may account for some of the different effects noted.

1.8.3 Egg quality

In terms of egg quality, the majority of studies have found that HBT does not alter egg quality or size (Cunningham, 1992). Lee and Reid (1977) found no effects on egg weight or eggshell thickness, and Carey (1990) and Dennis et al. (2009) reported similar results. Only one study has reported a negative effect of beak treatment on egg weight (Lee, 1980). The author found that birds that were HBT at 4 and 8 wk of age had significantly lower feed intake and egg weight as compared to C birds. Feed intake and egg weight for birds that were HBT at 1 d of age did not differ from C birds (Lee, 1980).

1.8.4 Feather cover

Feather development is influenced by both direct and indirect factors. Direct factors include hormonal output from the thyroid and gonads (thyroxine and estrogen, respectively) (Leeson and Walsh 2004). Indirect factors include environment, housing system, and nutritional status, as well as testosterone produced by the gonads (Leeson and Walsh, 2004). Feather cover is important as feathers play an integral role in thermoregulation and protecting the skin of the bird (Leeson and Walsh, 2004). In cold temperatures, feathers act in an insulative capacity. Birds erect their feathers (piloerection) to trap and increase the volume of warm air within their plumage (Leeson and Walsh, 2004). In hot temperatures, one method that birds dissipate heat is by erecting their feathers to release hot air. This can be done by lifting their wings, ruffling their feathers, preening, and dustbathing (Gerken et al., 2006).

Feather cover is also important in terms of feather pecking. Feather loss can occur when birds peck at and pull out the feathers of other birds. Although some feather loss occurs in adult hens as a result of being housed in cages, the majority of feather loss in hens is a result of feather pecking (Leeson and Walsh, 2004). Poor feather cover can increase the risk of injury to the exposed skin as well increased energy utilization to maintain body temperature, leading to poor feed efficiency and greater feed costs (Leeson and Walsh, 2004). Feather scoring is a useful tool to assess feather cover and the damage from feather pecking. IRBT has been shown to reduce both the frequency of aggressive behaviours as well as the damage to plumage from feather pecking (Dennis et al., 2009). Blokhuis and Van Der Haar (1989) found that not only did HBT treated birds display less aggressive behaviours but that birds subject to aggressive behaviour such as feather pecking had better feather scores and less plumage damage in comparison to C birds that had intact beaks. Dennis et al. (2009) and Damme and Urselmans (2013) found similar results but examined the effects of IRBT on feather damage in addition to HBT.

1.8.5 Mortality

Beak treatment, regardless of method, can aid in reducing mortality (Guesdon et al., 2006; Damme and Urselmans, 2013; Weeks et al., 2016). A meta-analysis of mortality data from beak treated and intact beak flocks in the UK found that beak treatment resulted in significant reductions in mortality even when accounting for factors such as bird age, breed, flock size, and housing system (Weeks et al., 2016). The meta-analysis did not indicate whether flocks were treated using IRBT or HBT. Damme and Urselmans (2013) reported that IRBT reduced overall flock mortality by as much as 50 percent. This reduction in mortality was likely due to the reduced ability of the birds to damage the skin and plumage to the same degree as if the birds had intact beaks.

Cannibalism can account for a considerable percentage of flock mortality (Gentle et al., 1997; Kjaer and Sorenson, 2002). Guesdon et al. (2006) reported low levels of mortality for HBT treated birds and very high levels in untreated C birds, with cannibalism accounting for 99 percent of the mortality in C birds. Although cannibalism was not different between HBT treated birds and C birds, Schwean-Lardner et al. (2016) reported that cannibalism only occurred in C birds in their study. Kuo et al. (1991) also found that mortality from cannibalism was highest in C birds in comparison to birds who had one-quarter to one-half of their beaks removed using HBT. High mortality within a flock due to cannibalism not only represents a welfare concern but an economic concern as well. Guesdon et al. (2006) reported a 30 percent drop in THHP in C birds compared to beak treated birds and this drop in production was attributed to losses due to cannibalism. Currently, beak treatment remains one of the few consistent methods of preventing cannibalism and IRBT is an improvement with regards to animal welfare over more traditional beak treatment methods while still effectively controlling cannibalism.

1.9 Conclusion

Poultry husbandry practices are continually improving and the development of the IRBT system is reflective of this. IRBT offers producers another tool to improve economics and bird welfare. In order to determine whether IRBT is an acceptable method of beak treatment, it is necessary to understand its' effects on egg production birds. From previous studies that have examined the effects of IRBT, the majority suggest that IRBT has less of a negative effect on bird welfare, production, and behaviour than HBT. However, the majority of research on IRBT has been conducted studying the effects on hens and the effects of IRBT on pullets are still poorly understood. The data from this research will aid in understanding the overall impact of IRBT treatments in pullets and hens. In addition, the usage of various settings to create different beak shapes will aid in understanding the effects of beak shape on production and welfare characteristics.

1.10 Objectives

The primary objectives of this study were:

1. To confirm that IRBT treatment settings can be adjusted to purposely create different beak shapes;
2. To determine how different beak shapes (created either by altering IRBT settings or leaving beak untreated) and subsequent sloughing of the treated beak tissue affects the beak length, production performance, pecking force, behaviour, and welfare of Lohmann-LSL Lite and Lohmann Brown layer pullets.

A secondary objective was:

1. To follow the IRBT treatments through to the end of the egg production cycle.

1.11 Hypotheses

The overall hypothesis for this study is that the different IRBT treatments and subsequent beak shapes will not negatively affect the production or welfare of Lohmann LSL-Lite and Lohmann Brown pullets and hens.

Specific hypotheses of this study include:

1. IRBT treatments will have an effect on beak length
    a. IRBT treatments will result in varying beak lengths because different equipment settings were used for each treatment.

2. IRBT treatments will affect nutritive intake and growth during the rearing period only
    a. Birds treated using IRBT will have reduced feed intake and body weight during the period in which the beak tissue is sloughing as compared to intact control birds.
    b. There will be no differences in water disappearance between beak treatments or drinker types because birds treated using IRBT can successfully operate 360º nipple drinkers.
    c. As birds reach sexual maturity, any negative effects on production seen during pullet phase will no longer be apparent.

3. IRBT treatments will not affect pecking force because it has been reported that IRBT does not result in acute pain

4. IRBT treatments will not negatively impact pullet or hen behaviour
    a. Minor differences in behaviour between treatments may be observed but they will be transient because any negative effects of IRBT treatments on behaviour are no longer apparent 1 wk post-IRBT and the behaviour analysis for these studies all started after 1 wk of age.

5. IRBT treatments will affect feather cover and comb scarring

a. Birds treated using IRBT will have better feather and comb scores as compared to control birds because IRBT helps reduce the level of damage inflicted upon feathers and comb during feather pecking.

6. IRBT treatments will result in lower mortality
    a. There will be an absence of open wounds and less potential for infection as compared to other forms of beak treatment.
    b. Lower mortality due to cannibalism, as treated birds are not able to inflict as much damage with their beaks as compared to control birds.

2.0 Chapter 2: Effects of infrared beak treatment on the production, behaviour, and welfare of Lohmann LSL-Lite and Lohmann Brown pullets housed in cages from 1 to 29 days of age

The objectives of this work were to examine how different beak shapes including natural untreated beaks and those created by altering the infrared beak treatment settings to create specific beak shapes affects the production, behaviour, and welfare of layer pullets and hens. Chapter 2 focuses on the effects of the different beak shapes on productivity, pecking force, beak length, and behaviour during early life with a particular emphasis on the time in which the beak tissue is sloughing. Productivity indicators included feed intake, feed efficiency, body weight, and water disappearance.

2.1 Abstract

Although controversial, beak treatment remains one of the most effective methods of controlling and preventing cannibalism in egg production flocks. A newer technique, infrared beak treatment (IRBT), has been developed in recent years and differs from more traditional methods of beak treatment because it does not physically cut or result in immediate loss of the beak tissue. While the impacts of IRBT on pullet and hen production and behaviour have been examined in depth, little has been done to aid in understanding how the sloughing of the beak tissue that occurs with IRBT affects the pullet's ability to eat, drink, and peck. Three experiments were conducted to determine the effects of IRBT and the subsequent sloughing and change in beak shape on the productivity, beak length, pecking force, and behaviour of Lohmann LSL-Lite (LW) and Lohmann Brown (LB) pullets housed in cages from 1 to 29 d of age. IRBT settings were adjusted to create 4 specific beak shapes: shovel (SHV), step (STP), standard (STAN), and an untreated sham control (C). Birds were treated on day of hatch. Birds were randomly assigned to 1 of 4 beak treatments and 1 of 3 experiments. Experiment 1a (production) was a 4x2x2 factorial arrangement of IRBT treatments, bird strain, and drinker type (fount, nipple), in a completely randomized design (CRD). Birds (n=160) were housed in cages (n=32, 5 birds per cage) and given access to water through chick founts or 360° nipple drinkers. Feed was weighed at 1, 15, and 29 d for intake (FI) and efficiency (FE) calculations. Water disappearance (WD) was measured every second day from 1 to 28 d. Body weight (BW) was collected on a cage basis at 1, 15, and 29 d. Experiment 1b (beak length and pecking force) was a 4x2 factorial arrangement of IRBT and strain, in a CRD. Birds (n=80) were housed in cages (n=16, 5 birds per cage). Beaks were photographed at 1, 29, 57, 85, and 113 d for beak length calculations. Pecking force (PF) was tested at 4, 11, 18, 25, 53, 81, and 109 d of age using 2 birds per cage. At 29 d, birds from Experiment 1b were transferred from cages and housed in floor pens (n=2, 1 pen per strain). Experiment 1c (behaviour) was a 4x2 factorial arrangement of IRBT and strain, in a CRD. Birds (n=80) were housed in cages (n=16, 5 birds per cage). Behaviour was recorded in all cages for 8 h every second d from 10 to 28 d of age then videos were analyzed using scan sampling at 15 min intervals. Mortality for all 3 experiments was recorded daily. The effect of IRBT treatments, strain, and their interactions were analyzed using Proc Mixed of SAS® 9.4 with Tukey's range test to separate means. Differences were significant when $P \leq 0.05$. The IRBT treatments did not affect BW, FI, or FE. An IRBT x drinker type interaction existed for overall WD. When birds were given access to water via founts, WD was similar between treatments. When birds were given access to water via nipple drinkers, C birds had higher WD as compared to STP and STAN birds. The IRBT treatments were effective at shortening beak length and did not alter the force with which a bird uses to peck. STAN birds spent a greater percent of time performing active behaviours as compared to C birds over the 28 d period. In Experiment 1c, LW birds had higher mortality as compared to LB. Strain had minor effects on the parameters measured in these experiments. Overall, the results suggest that sloughing of the beak tissue and the change in beak shape that occurred as a result of varying IRBT settings had minimal impacts on the production, pecking force, or behaviour of LW and LB pullets during early life.

Keywords: beak shape, nipple drinker, pecking force, body weight

2.2 Introduction

The practice of beak treatment of egg production birds was initiated to aid in reducing the damaging effects of cannibalistic behaviour and injurious feather pecking (Kennard, 1937). Despite feather pecking being a multi-factorial problem (Pötzsch et al., 2001; Lambton et al., 2010), beak treatment remains one of the most effective methods of reducing and controlling the behaviour as well as subsequent cannibalism. Beak treatment is controversial as there is concern by some factions of society that any beak manipulation may result in pain, reduced function, and/or reduced sensory feedback (Glatz, 2000). Infrared beak treatment (IRBT) is currently 1 of 2 predominant methods of beak treatment used for commercial laying hens. This methodology was developed by Nova-Tech Engineering LLC and differs from the more traditional method of beak treatment, hot-blade trimming (HBT), in that the IRBT procedure does not result in the beak being physically cut or the beak tip immediately removed. During the IRBT procedure, day old chicks are placed into head-holding fixtures on the Poultry Service Processor (PSP) and their beak tips are exposed to an infrared light (Glatz, 2005). The infrared light penetrates the outermost layer of the beak, damaging the tissue below and stopping further regeneration of the beak tissue (Glatz, 2005). Between 7 and 14 d after IRBT, treated tissue sloughs, leaving the bird with a shorter, blunter beak as compared to an intact beak. The IRBT equipment is programmable and specific treatment settings are used based on factors such as bird species, parent flock ages, future housing systems, and bird hydration level (Schwean-Lardner, 2018). There are 3 components of the IRBT equipment that can be adjusted to create specific treatment settings based on these factors. The guard-plate determines how much of the top beak is exposed to the infrared light, the mirror design (shape and material) determines how much infrared light is reflected onto the bottom beak, and the power or intensity determines how much the infrared light penetrates the beak tissue.

Even though the loss of the beak tissue is more gradual with IRBT, ultimately it does result in a change in beak shape. Although IRBT predominantly results in top and bottom beaks reaching the same length, variability in shape does occur. Some previous studies have reported a high incidence of beak "abnormalities" (for example, a shovel beak where the bottom beak is elongated) in IRBT treated birds (Blatchford et al., 2016; Kajlich et al., 2016), while others have found that IRBT results in less beak "abnormalities" than HBT (Carruthers et al., 2012). It has been suggested that these beak "abnormalities" may negatively impact bird welfare (Kajlich et al., 2016), but this assertion is primarily based on the physical appearance of the beak and there is still very little research that has studied the relationship between variations in beak shape and the effect on production and welfare parameters. It is important to understand how differences in beak shape as a result of IRBT affects birds as there is also concern that these altered beak shapes may negatively impact the bird's ability to consume feed or perform natural behaviours (Prescott and Bonser, 2004). Other research also found that IRBT treated hens with shovel beaks of varying lengths had no differences in productivity and only minor differences in behaviour as compared to IRBT treated hens that had beaks where the top and bottom lengths were flush (Hughes et al., 2017).

Previous research has found that IRBT treated birds may demonstrate differences in nutritive intake and behavioural output compared to birds with intact beaks. For example, it has been noted that IRBT treated birds have reduced feed intake and body weight as compared to untreated birds (Marchant-Forde et al., 2008; Marchant-Forde and Cheng, 2010) during some period of their lives. However, these reductions typically coincide with the period of time in which the treated beak tissue is sloughing and are no longer apparent 3 to 4 wk post-treatment (Marchant-Forde et al., 2008; Marchant-Forde and Cheng, 2010). If or how IRBT affects water consumption has not been extensively studied. Swenson and van Gulijk (2014) reported that IRBT treated birds given access to water through 360º nipple drinker systems, which can be touched from any angle to produce a water droplet, were successfully able to manipulate the nipples. The authors found that these birds had improved body weight and lower mortality in comparison to IRBT treated birds given access to water through vertical pin nipple drinkers, which requires a specific up-and-down movement of the nipple to produce a water droplet. Swenson and van Gulijk (2014) also found that the size of the water droplet from the vertical pin nipple was much smaller than from the 360º nipple, which may influence the time IRBT treated birds spend at the drinker as well as the amount of water they consume. Changes in behaviour during early life have also been observed with IRBT treated birds spending less time at the feeder and drinker and more time being inactive (Marchant-Forde et al., 2008).

Two possible explanations have been suggested for why these reductions in production and behaviour occur. First, it may be because the beak treated birds are experiencing pain or sensitivity from the IRBT procedure and are therefore less motivated to peck at the feeder and drinker (Marchant-Forde et al., 2008). Pecking force can be used to judge if a bird may be experiencing pain or not. If IRBT treated birds are experiencing pain, it is expected that they will exhibit less pecking behaviour and peck with less force in comparison to birds with intact beaks (Jongman et al., 2008). Freire et al. (2008) found that, as compared to untreated birds, IRBT treated birds showed no reduction in pecking force, which suggests an absence of pain or sensitivity. Gentle and McKeegan (2007) found no behavioural evidence of pain in IRBT treated broiler breeder chicks and a more recent study by McKeegan and Philbey (2012) found no evidence of increased sensitivity to pain or chronic pain in laying hens following IRBT. The second explanation is that birds have to adapt to the change in beak length and shape and simply have difficulty manipulating or grasping the feed particles (Gentle et al., 1982).

Despite the research that has been conducted on the impact of IRBT on the production, behaviour, and welfare of egg production birds, the majority of these studies do no report the treatment settings that were used or the beak shapes that were observed post-treatment. Egg producers often prefer a standard treatment setting in which the top and bottom beak lengths are flush or symmetrical post-treatment (personal communication, Nova-Tech Engineering LLC, September 2018). However, variations in final beak shape can occur if parts of the PSP are damaged or if a quality control program is not in place. This can result in beak shapes such as shovel or step beaks where the bottom beak extends beyond the top beak. Although variation in beak shape is less common with IRBT than HBT (Carruthers et al., 2012), it is still important to understand how these variations in beak shape post-IRBT affect the productivity and welfare of layer pullets and hens. There is also a lack of understanding as to how IRBT and the potential variations in beak shape impact pullets during early life, particularly during the time that the treated beak tissue is sloughing. Finally, few studies conducted on IRBT have used brown and white layer strains or genotypes concurrently and it is not fully understood how different genetics react to IRBT.

Therefore, the objectives of this research were to:

1. Adjust IRBT treatment settings to purposely create 3 different beaks shapes that have been observed in commercial egg production flocks. Two of these treatment settings and their resulting beak shapes (SHV and STP) represent the most prevalent variations from the STAN treatment setting (resulting in a flush or symmetrical beak) that is most commonly applied in the egg industry.
2. Compare the 3 IRBT-created beak shapes to a natural, untreated beak shape.

3. Investigate how the 4 different beak shapes (3 IRBT-created and 1 natural, untreated) impacts the productivity, behaviour, pecking force, and mortality of LW and LB pullets housed in cages from 1 to 29 d of age.

To reach these objectives, 3 experiments were conducted using chicks from the same hatch. The first experiment (Experiment 1a) examined the effects of different beak shapes, creating by altering IRBT settings or using sham treatment only, bird strain (LW, LB), and drinker type (chick fount, 360° nipple drinker) on body weight, feed intake, feed efficiency, and water disappearance. It was hypothesized that the beak shapes created by IRBT as compared to the untreated controls:

1. Would result in a reduction in feed intake and growth during the period in which the beak tissue is sloughing due to the bird experiencing pain or sensitivity in the beak or adapting to specific beak lengths and shapes.
2. Would not affect water disappearance as birds have been shown to operate 360º nipple drinkers after IRBT.

The second experiment (Experiment 1b) examined the effects of different IRBT treated beak shapes and bird strain on the beak length and pecking force of LW and LB pullets. It was hypothesized that the different beak shapes created by IRBT:

1. Would effectively reduce beak length compared to untreated controls. In addition, beak length would vary for birds treated with different settings, as again the objective of changing adjustments is to alter beak shapes.
2. Would not affect pecking force because previous literature has suggested that IRBT does not result in acute pain.

Finally, the third experiment (Experiment 1c) examined the effects of different beak shapes and bird strain on behaviour. It was hypothesized that IRBT treatment in general:

1. Would not alter the behaviour of pullets over the 10 to 28 d period examined as previous studies have shown that there are no effects of IRBT on behaviour by 7 d post-treatment.

2.3 Materials and Methods

2.3.1 Experimental design

The experimental protocols for these experiments were approved by the University of Saskatchewan Animal Research Ethics Board and all birds were cared for as specified in the Guide to the Care and Use of Experimental Animals by the Canadian Council of Animal Care (1993, 2009). Three 28 d experiments were conducted from April to May 2016. Experiment 1a examined the effects of IRBT treatments, bird strain (LW, LB), and drinker type (chick fount, 360° nipple drinker) on the production performance (feed intake, feed efficiency, water disappearance, and body weight) of pullets housed in cages from 1 to 29 d of age. Experiment 1b examined the effects of IRBT treatments and bird strain (LW, LB) on the beak length and pecking force of pullets housed in cages from 1 to 29 d of age and Experiment 1c examined the effects of IRBT treatments and bird strain (LW, LB) on the behaviour of pullets housed in cages from 1 to 29 d of age.

2.3.2 Beak treatments

Newly hatched LW (n=160) and LB (n=160) female pullets were randomly assigned to 1 of the 4 beak treatments (n=40 birds per IRBT x strain). Infrared beak treatment settings were adjusted to create 4 specific beak shapes: shovel (SHV), step (STP), standard (STAN), and a sham untreated control group (C) (Figure 2.1). The specific IRBT equipment settings for each treatment are described in Table 2.1. The different treatment settings for each strain were created by adjusting the guard-plate, mirror design, and power. Figures 2.2 and 2.3 show the guard-plates and mirrors that were used. All treatments were applied immediately post-hatch using the PSP developed by Nova-Tech Engineering LLC (Willmar, MN, USA) at Clark's Poultry Inc. in Brandon, MB on April 18, 2016 prior to the pullets being transported to and housed at the University of Saskatchewan Poultry Centre the following day. Pullets in the control treatment were handled and loaded on the PSP to simulate conditions experienced by the IRBT treated chicks; however, their beak tips were not exposed to the infrared light.

The definitions for the beak types are based on the difference between the top and bottom beaks. A shovel beak was defined as a large difference between the top and bottom beak lengths. The goal for this beak shape was to create the largest elongation of the bottom beak of the 3 IRBT-created beak shapes. A step beak was defined as an intermediate difference between the top and bottom beak lengths. The goal for this beak shape was to create an intermediate top beak length with the bottom beak being just slightly longer than the top beak. Finally, a standard beak was defined as a small difference between the top and bottom beak lengths. The goal for this beak shape was to create a symmetrical beak profile (i.e. top and bottom beaks are flush).

2.3.3 Animal housing and husbandry

All pullets were housed in cages (50 cm x 50 cm) with 5 pullets per cage within an environmentally controlled room at the University of Saskatchewan Poultry Centre. All pullets had *ad libitum* access to water and nutritionally balanced (met or exceeded Lohmann Tierzucht, 2016a,b specifications) commercial chick starter (crumble, 1 – 28 d). Feed, medicated with Amprolium (coccidiostat), was provided via chick feeders for the first 14 d and then in metal front trough feeders for the remaining time. The lighting program was 23L:1D at 20 lux for the first 7 d and then 8L:16D at 10 lux from 8 d onwards using incandescent light bulbs as the light source. Dawn and dusk periods were simulated by gradually increasing and decreasing the light intensity over a 15-minute period. Room temperature started at 32°C at 1 d and decreased to 29°C by 7 d. After 7 d, temperature decreased by 2.0°C every wk to reach a final room temperature of 23°C at 28 d of age. Heat was provided by hot water pipes running along the walls of the rooms and monitored via thermometer.

All pullets were vaccinated at the hatchery for Marek's disease (Marek's Rispens, HVT-IBD) immediately post-hatch. At 14 d of age, pullets were vaccinated with a Newcastle Bronchitis B1 type, B1 strain, Mass and Conn type live virus Combo-Vac 30 vaccine (serial # 02030024) that was administered by coarse spray. At 29 d of age, birds from Experiment 1b pullets were transferred from cages to floor pens then vaccinated with the same Newcastle Bronchitis B1 type, B1 strain, Mass and Conn type live virus Combo-Vac 30 vaccine at 42 and 70 d of age. At 116 d of age, Experiment 1b pullets were vaccinated with a Newcastle Bronchitis vaccine, Mass type, killed virus, *Salmonella enteriditis* Bacterium vaccine (serial # 01260019) administered by intramuscular injection.

Experiment 1a. The treatments tested in Experiment 1a include beak shape, strain, and drinker type, and focused on the early life of the chicks (1 – 29 d of age). Pullets (n=160; 10 birds per IRBT x strain x drinker type) were housed in cages (n=32; 2 replicate cages per IRBT x strain x drinker type) to measure production (feed intake, feed efficiency, water disappearance, and body weight). They were given *ad libitum* access to water through either chick founts or 360º nipple drinkers (Figure 2.4). The chick fount system consisted of a 1 L plastic jar that was filled with water from the same water system as provided through the nipples, and then screwed into a plastic base. After filling, founts were placed onto the cage floor. At 22 d of age, the chick founts were placed onto small, wooden blocks to ensure birds could access water properly. The nipple drinker system consisted of a water jug that was filled and suspended over top of the cage. Tubing ran down from the jug and connected to the nipple device inside the cage (2 nipples per cage). The 360° nipples could be touched from any side or at any angle to produce a water droplet. The height of the nipple device was raised as the pullets grew to ensure proper water access.

Experiment 1b. Experiment 1b examined the effects of beak shape and bird strain on beak length and pecking force during the rearing period (1 – 113 d of age), with a particular emphasis on the early life of the chicks (1 – 29 d of age). Pullets (n=80; 10 birds per IRBT x strain) were housed in cages (n=16; 2 replicate cages per IRBT x strain) to measure beak length and pecking force. Pullets were given *ad libitum* access to water through 360º nipple drinkers. Supplemental water was provided using ice cube trays for the first 7 d (1 tray per cage). After the 28 d period, the pullets were transferred to 2 floor pens (1 pen/strain) and kept until 113 d of age to continue monitoring beak length and pecking force.

Experiment 1c. The treatments tested in Experiment 1c were beak shape and bird strain and focused on behaviour during the early life of the chicks (1 – 29 d of age). Pullets (n=80; 10 birds per IRBT x strain) were housed in cages (n=16; 2 cages per IRBT x strain) to record behaviour. They were given *ad libitum* access to water through 360º nipple drinkers. Supplemental water was provided using ice cube trays for the first 7 d (1 tray per cage).

2.3.4 Data collection

Body weight. Pullets were counted and weighed (on a cage basis) at 1, 15, and 29 d of age for average body weight calculation.

Feed intake and efficiency. Feed was weighed at 1, 15, and 29 d of age for intake and efficiency calculations. Feed efficiency was calculated as mortality corrected feed-to-gain ratio using the following formula.

$$F{:}G^{m} = \frac{\textit{Feed intake (per cage)}}{\textit{(Body weight (per cage) + mortality weight (per cage) - initial body weight (per cage))}}$$

Water disappearance. The founts and jugs containing water were weighed every second day from 1 to 29 d of age and the weight difference was calculated to determine water disappearance. A chick fount was filled and placed inside an empty cage and was weighed at the same time to correct for evaporation within the room. Any obvious spillage from the chick founts was recorded and removed from data analyses, leaving a minimum of 1 replicate cage for each weigh time.

Beak length. Beak length was measured using 10 replicate birds per IRBT x strain subclass at 1, 29, 57, 85, and 113 d of age. Digital photographs of the beaks were taken using the Nova-Tech Beak Scale (Nova-Tech Engineering LLC., Willmar, MN, USA) and a Canon Power Shot SD 1200 IS Camera (Canon Canada Inc., Mississauga, ON, CAN). Photographs were analyzed to calculate beak length (distance between the anterior end of the nares (end closest to beak tip) to the end of the upper and lower beak at each age), beak length ratio (ratio of upper beak length to lower beak length at each age), top beak growth (difference between the beak length at 113 and 1 d of age), and bottom beak growth (difference between the beak length at 113 and 29 d of age) using Image J software. Bottom beak growth was calculated from 29 to 113 d of age as bottom beak length at 1 d of age could not be calculated from the Image J software. IRBT treated chicks were also individually examined daily starting at 7 d of age to determine initiation and completion of beak sloughing. To perform this, chicks were removed from the cage one at a time and their top and bottom beaks were examined and identified as either intact, partially sloughed, or completely sloughed.

Pecking force. The force with which pullets pecked at a nutritive food object was measured weekly at 4, 11, 18, and 25 d of age (same pullets tested at each age; 4 replicate birds per IRBT x strain). Feed was removed 1 h prior to testing to encourage the pullets to peck at feed placed on top of the force plate. Pullets were first weighed to determine body weight and then placed onto a wooden platform with a force plate connected to a load cell, which was connected to a P-3500 Portable Strain Indicator unit (Vishay Measurements Group, Raleigh, NC, USA) and visualized on a TDS1002R oscilloscope (Tektronix Inc., Beaverton, OR, USA) (Figure 2.5). Three pecks per pullet were recorded and averaged. A peck was considered any hit from the beak onto the load cell. Once a pullet had successfully pecked the force plate, the maximum force (measured in mV) was recorded and converted to newtons (N). Force in N was calculated by multiplying the mV value by the sensitivity reciprocal. The calculation for the sensitivity reciprocal is shown below. Pecking force was equalized for body weight (calculated as N per 100 g of body weight) and then averaged per bird. Pecking force continued to be measured at 53, 81, and 109 d of age after the pullets were transferred from the cages to floor pens (same pullets tested at each age; 4 replicate birds per IRBT x strain).

$$Sensitivity\ reciprocal = \frac{(m/1000) * 9.81}{System\ output} = \frac{(1000/1000) * 9.81}{640} = 0.01532815$$

m = known mass = 1000 g

System output = 640 mV

Behaviour. Pullets housed in 2 cages per IRBT x strain were video recorded for 8 continuous h every second day from 10 to 28 d of age for behaviour analyses. Videos were recorded using Canon Vixia HFR700 Camcorders (Canon Canada, Mississauga, ON, CAN) that captured the entire cage and data were stored on 2GB SanDisk memory cards (Canon Canada, Mississauga, ON, CAN), then observed for behavioural expression at a later date. The percent of time pullets spent performing nutritive, active, resting, preening, comfort, exploratory, and aggressive behaviours (described in Table 2.2) was evaluated using scan sampling at 15-minute intervals. Behavioural output was analyzed and presented as an average of the entire period (10 to 28 d of age). To determine if behaviour changed during the sloughing period (11 to 25 d of age), behavioural expression was also analyzed by day.

Mortality and cause of mortality. Pullets for all experiments were monitored daily throughout the 28 d period. Cull or sick pullets were humanely euthanized using manual cervical dislocation. All found-dead and euthanized pullets were recorded, weighed, and submitted to

Prairie Diagnostic Services (PDS), University of Saskatchewan for necropsy to determine cause of death.

2.3.5 Statistical analyses

The experimental design and arrangement for the experiments were as follows: Experiment 1a was a 4x2x2 factorial arrangement of IRBT, strain, and drinker type, in a completely randomized design with 2 replicates per IRBT x strain x drinker type. Experiment 1b was a 4x2 factorial arrangement of IRBT and strain, in a completely randomized design with 2 replicates per IRBT x strain. Experiment 1c was a 4x2 factorial arrangement of IRBT and strain, in completely randomized design with 2 replicates per IRBT x strain. Data were analyzed using Proc Mixed (cage as replicate unit for Experiments 1a and 1c and bird as replicate unit for Experiment 1b) (SAS® 9.4, Cary, NC) with Tukey's range test to separate means. Pecking force data was correlated with body weight data using Proc CORR (SAS® 9.4, Cary, NC). Percentage data was checked for normality using Proc UNIVARIATE prior to running ANOVA (SAS® 9.4, Cary, NC) and log transformed (data log + 1) when necessary. Differences were considered significant when $P \leq 0.05$ and a trend was noted when $0.05 < P \leq 0.10$.

2.4 Results

2.4.1 Beak sloughing

Beak sloughing of the affected tissue was first noted at 11 d of age and was completed by 25 d of age (Figure 2.6). Within the IRBT treated pullets, beak sloughing began at 11 d of age for the SHV treatment with sloughing being initiated in 6 percent of pullets; 15 d of age for the STP treatment with sloughing being initiated in 5 percent of pullets; and 12 d of age for the STAN treatment with sloughing being initiated in 10 percent of pullets. For the SHV and STP treatments, all beaks completed sloughing by 24 d of age and for the STAN treatment, all beaks completed sloughing by 25 d of age.

LW pullets began to slough sooner and were faster at sloughing throughout (Figure 2.7). Sloughing was first noted for LW at 11 d of age with 3 percent of pullets identified as having sloughing initiated. Sloughing was not noted for LB pullets until 14 d of age, with sloughing being initiated in 8 percent of pullets. By 25 d of age, 100 percent of the IRBT treated LB and LW pullets had sloughed beaks.

2.4.2 Beak length

Length. Each of the 3 beak treatments used in this study were effective at reducing top beak length. A trend was noted at 1 d of age, with C pullets having longer top beak lengths as compared to IRBT treated pullets (Table 2.3). However, by 85 and 113 d, C pullets clearly had the longest top beak, and SHV top beaks were longer than STAN. The strains also demonstrated differences in top beak length, and LB had longer top beaks than LW at both 85 and 113 d of age (Table 2.3).

An interaction between IRBT treatment and strain was noted in top beak length at both 29 and 57 d of age and interestingly, the 2 strains reacted very similarly (Table 2.4). At both ages, C top beaks for both strains were the longest compared to IRBT treatments and differences between the IRBT treatments and top beak lengths were in magnitude only.

The length of bottom beaks changed across treatments as pullets aged, indicating that beak growth may have occurred. At 29 d of age, C pullets had the longest bottom beak length followed by the SHV, STP, and STAN treatments (9.57, 8.67, 7.86, 7.39 mm, respectively). By 57 and 85 d, bottom beak length was not different between C and SHV pullets; however, both treatments had significantly longer bottom beaks as compared to pullets in the STP and STAN treatments (Table 2.4). At 113 d, SHV pullets had longer bottom beaks than STP and STAN pullets (15.20, 13.43, 12.81 mm, respectively). Control pullets had similar bottom beak lengths to SHV and STP pullets but longer bottom beaks than STAN pullets. Bottom beak length was not different between STP and STAN pullets.

Beak length ratio. The creation of different beak shapes using the IRBT settings resulted in variations in the ratio of upper to lower beak (Table 2.5). A ratio above 1 indicates that the top beak was longer than the bottom and a ratio below 1 that the bottom beak was longer than the top. Throughout the 112 d period, C birds consistently had ratios over 1, which indicates that a natural or untreated beak demonstrates a top “hook” which overhangs the bottom beak (Table 2.5). Interestingly, at 29 d of age, the ratios for the SHV, STP, and STAN treatments were also above 1 (1.03, 1.10, 1.15, respectively), indicating that the top beak still extended over the bottom at this age. However, each ratio was still lower than the C treatment, demonstrating that IRBT treated pullets no longer had a “hook” shaped beak and that sloughing had occurred. At 57 d, within the 3 groups of IRBT treated pullets, SHV birds had longer bottom beaks than STP pullets as indicated by a smaller ratio (0.90 vs. 0.99, respectively). By 113 d of age, no differences were seen between IRBT treated pullets.

Differences in beak ratio were seen between the strains at 113 d of age with LB pullets having a ratio above 1 (1.01), indicating that the top beak still extended out over the bottom beak at this age whereas LW pullets had a ratio below 1 (0.95), indicating that the bottom beak extended beyond the top beak (Table 2.5).

At 85 d of age, an interaction between IRBT and strain was noted for beak length ratio. C pullets for both strains had significantly higher ratios (above 1) compared to IRBT treated pullets, indicating a natural beak shape (top “hook” overhangs bottom). Ratios did not differ between IRBT treated pullets of both strains except for within the SHV treatment where LB pullets had a higher ratio as compared to LW (0.97 vs. 0.82, respectively), which indicates that while both strains had a shovel beak (bottom beak longer than the top), LW pullets had a longer bottom beak compared to LB (Table 2.4).

Beak growth. Top and bottom beak growth during the rearing period was affected by IRBT. When measured at 113 d of age (compared to length at 1 d), an interaction occurred between strain and IRBT (Table 2.4). For both strains, C pullets demonstrated the most beak growth, but within the IRBT treatments, strains responded differently. For LB pullets, SHV beaks grew the most, followed by STAN, and then STP beaks the least. LW however differed, with the most growth occurring for the SHV beaks, second STP and the STAN beaks growing the least. This interaction was not noted with bottom beak growth (29 – 113 d) and for both strains, growth was longer for SHV beaks as compared to C only (6.50 vs. 4.95 mm, respectively) (Table 2.6).

2.4.3 Body weight

The use of IRBT as compared to maintaining untreated control beaks did not have any impact on pullet body weight during early life. At 1, 15, and 29 d of age, shortening the beak in any manner did not reduce body weight. Strains, however, did vary in weight, but only significantly at 15 d of age, with LW pullets being heavier than LB (138.1 vs. 128.4 g, respectively) (Table 2.7).

2.4.4 Feed intake and efficiency

Shortening the beak in any manner, as compared to intact beaks, did not alter the amount of feed pullets consumed, nor the feed efficiency of pullets (Table 2.7). Feed intake was significantly different between the strains from 15 to 29 d of age, with LB pullets consuming more feed than LW (30.6 vs. 28.6 g/bird/d, respectively), and although not significant, the opposite trend was noted from 1 to 15 d of age. There was no effect of strain on feed efficiency (Table 2.7).

2.4.5 Water disappearance

With regards to water disappearance, the change in beak shape that resulted from IRBT treatment affected pullets with STP beaks as they had lower water disappearance than C pullets from 9 to 29 d of age (Table 2.8). Strain affected water disappearance from 9 to 16 d of age with LW pullets having higher water disappearance than LB (29.29 vs. 25.64 g/bird/d, respectively) (Table 2.8); a similar trend was noted from 17 to 22 d (P=0.059). Drinker type had an effect on water disappearance from 17 to 22 d of age with pullets given access to water using a fount having higher water disappearance than pullets given access to water using a nipple drinker (46.67 vs. 40.27 g/bird/d, respectively).

An interaction between the specific beaks shapes and drinker type was noted (Table 2.9). Over the 28 d test period, C pullets given access to a 360º nipple drinker had higher water disappearance than STP and STAN pullets given access to a 360º nipple drinker. However, water disappearance was similar between beak treatments for fount drinkers.

2.4.6 Pecking force

Pecking force was found to be strongly correlated with body weight (r=0.79). Shortening the beak using IRBT, regardless of beak shape, did not alter the force with which pullets used to peck at food over the 112 d testing period. Sloughing of the treated beak tissue also did not affect pecking force during both the sloughing period (11 to 25 d of age) and after sloughing was completed (25 to 112 d of age) (Table 2.10).

There was an effect of strain from 11 to 109 d of age. From 11 to 25 d, LB pullets pecked with more force per 100 g body weight. At 53 and 109 d, LW pullets pecked with more force per 100 g body weight (Table 2.10).

2.4.7 Behaviour

IRBT treatments had minimal impacts on early pullet behaviour when monitored every second day from 10 to 28 d of age (during the sloughing period) (Table 2.11), with differences noted only in the percent of time spent performing active behaviours (standing and walking). Pullets in the STAN treatment spent a greater percent of time active as compared to C pullets (41.70 vs. 36.46 %, respectively). However, use of IRBT, and the subsequent sloughing of the beak tissue, did not alter the percent of time pullets spent performing nutritive behaviours.

Strain had a larger impact on behaviour than beak treatments. An effect on the percent of time spent performing active, resting, exploratory, and other behaviours (Table 2.11). LB pullets spent a greater percent of time performing active, resting, and other behaviours while LW pullets spent a greater percent of time performing exploratory behaviours (gentle and object pecking).

2.4.8 Mortality and cause of mortality

Regardless of experiment (1a, 1b, and 1c), beak treatment did not affect mortality levels over the 28 period (Table 2.12). The majority of the mortality during the 28 d period for each experiment was due to infectious causes such as yolk sac infection, pericarditis, and enteritis and not from the IRBT treatment.

Mortality between the strains was also not affected by beak treatment for all 3 experiments; however, there was trend for LW pullets to have higher infectious mortality compared to LB pullets over the 28 d period (P=0.081) in Experiment 1a.

2.5 Discussion

2.5.1 Infrared beak treatment

The purpose of treating beaks is to reduce the damage resulting from cannibalism in egg production flocks. This is important as the removal of feathers and the physical damage of tissue likely results in pain (Gentle and Hunter, 1990) and is a welfare concern as the presence of blood in damaged tissue can increase the risk of cannibalism in egg production flocks (Savory, 1995). By shortening or blunting the beak, birds are less able to grasp feathers or tissue (Dennis and Cheng, 2012), and prior research has clearly shown this to be effective (Hughes and Michie, 1982; Gentle et al., 1997; Gabrush, 2011; Dennis and Cheng, 2012; Damme and Urselmans, 2013). It is also important to understand if and how variations in beak length affects how pullets are able to consume feed and water, grow, and peck. If the bird's ability to use its beak is altered, this may be a welfare concern as it may indicate birds are in pain and/or that they are unable to express behaviours necessary for survival, such as feeding and drinking (Duncan, 1998).

Final IRBT treatment configuration are decided based on a number of factors including genetics, pullet and layer housing environment (temperature, density, lighting), environmental stressors, nutrition, and regulations regarding beak treatment in the country the flock is located in (personal communication, Nova-Tech Engineering LLC, May 2018). Birds in higher stress environments, such as those where birds are exposed to higher light intensities (Prayitno et al., 1997) or are housed in extensive systems (Nicol et al., 2006), may require shorter beaks than birds that are raised in systems that are more conventional where the environment is completely controlled (personal communication, Nova-Tech Engineering LLC, May 2018).

The beak length data collected in the present study suggest that the IRBT settings used to create the different treatment groups worked as expected. Not only were untreated upper beaks longer, but also controlled altering of equipment settings resulted in beaks reaching the targeted shapes. It is interesting to note that the beak treatment had a very quick impact on tissue, as a trend appeared for STP and STAN birds to have shorter top beak lengths as compared to C birds at 1 d of age, which supports data presented by Henderson et al. (2009) and suggests that the IRBT treatment was already affecting the beak tissue at a cellular level. However, in both the present study and the one conducted by Henderson et al. (2009), beak length measurements were not taken immediately post-treatment. In both cases, there was a delay due to having to transport birds. When beaks were measured immediately post-treatment, most research has found no significant difference between IRBT and C birds in top beak length at 1 d (Gentle and McKeegan, 2007; Marchant-Forde et al., 2008; Marchant-Forde and Cheng, 2010).

In addition to the variance in time of measurement (immediately post-treatment vs. delayed), the discrepancy in beak length at 1 d of age between these studies may have been due to the actual mechanism of beak length measurement. It appears that Henderson et al. (2009) attempted to measure what length the beak would slough to in IRBT treated birds and the authors did this by measuring the distance between the anterior end of the nares to the treatment line (blanch line). Other studies have measured from the anterior end of the nares to the beak tip (Gentle and McKeegan, 2007; Marchant-Forde et al., 2008; Marchant-Forde and Cheng, 2010) to help evaluate the effects of beak treatment on beak growth. Similar to these studies, in the present study beak length was measured from the anterior end of the nares to the beak tip regardless of if the beak was treated or not.

Inhibiting beak growth is important because it reduces the potential of having to re-trim birds later in age (Marchant-Forde and Cheng, 2010) and it ensures that the beak tissue does not grow back enough that birds are more successful at damaging the skin and plumage of conspecifics. Marchant-Forde et al. (2008) found that the top and bottom beaks of IRBT treated birds demonstrated similar rates of growth; however, IRBT treated birds did not show enough compensatory growth to warrant further beak treatment at a later age (Marchant-Forde et al., 2008). This led the authors to conclude that IRBT was more effective at preventing beak growth than HBT. The results of the present study suggest that the top beak grows more than the bottom; however, part of this may be due to the difference in age at first measured beak length. Top beak growth was calculated as the difference between beak length at 113 d of age and 1 d of age, whereas bottom beak growth was the difference between beak length at 113 d of age and 29 d of age. The results also suggest that depending on the strain of bird, certain IRBT treatments (STAN treatment for LW strain and STP treatment for LB) may control growth better than others. If this is true, it helps emphasize how important it is for hatcheries to use specific IRBT settings that take into account factors such as bird strain, beak pigmentation, and the housing system in which the flock will be raised (Schwean-Lardner, 2018).

There is concern that beak treatment in general could impede the pullet's ability to grasp feedstuffs (Gentle et al., 1982; Prescott and Bonser, 2004), which could be both a welfare and production concern (relates to body weight). To date, this has not been reported during the time of beak sloughing to the author's knowledge, including how various beak shapes could impact this. Henderson et al. (2009) found that IRBT treated birds had heavier body weights at 1 d of age as compared to C birds; however, the chicks picked for IRBT were not randomly selected and it is possible that larger chicks were picked. In a second experiment, Henderson et al. (2009) saw no differences in body weight at 1 d of age between IRBT treated and C birds. At 2 wk of age, IRBT treated birds were slightly heavier than C birds; however, differences in body weight were not seen after this age (Henderson et al., 2009). Similar to Henderson et al. (2009), the body weight data collected in the present study suggests that the beak shapes resulting from different IRBT treatments did not have a negative effect on growth during early life. Some previous literature has reported reductions in body weight in IRBT treated birds from as early as 2 d post-treatment until 4 wk of age (Gentle and McKeegan, 2007; Marchant-Forde et al., 2008; Marchant-Forde and Cheng, 2010; Angevaare et al., 2012). This reduction typically coincides with the period that the beak tissue is sloughing and could be a result of birds experiencing pain or sensitivity from IRBT or having to adapt to the change in beak length and shape. During the sloughing period in the present study, there were no differences in body weight between birds with treated beaks and those with untreated beaks, suggesting that the change in beak shape did not hinder the bird's ability to consume feed and gain weight. It was also interesting to see that despite the later initiation of sloughing in the STP treatment, this did not cause differences in body weight, further supporting that sloughing of the beak tissue did not have a significant impact on the pullets.

Feed intake and its relationship to beak treatment is important to assess, not only because changes in feed intake can influence other production parameters such as growth and egg production (both of which have economic consequences) but because it may also indicate changes in the welfare of the bird. Research has shown that IRBT treated birds can have reduced feed intake for up to 4 wk post-treatment as compared to C birds (Marchant-Forde et al., 2008; Marchant-Forde and Cheng, 2010). Similar to body weight, these reductions typically coincide with the period of time in which the beak tissue is sloughing. This temporary reduction in feed intake often corresponds with a reduction in feeding activity in beak treated birds (Marchant-Forde et al., 2008). Reduced feeding activity and feed intake may indicate that the beak treated birds are experiencing pain or sensitivity from the IRBT procedure; however, the differences between beak treated and C birds seen in previous studies may also be due increased feed wastage in C birds rather than more feed consumed (Marchant-Forde et al., 2008; Marchant-Forde and Cheng, 2010). These findings are not consistent with the results of the present study, where none of the beak shapes resulting from the different IRBT treatments caused a reduction in feed intake during early life. Much like with body weight, feed intake during the time of sloughing in the present study did not differ between treatments. This suggests that birds were able to adapt to the gradual change in beak shape and were able to manipulate and grasp feed as well as birds with intact beaks. However, feed presentation can affect treated birds' ability to grasp feed (Prescott and Bonser, 2004) and in the present study, feed was presented as a deep multilayer, which may have allowed easier manipulation of the feed than if it was presented as a single layer.

The beaks shapes created in the present study did not affect mortality corrected feed-to-gain ($F{:}G^{m}$), including during the sloughing period. This is inconsistent with previous studies, which have suggested that beak treatment (HBT or IRBT) improves feed efficiency as compared to untreated C birds (Eskeland, 1981; Blokhuis et al., 1987; Gentle et al., 1997; Damme and Urselmans, 2013). It has been suggested that the improved feed efficiency observed in IRBT treated birds is partially due to less feed wastage (Honaker and Ruszler, 2004; Marchant-Forde et al., 2008). Honaker and Ruszler (2004) found that as the birds grew, C birds tended to have poorer feed efficiency as compared to IRBT treated birds and attributed this to increased feed wastage from flipping feed out of the feed trough with their beaks. Marchant-Forde et al. (2008) also found that beak treated birds (HBT or IRBT) had lower feed wastage, although they did not see any effects of beak treatment or beak treatment method on feed efficiency.

Water intake also influences production, although how IRBT affects the water intake of layer pullets during early life is not yet fully understood. The results of the present study suggest that C birds were able to consume more water than birds with a STP shaped beak, although it is difficult to determine the extent of this effect. In both broilers and layers, feed and water intake are positively correlated (Savory, 1978; Lott et al., 2003; Symeon et al., 2010), meaning that when there is a reduction in water intake, there will be a decrease in feed intake. Similar effects have also been noted for water intake and body weight. Water restriction, even if it was short-term, reduced body weight in both broilers (Viola et al., 2009) and laying hens (Ahmed and Alamer, 2011). In the present study, there was no corresponding reduction in feed intake or body weight seen in STP birds, suggesting that the beak shape was not having a negative impact on overall growth. The differences in water disappearance between the STP and C treatments may have been due to other factors, such as spillage, play behaviour of the birds, and evaporative loss. Interestingly, no differences in water disappearance were seen between birds with SHV, STP, or STAN beak shapes. This is important because the SHV and STP treatments used in this study represent variations from the STAN beak shape and are associated with an elongation of the lower beak. The lack of difference between the SHV, STP, and STAN beak shapes in the present study suggest that even if some variation in beak shape does occur, birds were still able to drink. Most important and similar to body weight and feed intake, water disappearance was not affected during the sloughing period. This suggests that IRBT treated birds were not hesitant to peck at the 360° nipple (indicating that birds were likely not in pain) and that as the beak tissue sloughed the bird's ability to drink was not affected.

The format of water delivery may also play an important role in water intake as well as body weight and mortality. Swenson and van Gulijk (2014) found that IRBT chicks with access to a 360º nipple drinker had reduced mortality, improved body weight, better uniformity as compared to IRBT treated chicks with access to a vertical pin nipple drinker, and HBT treated chicks with access to the 360º nipple drinker. The interaction between the different beak shapes and drinker types noted for overall water disappearance in the present study suggests that IRBT treated birds, regardless of beak shape, can effectively drink from both founts and 360º nipple drinkers, although they may be able to drink more easily from founts than nipple drinkers. It also suggests that birds with certain beaks shapes (STP and STAN) may be less successful in operating 360º nipples as compared to birds with untreated natural beaks. However, the reduced water disappearance in birds with STP and STAN beak shapes given access to 360º nipple drinkers did not alter other production parameters such as feed intake or body weight, indicating that these birds were still able to manipulate the nipples and drink, which is in agreement with Swenson and van Gulijk (2014).

As alluded to previously, it is difficult to determine whether the transient reductions in intake and growth sometimes seen in IRBT treated birds are due to the birds experiencing pain or sensitivity from IRBT or are related to the required adaptation to the change in beak shape. Marchant-Forde et al. (2008) suggested that the reason for the reduced feeding behaviour and subsequent reductions in feed intake and body weight that were observed in IRBT treated birds was due to a decreased motivation to feed because the birds were in pain. This has also been reported in earlier studies conducted on HBT (Breward and Gentle, 1985; Gentle, 1986b). There was no evidence that the IRBT-created beak shapes used in the present study altered pecking force, suggesting then that pain or sensitivity was not an issue. This is in agreement with Freire et al. (2008) who found that IRBT treated birds did not show a reduction in pecking force at 11 wk of age compared to C birds and interpreted this as an absence of pain in IRBT treated birds. That IRBT treated birds were not experiencing pain or sensitivity is further supported by the behavioural data in the present study, in which no differences were seen for the percent of time spent performing beak-related behaviours such as nutritive, preening, and exploratory behaviours.

However, a possible limitation in the present study is that feed was withdrawn prior to the pecking force test. Because of this, birds may have been motivated to peck at the feed that was provided during the pecking force test and this may have masked differences in beak sensitivity or pain between the treatments. Jongman et al. (2008) found that after a period of feed withdrawal, commercial pullets (White Leghorn x Australorp) treated using HBT pecked at feed with the same amount of force as C birds. When the birds had to peck at an object rather than feed, HBT birds pecked with less force than C birds (Jongman et al., 2008). However, it is unlikely that the feed withdrawal prior to testing pecking force in the present study was masking pain or sensitivity because if birds were in pain, reductions in other parameters measured such as feed intake and growth would be expected, but were not seen.

It has been suggested that beak treatment causes a reduction in overall activity level, often reflected as increased time spent standing inactive or resting, and this reduction can be an indicator of pain (Duncan et al., 1989). Marchant-Forde et al. (2008) found that IRBT treated birds spent more time standing inactive or resting as compared to C birds and attributed this to acute pain caused by IRBT. It is important to note, however, that the effects of IRBT on behaviour in that study were short-lived and were no longer apparent by 7 d post-treatment (Marchant-Forde et al., 2008). Although the percent of time spent standing did differ between C birds and birds with STAN beak shapes in the present study, when taken in conjunction with the production and pecking force data, it is unlikely that the increase seen in STAN birds was due to pain. Besides being a possible indicator of pain, time spent standing has also been shown to increase with age (Gentle and McKeegan, 2007; Dennis and Cheng, 2012) and may just reflect normal behavioural development in the birds (Sandilands and Savory, 2002; Gentle and McKeegan, 2007).

During the period that the beak tissue was sloughing, there were no reductions or changes in behaviour with the exception of nutritive behaviours (time spent at the feeder and drinker) (Figure 2.8). It appeared that C birds spent a greater percent of time at the feeder than IRBT treated birds during the sloughing period; however, these differences were inconsistent across the days and treatments. One possible explanation for the increase in time spent at the feeder seen in C birds during the sloughing period may be play behaviour. Overall, the behavioural data collected in the present study shows that the different beak shapes had minor effects. As with many of the other parameters measured in this study, the amount of beak tissue treated and sloughed did not appear to affect behaviour as no differences were found between the SHV, STP, and STAN treatments. There were also no behaviours exhibited that indicated that the birds were experiencing pain or sensitivity from the IRBT procedure.

Although mortality during the rearing phase is not well reported in IRBT studies, it is unlikely that it results in higher mortality as the procedure does not result in an open wound on the beak immediately post-treatment (Marchant-Forde et al., 2008). When the treated beak tissue sloughs off, the underlying tissue is already healed, thereby reducing the risk of infection, inflammation, and pain (Dennis and Cheng, 2010a). In the present study, sloughing of the beak tissue did not affect mortality levels in the IRBT treated birds, suggesting that the treated beaks underwent proper healing prior to sloughing. Overall, the majority of mortality in the present study occurred prior to sloughing and was due to infectious causes such as yolk sac infection, pericarditis, and enteritis, meaning that pullet mortality over the 28 d period was likely not related to IRBT treatment.

2.5.2 Strain

The main objective of the present study was to determine the effects of variation in beak shape; however, 2 egg-layer strains were used to help determine if different genetics react differently to IRBT. The interactions observed for beak length, beak ratio, and top beak growth suggest that the 2 egg-layer strains used in the present study reacted differently to the IRBT beak treatments and subsequent change in beak shape during early life. This highlights the importance of using particular IRBT settings for different strains. It is not clear why the 2 strains reacted differently to IRBT. One possible explanation is that the types of tissues found within the beak differed between the strains. There may also be differences in bone formation between the strains (Damme and Urselmans, 2013); however, detailed studies of the beak anatomy and physiology of different strains of laying hens have yet to be conducted. Another possible explanation is that the pigmentation of the beak changes the way the infrared light penetrates it, thereby affecting the final shape of the beak. Although very few studies have examined the effects of beak treatment on different egg-layer strains simultaneously, it has been suggested that brown-feathered strains may react more negatively (Marchant-Forde et al., 2008) as they may exhibit more pain-related behaviours and neuroma formation following HBT (Breward and Gentle, 1985; Gentle, 1986b;

Kuo et al., 1991). It is not fully understood if brown-feathered strains are more negatively affected by IRBT as well.

During early life (first 14 d post-treatment) in the present study, LW birds were heavier than LB, which is in contrast to previous studies (Tauson et al., 1999; Singh et al., 2009). The heavier body weights observed in LW birds can be explained by the higher feed intake and water disappearance also observed in LW birds during the first 14 d post-treatment. This suggests that LW birds may have adapted more easily to the cage environment as compared to LB. When measuring pecking force, there were differences between LW and LB birds. From 11 to 25 d of age, LB pullets pecked with more force but were lighter in body weight resulting in a higher pecking force to body weight ratio. From 53 to 109 d of age, LW pullets pecked with less force and were lighter in body weight resulting in a higher pecking force to body weight ratio. The 2 strains also differed somewhat in their behaviour during the 28 d period. In the present study, regardless of if birds were beak treated or not, both strains spent a large percent of the 8 h photoperiod (during which behaviour was recorded) performing active behaviours. Increased activity levels have been associated with improved well-being in both broilers (Bizeray et al., 2002) and layers (Pohle and Cheng, 2009).

Overall, the results suggest that there is a genetic component associated with the IRBT treatments. Although it is evident that the 2 strains or genotypes used in the present study reacted differently to each of the IRBT treatments in terms of beak characteristics, that did not translate over to the production and behaviour parameters measured. Despite the concern within the poultry industry that brown-feathered strains may have more difficulty with IRBT than white-feathered strains, the results of the present study do not reflect this concern within the limits of the 2 strains or genotypes that were used.

2.6 Conclusion

The results of the present study demonstrate that by adjusting the guard-plate, mirror design, and infrared intensity of the IRBT equipment, different and predictable beak shapes can be created. Using different IRBT settings, thereby creating different beak shapes, resulted in different rates of beak growth. The STAN treatment (beak with small differentiation between top and bottom length) was the most effective at inhibiting growth in the LB strain but the STP treatment (beak with intermediate differentiation) was most effective in the LW strain. This may have implications for more extensive housing systems, in which there may be a higher risk of cannibalism.

The results of this study suggest that the different IRBT-created beak shapes, whether it be the variations from the STAN beak shape (SHV or STP) or the STAN beak shape itself, did not alter the pullet's ability to feed, grow, drink, or peck during early life. There was also no indication that these variables were further affected by sloughing of the treated beak tissue. During early life, pullets with STP beak shapes had lower water disappearance compared to pullets with intact beaks; however, this did not affect feed intake or growth. With regards to the format of water delivery, birds with a natural beak shape had higher water disappearance from the 360° nipples compared to birds with STP and STAN beak shapes; however, this did not negatively affect feed intake or growth. Pecking force was also not affected by IRBT treatment, suggesting that birds were not in pain post-treatment. Very few differences were seen in behaviour between IRBT treated and C birds, supporting that treated birds were not in pain.

Overall, the results of the present study demonstrate that LW and LB layer pullets are able to effectively cope with the changes in beak shape that occur as a result of IRBT. Despite previous research classifying SHV and STP beak shapes as "abnormal" and suggesting that any detectable difference between the top and bottom beak lengths is a welfare concern (Blatchford et al., 2016; Kajlich et al., 2016), the results of the present study do not reflect this. In the present study, very few differences were found between the SHV, STP, and STAN treatments, which suggests that even if some variation in beak shape does occur as a result of improper IRBT treatment application or tissue growth, bird welfare is not necessarily negatively affected. Although some minor variation may occur with IRBT, large variations in beak shape post-IRBT can be minimized by following the standard operating procedures for the PSP and implementing a quality control program at the hatchery.

2.7 Acknowledgements

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Table 2. 1. Infrared beak treatments applied on day of hatch to Lohmann LSL-Lite and Lohmann Brown chicks to create 4 specific beak shapes by adjusting the guard-plate, mirror, and power settings.

Strain	Treatment	Guard-Plate	Mirror	Power
LB	SHV	27/23C	Flat Glass	42
	STP	27/23C	Aluminum	42
	STAN	27/23C	Curve Glass	44
	C	27/23C	-	-
LW	SHV	26/23	Flat Glass	41
	STP	26/23	Curve Glass	41
	STAN	26/23	Mid Wrap	41
	C	26/23	-	-

SHV = large difference between top and bottom beak lengths
STP = intermediate difference between top and bottom beak lengths
STAN = small difference between top and bottom beak lengths
C = sham untreated control
LB = Lohmann Brown
LW = Lohmann LSL-Lite

Table 2. 2. Ethogram of behaviours commonly performed by commercial layer pullets and hens.

Category[a]	**Behaviour**	**Definition**[b]
Nutritive	Feeding	Head extended into feeder; manipulating or ingesting feed[3]
Nutritive	Drinking	Head extended to water line; manipulating water nipple[3]
Comfort	Wing stretch	Extension of wings away from body without flapping or walking[2]
Comfort	Leg stretch	Stretching leg out to the side or behind body and returning leg back under body without taking a step forward[2]
Comfort	Sham dustbathing	Trying to perform dustbathing behaviour (wing shaking, scratching ground with one leg) on cage/pen floor[2]
Comfort	Preening	Grooming own feathers with beak while standing or laying[2]
Comfort	Feather ruffling	Feathers of wings and body are raised/shaken out[4]
Active	Standing	Standing and idle; eyes may be open or closed[1]
Active	Walking	Taking at least 2 successive steps[3,4]
Active	Resting	Crouching with breast on floor of cage, otherwise inactive, with eyes open or closed[2]
Exploratory	Gentle pecking	Pecking at plumage of other birds; does not cause harm or damage[5]
Exploratory	Object pecking	Pecking at inedible objects (floor, water hose, bars, feeder)[2]
Aggressive	Aggressive pecking	Pecking which causes damage and causes birds to flinch and/or vocalize[5]
Other	Perching	Sitting or standing on an elevated object[2]
Other	Wing flapping	Extension of wings away from body and flapping up and down rapidly but without flight/walking[4]
Other	Head scratching	Using leg to scratch at head[2]
Other	Head shaking	Head is moved side to side/up and down rapidly[2]
Other	Beak wiping	Rapid stroking of alternate sides of the beak on the walls and/or floor of cage/pen[4]
Other	Unknown	Behaviour cannot be discerned because bird is not visible or is being blocked by other birds

[a]Categories adapted from Gabrush (2011)

[b]Definitions adapted from [1]Gentle and McKeegan (2007); [2]Hurnik et al. (1995); [3]Dennis et al. (2009); [4]Marchant-Forde et al. (2008); and [5]Savory (1995)

Table 2. 3. Effect of infrared beak treatments and strain on the top and bottom beak length (mm) of Experiment 1b Lohmann LSL-Lite and Lohmann Brown pullets housed in cages from 1 to 29 d and floor pens from 29 to 113 d of age.

Age (d)	Beak Treatment					Strain			Interaction	SEM
	SHV	STP	STAN	C	*P*-value	LB	LW	*P*-value	*P*-value	
Top beak										
1	5.41	5.36	5.33	5.57	0.070	5.36	5.47	0.102	0.068	0.036
29	8.94^{b}	8.61^{b}	8.41^{b}	11.78^{a}	<0.001	9.64^{a}	9.32^{b}	0.009	0.013	0.182
57	11.30^{b}	10.81^{bc}	10.32^{c}	14.78^{a}	<0.001	12.16^{a}	11.56^{b}	<0.001	0.012	0.233
85	13.23^{b}	12.43^{bc}	11.71^{c}	16.60^{a}	<0.001	13.97^{a}	13.12^{b}	<0.001	0.162	0.261
113	13.13^{b}	12.14^{bc}	12.11^{c}	16.88^{a}	<0.001	14.20^{a}	13.03^{b}	<0.001	0.139	0.280
Bottom beak										
1	-	-	-	-	-	-	-	-	-	-
29	8.67^{b}	7.86^{c}	7.39^{c}	9.57^{a}	<0.001	8.41	8.39	0.585	0.071	0.132
57	12.58^{a}	11.03^{b}	11.03^{b}	12.84^{a}	<0.001	12.13^{a}	11.62^{b}	0.013	0.368	0.153
85	14.90^{a}	13.30^{b}	12.69^{b}	14.63^{a}	<0.001	14.02	13.75	0.287	0.139	0.194
113	15.20^{a}	13.43^{bc}	12.81^{c}	14.56^{ab}	<0.001	14.20	13.80	0.189	0.203	0.214

$^{a\,b,c}$ Means within a main effect with different superscripts are significantly different ($P \leq 0.05$)

SHV = large difference between top and bottom beak lengths

STP = intermediate difference between top and bottom beak lengths

STAN = small difference between top and bottom beak lengths

C = sham untreated control

LB = Lohmann Brown

LW = Lohmann LSL-Lite

Table 2. 4. Interactions between infrared beak treatments and strain for beak characteristics of Experiment 1b Lohmann LSL-Lite and Lohmann Brown pullets housed in cages from 1 to 29 d and floor pens from 29 to 113 d of age.

Parameter	Age (d)	Strain x Beak Treatment							
		LB SHV	LW SHV	LB STP	LW STP	LB STAN	LW STAN	LB C	LW C
Top beak length, mm	29	9.14^{b}	8.65^{bc}	9.06^{bc}	8.12^{c}	8.68^{bc}	8.07^{c}	11.55^{a}	12.00^{a}
	57	11.98^{b}	10.62^{cd}	11.21^{bc}	10.36^{cd}	10.79^{cd}	9.73^{d}	14.64^{a}	14.93^{a}
Beak length ratio	85	0.97^{b}	0.82^{c}	0.94^{bc}	0.95^{b}	0.94^{bc}	0.91^{bc}	1.14^{a}	1.13^{a}
Top beak growth, mm	1 – 113	8.44^{b}	7.00^{bcd}	7.44^{bc}	6.12^{cd}	7.95^{b}	5.37^{d}	11.48^{a}	11.16^{a}

[a,b] Means within a row with different superscripts are significantly different ($P \leq 0.05$)
SHV = large difference between top and bottom beak lengths
STP = intermediate difference between top and bottom beak lengths
STAN = small difference between top and bottom beak lengths
C = sham untreated control
LB = Lohmann Brown
LW = Lohmann LSL-Lite

Table 2. 5. Effect of infrared beak treatments and strain on beak length ratio (upper:lower) of Experiment 1b Lohmann LSL-Lite and Lohmann Brown pullets housed in cages from 1 to 29 d and floor pens from 29 to 113 d of age.

Age (d)	Beak Treatment					Strain			Interaction	SEM
	SHV	STP	STAN	C	*P*-value	LB	LW	*P*-value	*P*-value	
1	-	-	-	-	-	-	-	-	-	-
29	1.03[c]	1.10[bc]	1.15[ab]	1.23[a]	<0.001	1.15	1.11	0.071	0.569	0.014
57	0.90[c]	0.99[b]	0.94[bc]	1.15[a]	<0.001	1.00	1.00	0.484	0.249	0.015
85	0.89[b]	0.94[b]	0.93[b]	1.14[a]	<0.001	1.00[a]	0.96[b]	0.031	0.033	0.015
113	0.87[b]	0.92[b]	0.96[b]	1.16[a]	<0.001	1.01[a]	0.95[b]	0.019	0.350	0.019

[a,b,c] Means within a main effect with different superscripts are significantly different ($P \leq 0.05$)

SHV = large difference between top and bottom beak lengths

STP = intermediate difference between top and bottom beak lengths

STAN = small difference between top and bottom beak lengths

C = sham untreated control

LB = Lohmann Brown

LW = Lohmann LSL-Lite

Table 2. 6. Effect of infrared beak treatments and strain on beak growth (mm) of Experiment 1b Lohmann LSL-Lite and Lohmann Brown pullets housed in cages from 1 to 29 d and floor pens from 29 to 113 d of age.

Age (d)	Beak Treatment					Strain			Interaction	SEM
	SHV	STP	STAN	C	*P*-value	LB	LW	*P*-value	*P*-value	
Top Beak										
1 – 113	7.72^{b}	6.81^{bc}	6.80^{c}	11.32^{a}	<0.001	8.83^{a}	7.57^{b}	<0.001	0.048	0.273
Bottom Beak										
29 – 113	6.50^{a}	5.56^{ab}	5.40^{ab}	4.95^{b}	0.032	5.77	5.38	0.284	0.728	0.191

^{a,b,c} Means within a main effect with different superscripts are significantly different ($P \leq 0.05$)

SHV = large difference between top and bottom beak lengths

STP = intermediate difference between top and bottom beak lengths

STAN = small difference between top and bottom beak lengths

C = sham untreated control

LB = Lohmann Brown

LW = Lohmann LSL-Lite

Table 2. 7. Effect of infrared beak treatments and strain on the production performance of Experiment 1a Lohmann LSL-Lite and Lohmann Brown pullets housed in cages from 1 to 29 d of age.

	Age (d)	Beak Treatment					Strain			Interaction	SEM
		SHV	STP	STAN	C	*P*-value	LB	LW	*P*-value	*P*-value	
Body weight, g	1	35.8	35.7	35.3	35.9	0.801	35.5	35.9	0.349	0.869	0.20
	15	133.3	129.8	131.7	138.2	0.219	128.4[b]	138.1[a]	0.002	0.913	1.63
	29	317.2	313.6	314.8	314.1	0.981	320.4	309.4	0.104	0.910	3.06
Feed intake, g/bird/d	1 – 15	13.4	13.0	13.2	14.3	0.501	12.9	14.1	0.062	0.364	0.33
	16 – 29	29.7	29.9	29.2	29.7	0.953	30.6[a]	28.6[b]	0.032	0.557	0.45
	1 – 29	21.5	21.5	21.2	22.0	0.753	21.7	21.4	0.446	0.574	0.24
Feed efficiency[1]	1 – 15	1.928	1.971	1.913	1.947	0.958	1.953	1.926	0.733	0.162	0.0385
	16 – 29	2.262	2.292	2.243	2.388	0.675	2.244	2.349	0.249	0.623	0.0430
	1 – 29	2.144	2.175	2.128	2.223	0.668	2.143	2.192	0.412	0.599	0.0275

[a,b] Means within a main effect with different superscripts are significantly different ($P \leq 0.05$)
[1]Feed-to-gain (g feed:g gain), corrected for mortality
SHV = large difference between top and bottom beak lengths
STP = intermediate difference between top and bottom beak lengths
STAN = small difference between top and bottom beak lengths
C = sham untreated control
LB = Lohmann Brown
LW = Lohmann LSL-Lite

Table 2. 8. Effect of infrared beak treatments, strain, and drinker type on the water disappearance (g/bird/d) of Experiment 1a Lohmann LSL-Lite and Lohmann Brown pullets housed in cages from 1 to 29 d of age.

Age (d)	Beak Treatment (T)					Strain (S)			Drinker (D)			Interactions (*P*-value)				SEM
	SHV	STP	STAN	C	*P*-value	LB	LW	*P*-value	Fount	Nipple	*P*-value	TxS	TxD	SxD	TxSxD	
1 – 8	16.60	16.06	16.04	20.76	0.148	16.39	18.34	0.238	16.48	18.24	0.286	0.743	0.387	0.445	0.708	0.801
9 – 16	26.52^{ab}	24.83^{b}	26.59^{ab}	31.91^{a}	0.035	25.64^{b}	29.29^{a}	0.037	28.57	26.35	0.186	0.631	0.700	0.982	0.605	0.903
17 – 22	43.04^{ab}	40.30^{b}	43.03^{ab}	47.51^{a}	0.025	41.97	44.97	0.059	46.67^{a}	40.27^{b}	<0.001	0.650	0.167	0.232	0.861	1.035
23 – 29	51.48^{ab}	49.76^{b}	50.24^{ab}	57.31^{a}	0.034	53.31	50.78	0.132	53.54	50.75	0.120	0.852	0.097	0.642	0.912	1.036
1 – 29	33.85^{ab}	32.74^{b}	33.97^{ab}	38.48^{a}	0.021	33.94	35.58	0.201	35.61	33.90	0.182	0.562	0.043	0.915	0.801	0.747

^{a,b} Means within a main effect with different superscripts are significantly different ($P \leq 0.05$)
SHV = large difference between top and bottom beak lengths
STP = intermediate difference between top and bottom beak lengths
STAN = small difference between top and bottom beak lengths
C = sham untreated control
LB = Lohmann Brown
LW = Lohmann LSL-Lite

Table 2. 9. Interaction between infrared beak treatments and drinker type for overall water disappearance (g/bird/d) from 1 to 29 d of age of Experiment 1a Lohmann LSL-Lite and Lohmann Brown pullets.

Drinker	Beak Treatment			
	SHV	STP	STAN	C
Fount	34.82^{ab}	35.21^{ab}	36.35^{ab}	36.09^{ab}
Nipple	32.88^{ab}	30.27^{b}	31.60^{b}	40.87^{a}

^{a,b} Means with different superscripts are significantly different ($P \leq 0.05$)
SHV = large difference between top and bottom beak lengths
STP = intermediate difference between top and bottom beak lengths
STAN = small difference between top and bottom beak lengths
C = sham untreated control

Table 2. 10. Effect of infrared beak treatments and strain on the pecking force per 100 g of body weight (N/100 g BW) of Experiment 1b Lohmann LSL-Lite and Lohmann Brown pullets housed in cages from 1 to 29 d and floor pens from 29 to 113 d of age.

Age	Beak Treatment					Strain			Interaction	SEM
(d)	SHV	STP	STAN	C	*P*-value	LB	LW	P-value	*P*-value	
4	14.1	14.8	16.9	15.1	0.791	16.1	14.2	0.254	0.936	0.67
11	12.7	14.2	14.2	11.5	0.094	15.8[a]	10.6[b]	<0.001	0.254	0.65
18	7.5	6.9	8.3	7.4	0.500	8.3[a]	6.8[b]	0.025	0.385	0.33
25	7.2	7.9	8.0	7.2	0.143	8.1[a]	7.0[b]	<0.001	0.188	0.18
53	3.3	3.1	3.4	3.2	0.392	3.0[b]	3.5[a]	0.012	0.190	0.09
81	3.1	2.9	3.2	3.9	0.138	3.0	3.6	0.078	0.692	0.16
109	3.0	2.5	3.0	2.8	0.268	2.6[b]	3.1[a]	0.005	0.501	0.10

[a, b] Means within a main effect with different superscripts are significantly different ($P \leq 0.05$)
SHV = large difference between top and bottom beak lengths
STP = intermediate difference between top and bottom beak lengths
STAN = small difference between top and bottom beak lengths
C = sham untreated control
LB = Lohmann Brown
LW = Lohmann LSL-Lite

Table 2. 11. Effect of infrared beak treatments and strain on the behaviour (% of time) of Experiment 1c Lohmann LSL-Lite and Lohmann Brown pullets over an 8-h period from 10 to 28 d of age.

Behaviour	Beak Treatment					Strain			Interaction	SEM
	SHV	STP	STAN	C	*P*-value	LB	LW	*P*-value	*P*-value	
Nutritive	23.05	24.50	22.55	27.96	0.111	22.36	26.67	0.234	0.313	0.964
Active	41.37^{ab}	40.62^{ab}	41.70^{a}	36.46^{b}	0.037	41.80^{a}	38.27^{b}	0.003	0.319	0.994
Rest	10.31	10.89	10.06	10.49	0.962	11.03^{a}	9.85^{b}	0.035	0.645	0.442
Preen	6.82	7.24	6.74	7.31	0.773	6.76	7.30	0.942	0.551	0.265
Comfort	0.86	0.76	0.70	1.01	0.307	0.81	0.85	0.966	0.323	0.058
Exploratory	3.23	3.55	4.79	4.19	0.645	2.45^{b}	5.43^{a}	0.004	0.757	0.521
Aggression	0.03	0.00	0.03	0.03	0.415	0.02	0.02	0.658	0.185	0.009
Low incidence	14.33	12.44	13.43	12.56	0.648	14.76^{a}	11.61^{b}	0.013	0.853	0.582

$^{a, b}$ Means within a main effect with different superscripts are significantly different ($P \leq 0.05$)

SHV = large difference between top and bottom beak lengths

STP = intermediate difference between top and bottom beak lengths

STAN = small difference between top and bottom beak lengths

C = sham untreated control

LB = Lohmann Brown

LW = Lohmann LSL-Lite

Nutritive = time at feeder + time at drinker

Active = standing + walking

Rest = resting

Preen = preening

Comfort = dustbathing + feather ruffling + leg stretching + wing stretching

Exploratory = gentle pecking + object pecking

Aggression = aggressive pecking

Low incidence = perching + head shaking + head scratching + beak wiping + wing flapping + unknown

Table 2. 12. Effect of infrared beak treatments, strain, and drinker type on the total mortality, infectious mortality, and non-infectious mortality (as a % of birds placed) of Experiment 1 Lohmann LSL-Lite and Lohmann Brown pullets from 1 to 29 d of age.

	Exp	Beak Treatment (T)					Strain (S)			Drinker (D)			Interactions (*P*-value)				SEM
		SHV	STP	STAN	C	*P*-value	LB	LW	*P*-value	Fount	Nipple	*P*-value	TxS	TxD	SxD	TxSxD	
Total mortality	1a	0.00	5.71	0.00	0.00	0.488	2.50	0.00	0.342	0.00	2.50	0.342	0.488	0.488	0.342	0.488	1.250
	1b	10.00	5.00	10.00	0.00	0.678	2.50	10.00	0.290	-	-	-	0.678	-	-	-	3.010
	1c	0.00	0.00	10.00	10.00	0.330	0.00	10.00	0.081	-	-	-	0.330				2.887
Infectious mortality[1]	1a	0.00	2.86	0.00	0.00	0.488	1.25	0.00	0.342	0.00	1.25	0.342	0.488	0.488	0.342	0.488	0.625
	1b	5.00	5.00	5.00	0.00	0.802	0.00	7.50	0.122	-	-	-	0.802	-	-	-	2.016
	1c	0.00	0.00	5.00	5.00	0.596	0.00	5.00	0.195	-	-	-	0.596	-	-	-	1.708
Non-infectious mortality[2]	1a	0.00	2.86	0.00	0.00	0.488	1.25	0.00	0.342	0.00	1.25	0.342	0.488	0.488	0.342	0.488	0.625
	1b	5.00	0.00	5.00	0.00	0.596	2.50	2.50	1.000	-	-	-	0.330	-	-	-	1.708
	1c	0.00	0.00	5.00	5.00	0.596	0.00	5.00	0.195	-	-	-	0.596	-	-	-	1.708

[a,b] Means within a main effect with different superscripts are significantly different ($P \leq 0.05$)

[1]Infectious mortality = yolk sac infection, pericarditis, enteritis

[2]Non-infectious mortality = dehydration, runt

SHV = large difference between top and bottom beak lengths

STP = intermediate difference between top and bottom beak lengths

STAN = small difference between top and bottom beak lengths

C = sham untreated control

LB = Lohmann Brown

LW = Lohmann LSL-Lite

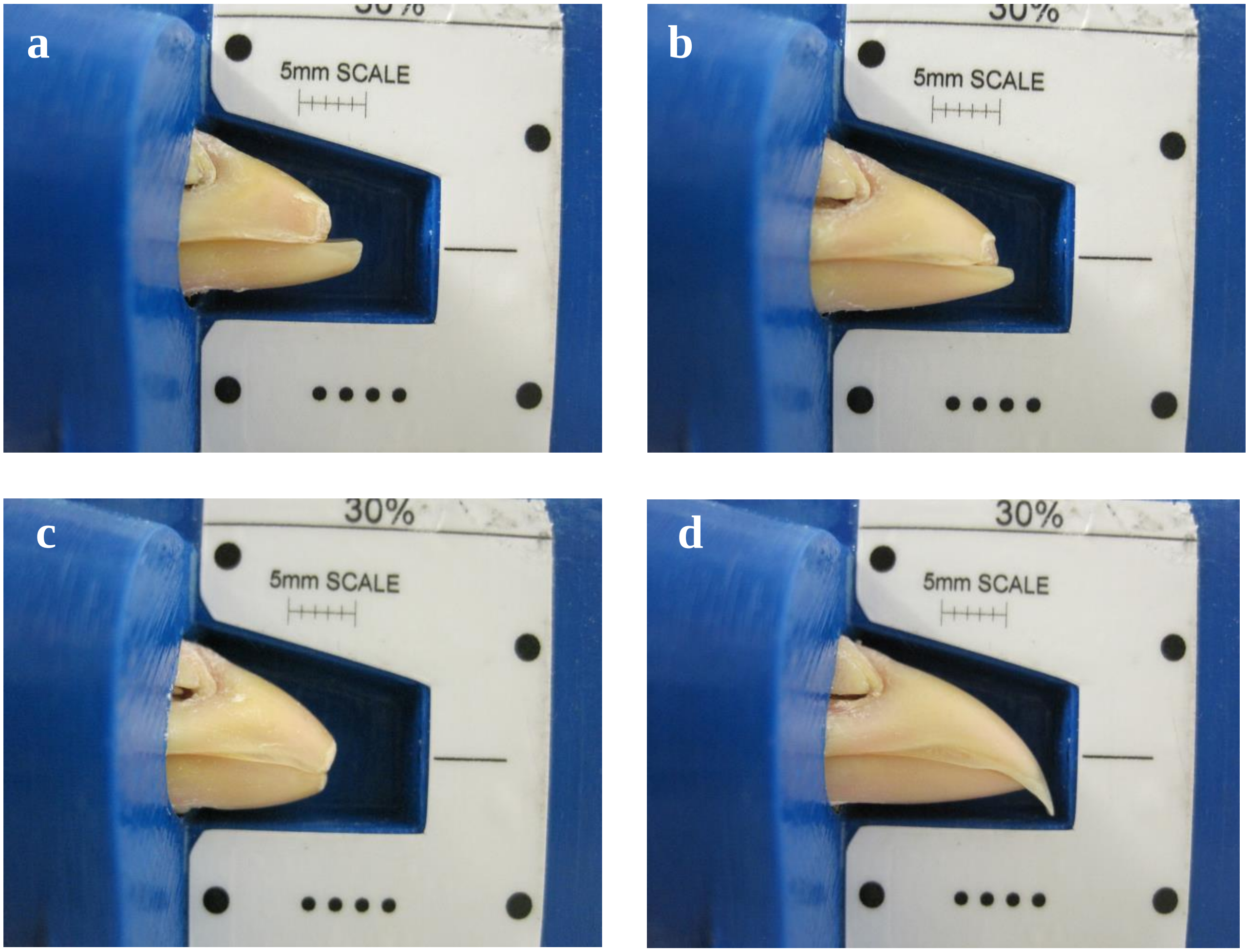

Figure 2. 1. The 4 beak shapes created for the present study: a) shovel beak, b) step beak, c) standard beak, and d) sham untreated control.

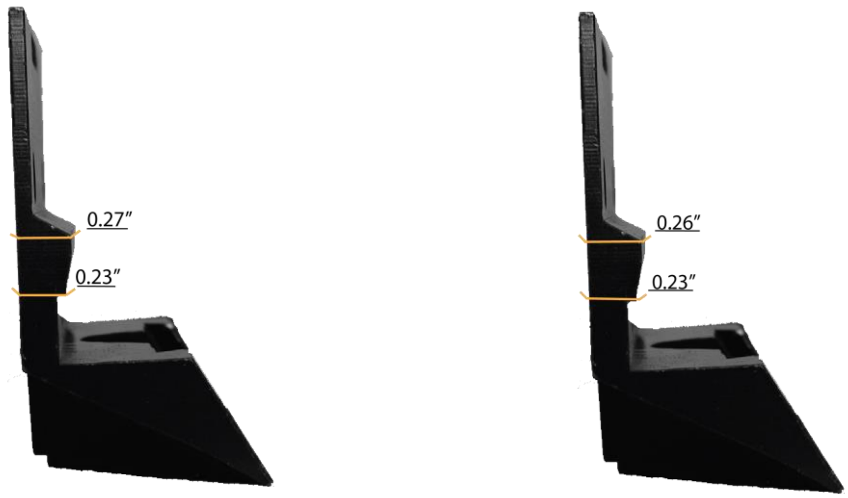

Figure 2. 2. Guard-plates used to create specific IRBT treatments. The 27/23C guard-plate (L) was used for the LB strain and the 26/23 guard-plate (R) was used for the LW strain.

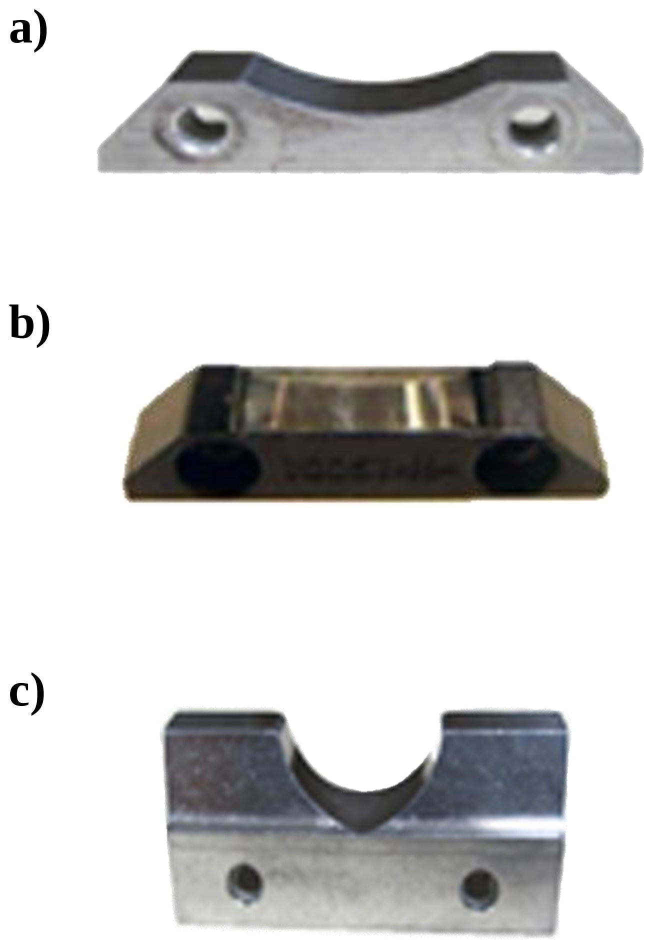

Figure 2. 3. Mirrors used to create different IRBT treatments: a) 3605b mirror was used to create the STP beak in the LB strain, b) curve glass mirror was used to create the STP beak in the LW strain and the STAN beak in the LB strain, and c) mid-wrap mirror was used to create STAN beak in the LW strain.

Figure 2. 4. Drinker types used for Experiment 1a (Production). Bird were given access to water using either a fount drinker (L) or a 360° nipple drinker (R).

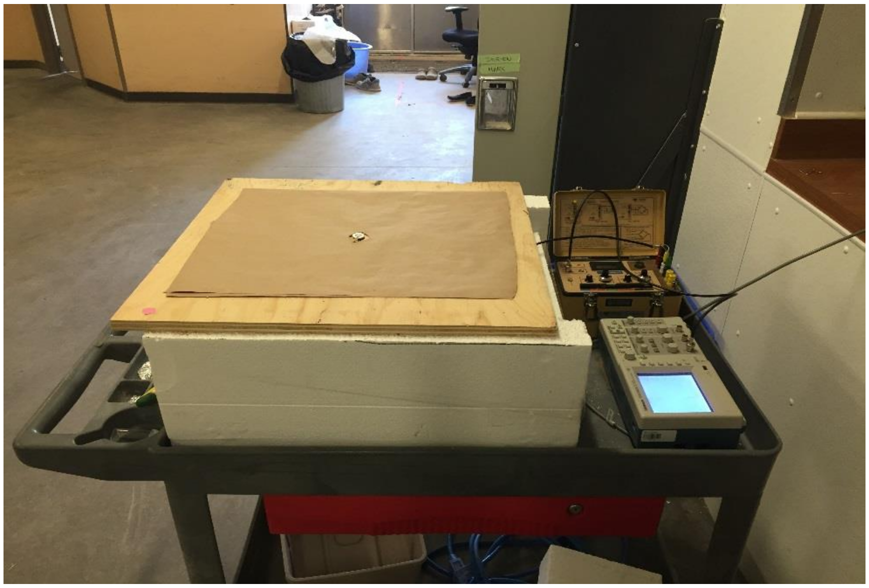

Figure 2. 5. Force plate apparatus. Force plate is located in the middle of the wood platform. Transducer is located underneath the wood platform.

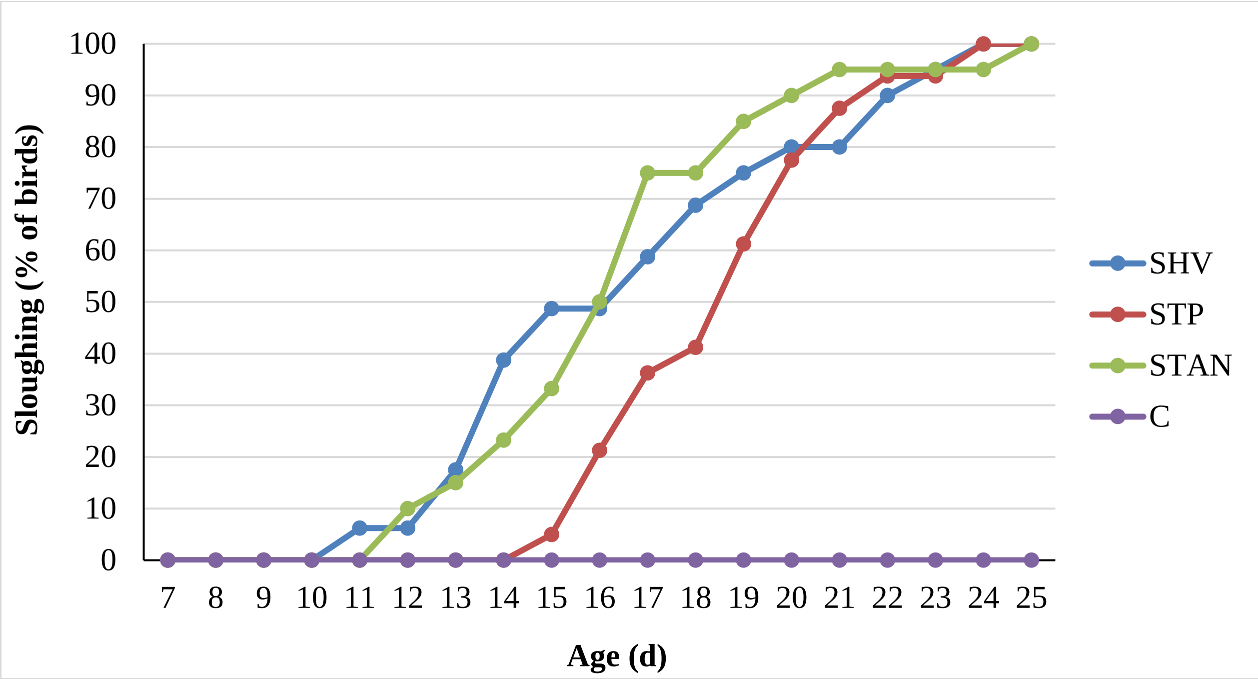

Figure 2. 6. Effect of infrared beak treatments on beak sloughing expressed as a percent of birds showing complete sloughing (top and bottom beak).

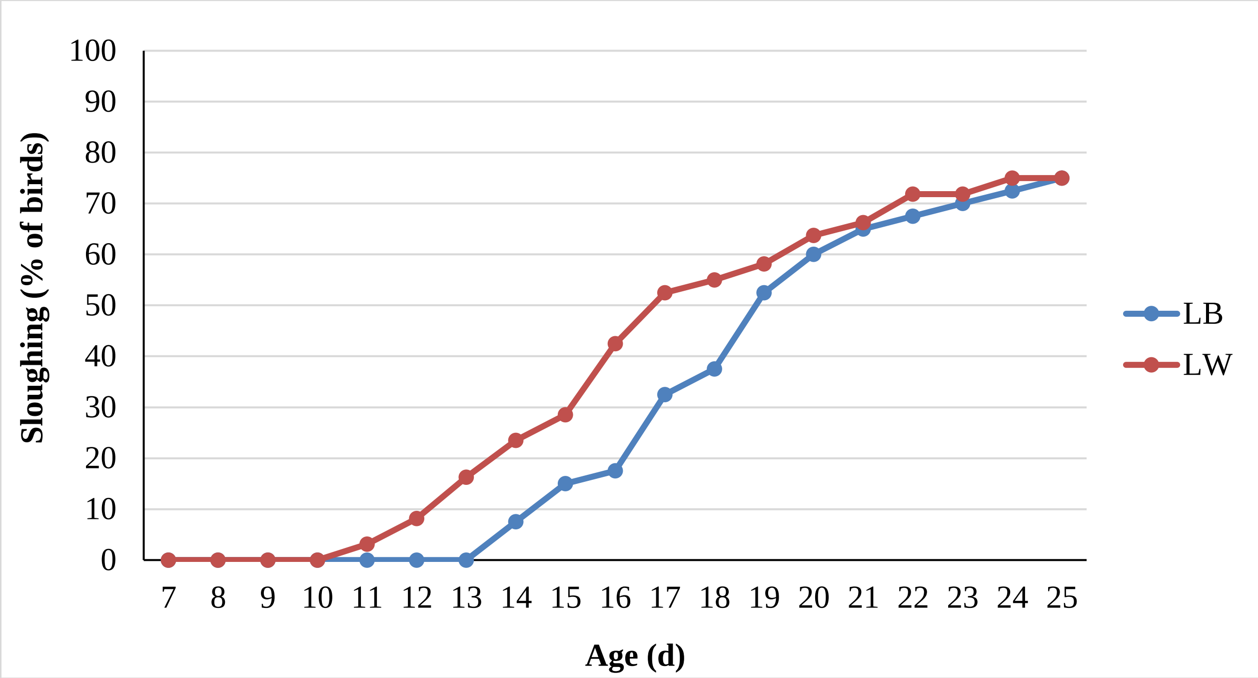

Figure 2. 7. Effect of strain on beak sloughing expressed as a percent of birds showing complete sloughing (top and bottom beak).

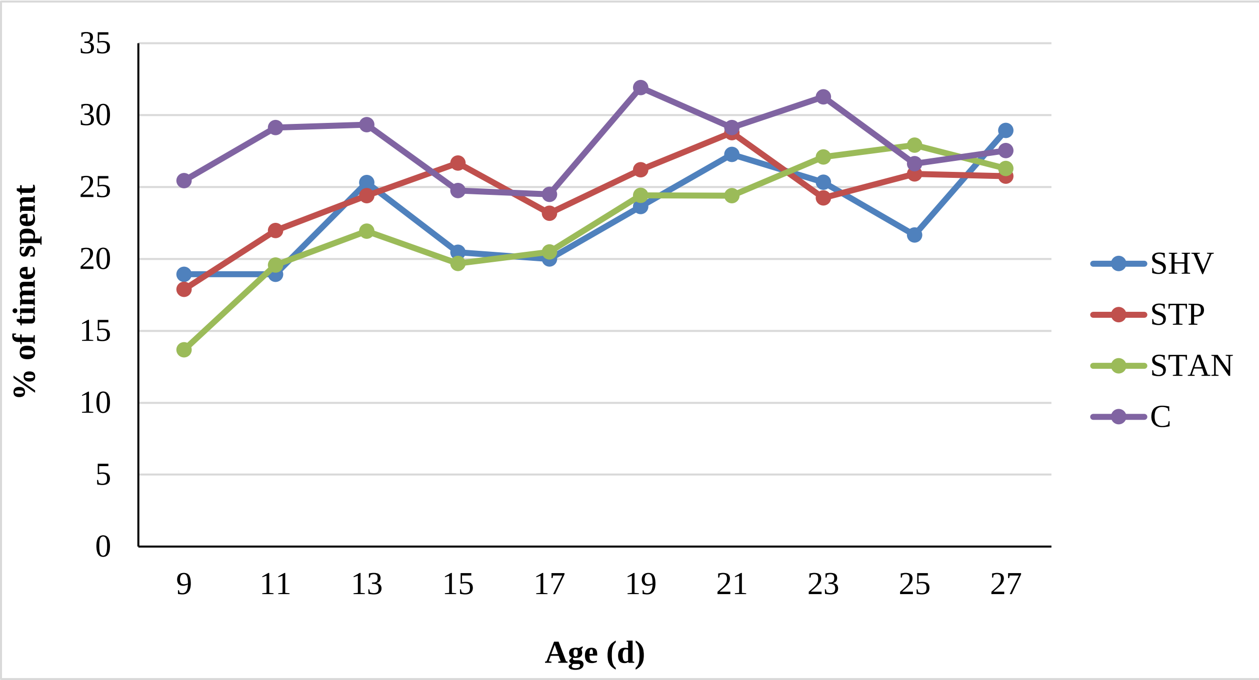

Figure 2. 8. Effect of infrared beak treatments on nutritive behaviours (percent of time spent at feeder and drinker) of Lohmann LSL-Lite and Lohmann Brown pullets during period of beak sloughing (11 to 25 d).

3.0 Chapter 3: Effects of infrared beak treatment on the production, behaviour, and welfare of Lohmann LSL-Lite and Lohmann Brown pullets and hens housed in floor pens from 1 day to 18 weeks of age and conventional cages from 18 to 60 weeks of age

Chapter 3 focuses on the effects of specific beak shapes, either created using different infrared beak treatment settings or left untreated, during the rearing and laying periods of egg production birds with a specific focus on body weight and behaviour during the rearing period and productivity, behaviour, and welfare during the laying period. Productivity indicators included feed intake, feed efficiency, body weight, egg production, and egg quality. Welfare indicators included feather cover, comb damage, and mortality rate and cause. The data presented in this chapter, in conjunction with that reported in Chapter 2, can aid in providing a comprehensive understanding of the effects of infrared beak treatment during the entire life cycle of layer pullets and hens.

3.1 Abstract

The impact of different infrared beak treatments (IRBT) and the subsequent changes in beak shape on production, behaviour, and mortality was examined using Lohmann LSL-Lite (LW) and Lohmann Brown pullets (LB), in a 4x2 factorial arrangement of IRBT and bird strain (18 to 42 wk of age) and a one-way ANOVA (42 to 60 wk of age), in a randomized complete block design. Four specific beak shapes were created by altering IRBT settings: shovel (SHV), step (STP), standard (STAN), and an untreated sham control (C). Birds were treated on day of hatch. Pullets (n=640) were housed in 1 of 2 rooms (block), which were separated into floor pens (n=8 per room, 40 birds per pen) from 1 d to 18 wk of age. Pullet body weight (BW) was collected on a pen basis at 1 d, 4, 8, 12, and 16 wk. Pullet behaviour was recorded in all pens for 24 continuous h at 5, 9, 13, and 17 wk of age using infrared video cameras, then analyzed using scan sampling at 15 min intervals. Mortality was recorded daily. At 18 wk, birds (n=576) were transferred to layer barn and housed in conventional cages (n=48, 12 birds per 2 cages) from 18 to 60 wk of age. Hen BW was measured at 18, 42, and 60 wk. Feed intake (FI) and egg quality (EQ) were measured every 4 wk from 22 to 60 wk. Egg production (EP) was recorded 5 d per wk. Behaviour was recorded in 24 cages for 24 h at 23 and 39 wk using infrared video cameras, then analyzed using scan sampling at 15 min intervals. Hens were scored for feather cover and comb damage at 18, 42, and 60 wk. Mortality was recorded daily. All LB hens were removed from trial at 42 wk of age due to cannibalism in C hens. Data were analyzed using Proc Mixed of SAS® 9.4 with Tukey's range test to separate means. Differences were significant when $P \leq 0.05$. STAN pullets were lighter than C pullets at 4 wk with no differences in BW noted after this age. Strain affected pullet BW from 4 to 16 wk and hen BW at 42 wk, with LB being heavier than LW. At 18 wk, an IRBT x strain interaction existed for hen BW with LB hens being heavier than LW in all treatments. During the laying period, the IRBT treatments and strain did not affect FI or EP. IRBT treatment had an effect on unsaleable eggs (UE), as C hens laid a higher percentage of UE compared to SHV and STP hens. There was no effect of IRBT treatment on EQ. Strain affected EQ with LB hens having better specific gravity. Beak treatment impacts on behaviour were minor during both the rearing and laying periods. At 5 wk, C pullets spent more time exploratory pecking than STP and STAN pullets. At 23 wk, SHV and STP hens preened more than C hens. During both periods, LW hens preened and rested more but were less active than LB. All of the IRBT treatments significantly improved feather cover and reduced comb damage as compared to C hens. During the laying period, LB C hens had higher mortality due to cannibalism in comparison to treated birds of both strains. Overall, the results indicate that the different IRBT treatments and subsequent beak shapes may have minor effects on BW and behaviour during early life, but as birds reach sexual maturity, these effects are no longer apparent. The results also suggest that IRBT can positively impact bird welfare by reducing feather loss, comb damage, and mortality from cannibalism.

Keywords: beak shape, laying hen, feather cover, cannibalism, egg quality

3.2 Introduction

Animal welfare is becomingly increasingly more important to consumers and in response to this, many countries have banned or are in the process of banning the practice of beak treatment as it is considered by some to be a mutilation (FAWC, 2007). The banning of beak treatment in egg production birds is a concern, from both an animal welfare and economic viewpoint as beak treatment remains one of the most effective methods of reducing and controlling injurious feather pecking and cannibalism in egg production birds. Infrared beak treatment (IRBT) is currently 1 of the main methods of beak treatment used in commercial egg production. The technique was developed by Nova-Tech Engineering LLC and differs from the older forms of beak treatment, such as hot-blade trimming (HBT), because it does not physically cut the beak tissue (Glatz, 2005). Day of hatch chicks are placed into head-holding fixtures on the Poultry Service Processor (PSP) and their beak tips are exposed to an infrared light (Glatz, 2005). The infrared light penetrates through the keratinised outer layer of the beak (rhamphotheca) and damages the underlying tissue thereby reducing the production of keratin proteins in these tissues and preventing the reformation of the sharp tip of the beak (Glatz, 2005; Lunam, 2005). Immediately after treatment, the rhamphotheca remains intact and after a period of 1 to 2 wk, the treated tissue softens and sloughs off, leaving the bird with a shorter, blunter beak that does not have the characteristic "hook" shape that is seen in untreated birds. This period allows the tissue surrounding the healthy remaining tissue to heal, leaving no open wound, thereby reducing the risk of infection and inflammation (Marchant-Forde et al., 2008).

Beak treatment is a controversial but important aspect of laying hen management. Most previous studies report an initial reduction in the feed intake and growth of egg production birds following IRBT (Honaker and Ruszler, 2004; Marchant-Forde et al., 2008; Marchant-Forde and Cheng, 2010; Damme and Urselmans, 2013); however these reductions are short-lived and disappear by 4 wk post-treatment. IRBT may also change bird behaviour during the rearing period, particularly for feeding, drinking, and standing behaviours. Marchant-Forde et al. (2008) reported that birds treated using IRBT spent less time feeding and drinking but more time standing inactive and resting as compared to birds with intact beaks; however, differences in these behaviours were not seen between IRBT treated and untreated birds to 28 d of age in more recent work (Struthers, Chapter 2). Similar to the effects of IRBT on production, the effects on behaviour are short-lived and disappear by 1 wk post-treatment (Marchant-Forde et al., 2008). As birds reach sexual maturity, the effects of IRBT on production parameters and behaviour are no longer apparent. IRBT does not negatively affect egg production or hen body weight (Dennis et al., 2009). In some studies, IRBT treated hens had higher egg production per hen housed as compared to intact control hens (Damme and Urselmans, 2013), required less feed per kg egg mass as compared to intact control birds (Damme and Urselmans, 2013), and had fewer production days lost due to mortality, resulting in less economic loss and higher profit per hen housed (Damme and Urselmans, 2013).

Despite IRBT becoming the predominant method of beak treatment in North America, research interpretation often links IRBT results to HBT results, despite evidence that impacts differ by method. Previous research indicates that IRBT represents a more welfare-friendly method of beak treatment as compared to more traditional methods and therefore offers producers another tool to help improve welfare and economics. However, to date few comprehensive studies on the impact of IRBT throughout the entire life cycle of egg production birds have been conducted. There is also a lack of understanding of how variations in beak shape post-IRBT affect egg production birds throughout the rearing and laying periods. Post-hatch, layer chicks are commonly infrared beak treated using a standard treatment setting or configuration, which results in a flush or symmetrical beak shape (top and bottom beak lengths are approximately equal). However, if there is improper treatment application or tissue growth, variations in beak shape can occur. Two of the more prevalent variations are the shovel and step beak shape, which are characterized by an elongation of the lower beak.

Currently, there is concern from some within the poultry industry that any variation from the standard beak shape that is created by IRBT is a welfare concern (Kajlich et al., 2016). In fact, The Welfare Quality Assessment Protocol for Poultry (2009) suggests that any beak shape beyond a flush or symmetrical one could be considered “abnormal”. Marchant-Forde et al. (2008) suggested that the upper and lower beak lengths should resemble those of untreated beaks post-IRBT, in which the upper beak is slightly longer than the bottom. However, despite these statements, very little scientific data has been published supporting why and how these shovel and/or step beak shapes negatively impact bird welfare. There are also very few studies conducted on IRBT that have used both brown and white layer strains within the same study. Industry feedback suggests that bird strains may react differently to IRBT, which makes using different strains concurrently an important aspect of understanding IRBT.

Therefore, the objectives of this research were to:

1. Intentionally create 3 beak shapes by altering IRBT treatment settings. Two of these beaks shapes (SHV and STP) would represent variations from the third beak shape (STAN).
2. Compare the 3 beaks shapes created by IRBT to an untreated, control beak shape.
3. Examine how the 4 beak shapes affects the productivity, behaviour, and mortality of LW and LB pullets reared in floor pens from 1 d to 18 wk of age and hens housed in conventional cages from 18 to 60 wk of age.

This was conducted in 2 experiments. Data measured included the body weight, behaviour, and mortality of LW and LB pullets. For Experiment 2a, it was hypothesized that during the rearing period, the beak shapes created by IRBT:

1. Would cause a reduction in body weight as compared to untreated controls, but only until 4 wk of age. This is because it has been shown that any negative effects of IRBT on body weight typically disappear by 4 wk post-treatment.
2. Would cause minor changes in behaviour relative to control birds, with these effects being transient and inconsistent across all ages. Any negative effects of IRBT on behaviour typically disappear by 1 wk post-treatment and since the behaviour analysis for this experiment did not start until 5 wk of age, minor differences were expected.

The second experiment (Experiment 2b) examined the effects of the different IRBT treatments (beak shapes) in addition to sham treated controls and bird strain on the productivity, behaviour, and welfare indicators of LW and LB hens. Production characteristics included body weight, feed intake, feed efficiency, egg production, and egg quality. Welfare indicators included behaviour, feather cover, comb damage, mortality, and cause of mortality. For Experiment 2b, it was hypothesized that during the laying period, the beak shapes created by IRBT as compared to untreated controls:

1. Would not negatively affect the production or behaviour of LW and LB hens. This is because as birds reach sexual maturity, the negative effects on production or behaviour sometimes seen during the rearing period are no longer apparent.
2. Would result in better feather cover and less comb damage. This is because birds with treated beaks are not able to inflict as much damage towards the plumage and combs of conspecifics.
3. Would effectively reduce mortality due to cannibalism. Again, this is because birds with treated beaks are not able to inflict as much damage.

3.3 Materials and Methods

3.3.1 Experimental design

The experimental protocol for this experiment was approved by the University of Saskatchewan Animal Research Ethics Board and all birds were cared for as specified in the Guide to the Care and Use of Experimental Animals by the Canadian Council of Animal Care (1993, 2009). One 18 wk experiment (Experiment 2a) was conducted from April to August 2016 to examine the effects of IRBT treatments and bird strain on the body weight, behaviour, and mortality of Lohmann LSL-Lite (LW) and Lohmann Brown (LB) pullets housed in floor pens. This experiment extended into a second 42 wk experiment (Experiment 2b), which was conducted from August 2016 to June 2017 to examine the effects of IRBT treatments and bird strain on the production performance, behaviour, feather cover, and mortality of LW and LB hens housed in conventional cages.

3.3.2 Beak treatments

Newly hatched LW (n=320) and LB (n=320) female pullets were randomly assigned to 1 of the 4 beak treatments (n=80 birds per strain per treatment). Four specific beak shapes were used in this study. Infrared beak treatment settings (guard-plate, mirror design, and infrared intensity) were adjusted to create 3 of these beak shapes: shovel (SHV), step (STP), and standard (STAN) (Figures 2.1-2.3; Table 2.1). The fourth shape was a sham untreated control (C) (Figure 2.1; Table

2.1). All treatments were applied post-hatch on April 18, 2016 using the PSP (Nova-Tech Engineering LLC, Willmar, MN, USA) at Clark’s Poultry Inc. (Brandon, MB) prior to the pullets being transported to and housed at the University of Saskatchewan Poultry Centre on April 19, 2016. Pullets in the control treatment were handled and loaded onto the PSP to mimic conditions experienced by the IRBT treated pullets; however, their beak tips were not exposed to the infrared light.

Definitions for each beak shape created by IRBT were established based on the differences in length between the top and bottom beaks. A shovel beak was defined as a large difference in length between the top and bottom beak, with a severe elongation of the bottom beak relative to the top. A step beak was defined as an intermediate difference in length between the top and bottom beak, with a slight elongation of the bottom beak relative to the top. Finally, a standard beak was defined as a small difference in length between the top and bottom beak, with the top and bottom beaks being flush.

3.3.3 Animal housing and husbandry

All pullets had *ad libitum* access to water and nutritionally balanced (met or exceeded Lohmann Tierzucht, 2016a,b specifications) commercial chick starter (crumble, 1 d – 6 wk), grower (crumble, 6 – 10 wk), developer (crumble, 10 – 16 wk), pre-lay (crumble, 16 – 18 wk), and layer diets (crumble, 18 – 60 wk). During the rearing period, feed, medicated with Amprolium (coccidiostat), was provided via aluminum tube feeders with a diameter of 36 cm for the first 5 wk and a diameter of 44 cm for the remaining time. Cardboard egg trays (1 tray per pen) were used as supplemental feeders for the first 7 d. Water was provided using Lubing EasyLine^{TM} nipple drinkers (6 360° nipples per pen; nipple 4078) (Lubing, Cleveland, TN). Supplemental water was provided in ice cube trays (1 tray per pen) for the first 7 d. During the laying period, feed was provided via metal front trough feeders and water was provided using Lubing EasyLine^{TM} nipple drinkers (1 360° nipple per cage; nipple 4077).

All pullets were vaccinated at the hatchery for Marek’s disease (Marek’s Rispens, HVT-IBD) immediately post-hatch. At 2 wk of age, pullets were vaccinated with a Newcastle Bronchitis B1 type, B1 strain, Mass and Conn type live virus Combo-Vac 30 vaccine (serial # 02030024) that was administered by coarse spray. At 6 and 10 wk, birds were vaccinated with the same Newcastle

Bronchitis B1 type, B1 strain, Mass and Conn type live virus Combo-Vac 30 vaccine. At 16 wk of age, pullets were vaccinated with a Newcastle Bronchitis vaccine, Mass type, killed virus, *Salmonella enteriditis* Bacterium vaccine (serial # 01260019) that was administered by intramuscular injection.

Experiment 2a. Pullets were housed in floor pens (n=16, 2.4 m x 2.0 m) with 40 pullets per pen within 2 environmentally controlled rooms at the University of Saskatchewan Poultry Centre. The lighting program was 23L:1D at 20 lux for the first 7 d and then 8L:16D at 10 lux from d 8 onwards using incandescent light bulbs as the light source. Dawn and dusk periods were simulated by gradually increasing and decreasing the light intensity over a 15-minute period. Room temperature started at 32°C at 1 d and decreased to 29°C by 7 d. After 7 d, temperature decreased by 2.0°C every wk to reach a temperature of 21°C at 5 wk of age, which was maintained for the remainder of the experiment. Heat was provided by hot water pipes running along the walls of the rooms and monitored via thermometer.

Experiment 2b. At 18 wk of age, pullets (n=576) were transferred to the laying facility at the University of Saskatchewan Poultry Centre. In the layer barn, birds were housed in conventional cages (n=48; 60.0 cm wide x 49.0 cm deep; height 43.2 cm at front and 39.4 cm at back) with 12 birds housed in 2 cages for each replication. Bird density was 489 cm^2 per bird, within the minimum requirements set by the National Farm Animal Care Council Codes of Practice for the Care and Handling of Pullets and Laying Hens (432 cm^2 for white layers and 484 cm^2 for brown layers) (NFACC, 2016b). Light was provided by incandescent bulbs and was kept at 14L:10D at 10 lux from 18 wk of age onward with the same dawn and dusk periods as during the rearing period. Heat was provided by hot water pipes running along the walls of the barn and barn temperature was maintained at approximately 20°C.

3.3.4 Data collection

Body weight. Pullets were weighed on a pen basis at 1 d, 4, 8, 12, and 16 wk of age. All LB and LW hens were weighed on an individual bird basis at the start (18 wk of age); and middle (42 wk of age) of the laying period. Because of cannibalism occurring in the LB C hens, all LB hens were removed from the trial at 42 wk of age. LW hens were also weighed at 60 wk of age. Average body weight on a cage basis was calculated from the individual body weights.

Feed intake. Feed intake was not measured during the rearing period, but was measured every 4 wk from 22 to 60 wk of age during the laying period.

Egg production and quality. Egg production was recorded on a cage basis 5 d per wk from 18 until 60 wk of age. Double yolk, soft-shell, cracked, and abnormal eggs were identified and recorded at the time of collection. Egg quality (egg weight and shell density, as measured by specific gravity) was measured every 4 wk, starting at 21 wk of age. All eggs from one day's production were individually marked for treatment and replication identification, weighed, and their specific gravity recorded using the saline water baths and floatation method described by Holder and Bradford (1979). The saline water baths ranged from 1.060 to 1.100 and increased in increments of 0.005.

Behaviour. During the rearing period, pullet behaviour was recorded in all pens for 24 continuous hours at 5, 9, 13, and 17 wk of age. Ceiling-mounted infrared video camera systems (Panasonic WV-CF224FX; Panasonic Corporation of North America, One Panasonic Way 7D-4, Secaucus, NJ, USA) captured the entire pen, and recorded to a computer system in continuous real-time mode. Nutritive, comfort, active, resting, exploratory, and aggressive behaviours described in Table 2.3 were evaluated using scan sampling at 15-minute intervals.

During the laying period, hen behaviour was recorded using 3 replicates per IRBT x strain for 24 continuous hours at 23 and 39 of age. Behaviour was recorded using tripod-mounted infrared video cameras (Panasonic WV-CF224FX; Panasonic Corporation of North America, One Panasonic Way 7D-4, Secaucus, NJ, USA) placed in front of the cages which captured the entire 2 cages (1 replicate). The cameras recorded to a computer system in continuous real-time mode. The percent of time spent performing nutritive, active, resting, preening, comfort, exploratory, and aggressive behaviours described in Table 2.2 was evaluated using scan sampling at 15-minute intervals.

Feather cover and comb damage. Hens were individually scored for feather cover and comb damage at the start (18 wk of age) and middle (42 wk of age) of the laying period by the 2 same independently working individuals. Because of the removal of LB hens from the trial at 42 wk of age, only LW hens were feather and comb scored at the end (60 wk of age) of the laying period. Each bird was scored for 5 areas, including the neck, back, breast, wings, and tail. These areas were given a score ranging from 1 (no feather cover) to 4 (full plumage) using a scale adapted from Davami et al. (1987) and Sarica et al. (2008) as described in Table 3.1. Combs were given a score ranging from 0 (no damage) to 4 (extensive damage) using a scale adapted from Ali and Cheng (1985) as described in Table 3.1. Feather cover and comb damage scores were calculated as an average of the scores given by each individual scorer for statistical analyses.

Mortality and cause of mortality. Birds were monitored daily for mortality or morbidity and were humanely euthanized using manual cervical dislocation when culling was necessary. All found-dead and euthanized birds were recorded, weighed, and submitted for necropsy to determine cause of death to Prairie Diagnostic Services (PDS), University of Saskatchewan. Mortality was categorized according to cannibalism, metabolic, infectious, skeletal, mechanical, other, and unknown causes.

Once in the laying period, any hen that was being actively pecked as evident by the presence of blood and/or minor tissue damage was removed from the trial and placed into a non-experimental cage to recuperate. At 42 wk of age, all LB hens were removed from the experiment due to high mortality from cannibalism and injurious pecking. At this time, an unexpected power outage occurred in the barn causing a number of LW and LB hens to be found with broken wings during data collection. These birds were humanely euthanized using manual cervical dislocation. Because LB hens were no longer part of the trial when the power outage occurred, only LW mortality was included in statistical analyses.

3.3.5 Statistical analyses

The experimental design and arrangement for Experiment 2a (1 d t o18 wk of age) and Experiment 2b (18 to 42 wk of age) was a 4x2 factorial arrangement of IRBT and bird strain, in a randomized complete block design with 2 (pullets) or 6 (hens) replicates per IRBT x strain and blocked by either room (pullets) or row (hens). After LB hens were taken off trial at 42 wk of age, Experiment 2b was a one-way analysis of variance, in a randomized complete block design with

6 replicates per IRBT x strain and blocked by row. Data were analyzed using Proc Mixed (pen as replicate unit for pullets and 2 cages as replicate unit for hens) (SAS® 9.4, Cary, NC) with Tukey's range test to separate means. Percentage data was checked for normality using Proc UNIVARIATE (SAS® 9.4, Cary, NC) and log transformed (data log + 1) when necessary. Differences were considered significant when $P \leq 0.05$ and a trend was noted when $0.05 < P \leq 0.10$.

3.4 Results

3.4.1 Experiment 2a - Pullets

Body weight. The IRBT treatments had little effect on body weight, with a significant difference only noted at 4 wk of age. Even at this age, only one beak shape, the STAN shaped beak, resulted in lower body weight than noted in C pullets (0.295 vs. 0.303 kg, respectively) (Table 3.2). This trend continued with body weight at 8 wk of age (P=0.085). The strains also demonstrated differences in body weight with LB pullets being heavier than LW from 4 to 16 wk of age (Table 3.2).

Behaviour. IRBT treatment did not impact behaviour at any age during brooding and rearing, with the exception of exploratory behaviour at 5 wk of age (Table 3.3). At this time, C pullets spent a greater percent of time exploring their environment as compared to pullets in the STP and STAN treatments (8.13 vs. 6.62 and 6.55 %, respectively).

Strains in general presented a slightly different behavioural profile (Table 3.3). For example, differences in the activity of pullets were noted, with LB pullets spending a greater percentage of time in active behaviours at 5, 9, and 17 wk of age as compared to LW. Expression of low incidence behaviours (perching, head shaking, head scratching, beak wiping, wing flapping, and unknown) also differed between the 2 strains at multiple ages with LW pullets spending a greater percentage of time performing these behaviours than LB pullets.

At 5 wk of age, an interaction occurred, as IRBT treatments affected how each strain responded with respect to the percent of time spent performing low incidence behaviours (perching, head shaking, head scratching, beak wiping, wing flapping, and unknown). LW STAN birds performed these behaviours more than LB regardless of treatment and more than LW SHV and LW C birds (Table 3.4).

Mortality and cause of mortality. The use of IRBT, or the beak shapes that resulted from altering IRBT settings, had no impact on mortality levels during the rearing period. Strain also did not affect mortality levels, although there was a trend for LW pullets to have higher mortality than LB from 1 d to 4 wk of age (*P*=0.053) (Table 3.5). When mortality levels were analyzed by cause, there was no effect of the IRBT treatments; however, LW pullets had higher mortality from yolk sac infections as compared to LB during the rearing period (Table 3.6).

3.4.2 Experiment 2b – Hens

Production parameters. The use of IRBT to create various beak shapes as compared to maintaining untreated beaks did not affect hen body weight during the late laying period (42 to 60 wk of age) (Table 3. 7). Body weight was only affected by strain at 42 wk of age, with LB hens being heavier (Table 3.7). The 2 strains reacted differently with regards to body weight to IRBT treatment at 18 wk of age (Table 3.8). At this time (placement in the laying facility) within the LB strain, C hens were numerically lighter than hens with SHV, STP, or STAN beak shapes; however, within the LW strain, C hens were numerically heavier than the IRBT treated hens. Comparison between the strains shows that LB hens were significantly heavier than LW hens, regardless of whether hens were beak treated or not.

During the early to mid-laying period (18 to 42 wk of age), shortening the beak to any degree using IRBT, as compared to a natural, untreated beak shape, did not affect the amount of feed hens consumed, the total feed per egg mass (TFEM), or the total feed per dozen eggs (TFDE) (Table 3.7). Strain did have an effect on hen feed intake or TFEM during this time with LB hens having higher feed intake compared to LW. Similarly, from 42 to 60 wk of age there was no effect of IRBT and the subsequent beak shapes on hen feed intake or TFEM. However, there was a trend for hens with a STP beak shape to have better TFDE as compared to hens with an intact beak shape (*P*=0.054) (Table 3.7).

During the laying period, hen-day production (HDP) and hen-housed production (HHP) were not affected by IRBT treatment or the subsequent change in beak shape (Table 3.7).

Interestingly, from 18 to 42 wk of age, differences in unsaleable egg production were seen between hens with IRBT treated beaks and hens with untreated beaks (Table 3.7). Hens with intact beaks (C) had higher total unsaleable egg production compared to birds with SHV or STP beaks (1.46 vs. 0.86 vs. 0.71 %, respectively). However, when unsaleable egg production from 18 to 42 wk of age was analyzed by type (double yolk, soft-shelled, etc.), STAN hens laid a higher percentage of cracked and abnormal eggs as compared to SHV and STP hens. The only egg production parameter affected during the mid to late laying period (42 to 60 wk of age) was the percentage of abnormal eggs laid with C hens laying a higher percentage in comparison to SHV, STP, and STAN hens (0.23 vs. 0.00 vs. 0.02 vs. 0.02 %, respectively) (Table 3.7). Strain had an effect on egg production from 18 to 42 wk of age with LB hens having higher HDP compared to LW (Table 3.7). There was a trend for LW hens to have higher HHP than LB during this period. In regards to unsaleable egg production, LB hens laid a higher percentage of cracked and abnormal eggs than LW hens from 18 to 42 wk of age. During the early to mid-laying period (18 to 42 wk of age), interactions occurred, with the IRBT treatments affecting the percentage of saleable and broken eggs laid by each strain in a different manner (Table 3.9). LW hens with a STP or STAN beak shape laid significantly more saleable eggs as compared to LW C, LB STAN, and LB C hens. Within the LW strain, the percentage of broken eggs did not differ between the different beak shapes. Within the LB strain, hens with a STAN beak shape laid a higher percentage of broken eggs than birds with a SHV or STP beak shape. Comparison between the strains shows that LB hens with a STAN beak shape laid a higher percentage of broken eggs compared to LW hens in all treatment groups.

Egg quality during the laying period (as measured by egg weight and shell thickness) was not affected by IRBT treatment or the various beak shapes, although there was a trend for hens with intact beaks (C) to have heavier egg weights than hens with a STP beak (P=0.086) from 42 to 60 wk of age. Strain, however, did have an effect on shell thickness (as measured by specific gravity) from 18 to 42 wk of age with LB hens having higher specific gravity than LW (Table 3.7).

Behaviour. Similar to the rearing period, IRBT treatment and the various beak shapes had minimal effects on behaviour during the laying period (Table 3.10). At 23 wk of age, the only effect of IRBT treatments was found in the percent of time spent preening with hens with SHV and STP beak shapes spending a greater percent of time spent preening than C hens (6.36 and 6.83 vs. 5.43 %, respectively). There was no effect of the IRBT treatments at 39 wk of age. LB hens were more active than LW at 23 wk of age but spent less time resting, preening and performing other behaviours (Table 3.10). At 39 wk, LW hens spent a greater percent of time performing nutritive, resting, and preening behaviours than LB.

Feather cover and comb damage. At the time of placement in the laying facility (18 wk of age), there was no effect of the IRBT treatments or strain on feather cover, as feathering was excellent moving into the lay cages (Table 3.11). Later in the laying period (42 wk of age), IRBT treatment had an effect on the feather cover score of the wings with C hens having poorer feather cover in comparison to the other treatments (3.7 vs. 3.9, respectively). Strain also had an effect on the feather cover score of the wings at this age with LB hens having poorer feather cover than LW (3.8 vs. 3.9, respectively). When LW hens were scored at the end of the trial (60 wk of age), hens with shortened or blunted beak shapes (SHV, STP, and STAN) had better feather cover in all regions as compared to C hens (Table 3.11).

Shortening of the beak as a result of the different IRBT treatments was effective at reducing feather loss in both strains, as evident by the interactions between IRBT treatment and strain noted in the neck, back, breast, and tail regions at 42 wk of age (Table 3.12). In the neck region, C hens of both strains had the poorest scores and within the SHV and STP treatments, LB hens had poorest scores compared to LW. Interestingly, for the back, breast, and tail regions, LW C hens had the poorest score compared to the other treatments, but LB C hens did not.

Comb damage was assessed to help quantify aggression during the laying period and data are shown in Table 3.12. At 42 wk of age, C hens had significantly higher scores than the SHV, STP, and STAN treatments (1.9 vs. 1.5, 1.2, and 1.3, respectively).

Mortality and cause of mortality. Regardless of final beak shape, IRBT treatment alone did not have an effect on total mortality levels during the laying period, although numerically, over 11 percent of C hens died compared to less than 3 percent in any treated group. A trend was noted from 26 to 29 wk of age with C hens having higher mortality than IRBT treated hens (4.86 vs. 0.00 %, respectively) (Table 3.13). Strain alone also did not influence mortality levels but trends were noted from 29 to 33 wk and 37 to 41 wk of age with LB hens having higher mortality than LW (Table 3.13). During the early to mid-laying period (18 to 42 wk of age), an interaction occurred between IRBT treatments and strain on overall mortality (Table 3.14). Mortality did not differ between the beak treatment groups within the LW strain. Within the LB strain, C hens had significantly higher mortality compared to STP and STAN hens (22.22 vs. 0.00 vs. 0.00 %, respectively). Comparison between the strains shows that LB C hens had higher mortality than LW SHV, LW STAN, and LW C hens.

When mortality levels from 18 to 42 wk of age were analyzed by cause, there was trend for LB birds to have higher mortality due to metabolic causes as compared to LW (Table 3.15). During this period, an interaction also occurred between IRBT treatments and strain on mortality due to cannibalism, with LB C birds having significantly higher mortality as compared to LB hens in the STP and STAN treatments and LW hens in all treatments (Table 3.16).

When mortality levels from 42 to 60 wk of age were analyzed by cause (LW hens only), hens with STAN beaks had higher mortality due to mechanical causes (broken wings) as compared to SHV, STP, and C hens (5.56 vs. 0.00 %, respectively) (Table 3.15). It is important to note that the mortality due to mechanical causes seen during this period was due to having to cull hens that had broken wings resulting from an unexpected power outage in the laying barn.

3.5 Discussion

3.5.1 Infrared beak treatment

For egg producers, arguably one of the most important objectives of raising laying hens is to achieve optimal egg production while reducing flock mortality. This makes management practices that optimize not only production, but also bird well-being very important. IRBT is one of these management practices that can help make a significant difference from both an economic and welfare viewpoint.

Most previous studies have reported an initial depression in body weight following IRBT as compared to untreated birds during the early rearing period (0 to 4 wk of age) (Honaker and Ruszler, 2004; Gentle and McKeegan, 2007; Marchant-Forde et al., 2008; Marchant-Forde and Cheng, 2010). Specific IRBT settings may result in differences in body weight and this was seen in the present study as pullets with intact beaks were heavier than pullets with a STAN beak shape (top and bottom beak length are flush) at 4 wk of age. This initial depression in body weight may be a result of reduced feeding and drinking behaviour, which could indicate that birds are hesitant to peck at the feeder or drinker because of pain or sensitivity in the beak (Lee and Craig, 1990; Marchant-Forde et al., 2008). However, this does not appear to be the cause for the reduction in pullet body weight observed in the present study. Just prior to when body weights were measured at 4 wk of age was the period when the treated beak tissue began to slough (Struthers, Chapter 2). It is possible that the temporary reduction in body weight seen in STAN pullets was due to alterations in feed intake as the pullets adapted to the change in beak shape post-sloughing. Rather than pain, beak treatment may alter the pullet's physical ability to manipulate and grasp feed causing them to peck at the feeder more and be less successful in transferring the feed to the pharynx where it can be swallowed (Gentle et al., 1982). Feed intake was not measured during the rearing period in the present study so it is not known whether there was a corresponding decrease in feed intake to support this. However, pullets with the STAN beak shape did spend a numerically greater percent of time at the feeder and drinker than C pullets during this time. As pullets reached sexual maturity, there was no impact of the different beak shapes created by IRBT on body weight. This is in agreement with Honaker and Ruszler (2004) who found that despite an initial reduction in the body weight of IRBT treated birds, after 18 wk of age body weight did not differ between IRBT treated and C birds.

The final beak shapes resulting from the different IRBT settings did not affect hen feed intake, which suggests that regardless of how far the bottom beak extended beyond the top within the tested range, hens were still able to consume feed and manipulate the drinker. This is somewhat inconsistent with what has been reported previously, however, comparisons may not be valid, as the majority of the research that has studied the effects of beak treatment during the laying period has used HBT rather than IRBT. Schwean-Lardner et al. (2016) found that during the laying period, C birds tended to have higher feed intake as compared to HBT birds trimmed at either 0, 10, or 35 d of age. Gabrush (2011) found varying effects of IRBT on feed intake during the laying period. When treatment severity (amount of tissue removed or treated) was varied by guard-plate hole size, C birds had higher intake compared to IRBT treated birds. However, when treatment severity was varied by infrared intensity, no differences in feed intake were noted (Gabrush, 2011). It is not clear why there were differences in feed intake between the 2 groups of IRBT treated birds in the study conducted by Gabrush (2011) especially when beak lengths were comparable between the 2 groups; however, the author suggested that the difference may be related to the strains and/or the specific IRBT techniques used.

Possible explanations for the differences in feed intake noted in previous studies include that hens with intact beaks may waste more feed than beak treated hens (Gabrush, 2011; Schwean-Lardner et al., 2016). This is supported by the fact that body weight and egg size did not differ between IRBT and C hens but feed efficiency was poorest in C hens (Gabrush, 2011; Schwean-Lardner et al., 2016). Similar to these studies, hen body weight and egg weight in the present study did not differ between hens with various beak shapes created by IRBT and those with untreated beaks. However, feed efficiency (total feed per dozen eggs) was better in IRBT treated hens compared to C hens; particularly hens with STP shaped beaks, which supports data presented by Damme and Urselmans (2013). In addition to less feed wastage, the improved feed efficiency found in hens with IRBT treated beaks could be related to better feather cover observed in the IRBT treated hens. Feed efficiency and feather cover are correlated (Leeson and Morrison, 1978). Feathers are important for thermoregulation (Leeson and Walsh, 2004) and adequate feather cover can reduce the amount of energy that is partitioned towards maintenance of body temperature rather than growth, improving feed efficiency (Leeson and Morrison, 1978).

Similar to the other production parameters measured during the laying period, variations in beak shape created by altering IRBT settings in the present study did not affect HDP or HHP in comparison to hens with intact beaks. This is in agreement with Honaker and Ruszler (2004), who found no differences in HHP between C and IRBT birds. The lack of difference in HHP reported by Honaker and Ruszler (2004) was likely due to the low mortality rates in both IRBT and C hens. Research that is more recent has reported no differences in THDP and an improvement in HHP in IRBT treated hens in comparison to untreated controls (Gabrush, 2011; Damme and Urselmans, 2013). The improvement in HHP is a result of lower mortality levels in IRBT birds (Gabrush, 2011; Damme and Urselmans, 2013). It is surprising that no differences in HHP were observed between IRBT treated and C birds in the present study. Although not statistically different, the data in the present study certainly demonstrates biological difference, considering that the C birds had significantly higher mortality due to cannibalism as well as poorer feather cover, which has been shown to negatively affect egg production (Hughes and Duncan, 1972).

Egg quality (as measured by egg weight and specific gravity) can be affected by a number of factors including bird strain, bird age, nutrition, stress, disease status, and production system (Roberts, 2004). Egg quality can also influence the production of unsaleable eggs (double yolk, soft-shelled, cracked, broken, and abnormal). In the present study, IRBT did not alter egg weight or specific gravity, which is consistent with previous beak treatment studies (Yannakopoulosy and Tserveni-Gousi, 1986; Guesdon et al., 2006; Mertens et al., 2009; Gabrush, 2011). Schwean-Lardner et al. (2016) found that birds trimmed using HBT at 35 d of age had the lowest specific gravity (poorest shell quality) as compared to birds trimmed using HBT at 0 and 10 d of age and birds that were untrimmed. However, the authors did not see a corresponding change in the levels of unsaleable eggs between the treatment groups. This was not the case in the present study in which C hens laid a higher percentage of unsaleable eggs as compared to hens with SHV or STP beaks. Feed intake can also influence egg quality and the production of unsaleable eggs; however, in the present study, no differences in feed intake were found between the beak treatment groups. This suggests that another factor was responsible for the increased production of unsaleable eggs observed in C hens.

If birds experience stress prior to the egg reaching the shell gland, this can cause the mammillary layer to be improperly formed and subsequent tissue layers to be disorganized resulting in soft- or thin-shelled eggs (Solomon, 1991). North (2002) found that untrimmed birds laid a higher percentage of soft-shelled eggs as compared to birds trimmed using HBT. The author suggested this increase was due to higher stress levels in the untrimmed birds, leading to higher oxytocin, vasopressin, and adrenaline levels. An increased circulating concentration of these hormones may cause the oviduct to contract more frequently; reducing the amount of time the egg spends in the shell gland being calcified, resulting in more soft-shelled eggs (Pizzolante et al., 2007). Although only a numerical difference, the increase in soft-shelled eggs laid by hens with untreated intact beaks in the present study is in agreement with earlier research and suggests that these C hens were experiencing higher levels of stress than the IRBT treated birds, which influenced egg production. This is further supported by the fact that C hens spent a numerically greater percent of time performing aggressive behaviours and had significantly higher mortality due to cannibalism as compared to IRBT treated birds.

Pullet and hen behaviour has been extensively studied in regards to its relationship with beak treatment. Behavioural studies of birds treated using HBT or IRBT often demonstrate a reduction in feeding, drinking, preening, and locomotor activity following beak treatment (Breward and Gentle, 1985; Duncan et al., 1989; Gentle et al., 1997; Marchant-Forde et al., 2008); however differences in behaviour are often no longer apparent as soon as 1 wk post-treatment (Marchant-Forde et al., 2008). These reductions in comfort and nutritive related behaviours have been used to support the presence of acute pain due to HBT (Duncan et al., 1989) and IRBT (Marchant-Forde et al., 2008).

Exploratory behaviour is thought to be expressed when birds are not in pain and their basic needs have been met (Duncan, 1998). This behaviour functions as a way to explore both the physical and social environment (Duncan, 1998). During the early rearing period in the present study, pullets with intact beaks spent more time exploring their physical environment as compared to pullets with STP and STAN beak shapes. Taken in conjunction with the reduced body weight of STAN birds at this age, it would appear that the pullets with a STAN beak shape were demonstrating a reluctance to use their beaks, suggesting that they may have been experiencing pain or sensitivity from IRBT. However, no other beak-related behaviours (time spent at feeder, at drinker, and preening) were affected by these beak shapes at this age. Taking this into consideration, as well as the fact that there were no differences in pecking force at this age (Struthers, Chapter 2) and no effects on behaviour after 5 wk of age, it is unlikely that the pullets were experiencing pain or sensitivity. One possible reason for the reduction seen in STP and STAN pullets at 5 wk could be reduced sensory feedback in the treated beaks, which would make exploratory pecking less rewarding and pullets would be less motivated to perform the behaviour (Freire et al., 2008; Jongman et al., 2008).

Preening may decrease following HBT (Duncan et al., 1989; Gentle et al., 1997) suggesting pain or sensitivity in the beak tissue. However, Duncan et al., (1989) trimmed birds at 16 wk of age and removed as much as 50 percent of the upper and lower beaks. When chicks were beak treated using either HBT or IRBT at 1 d of age with approximately one-third of the beak treated, Marchant-Forde et al., (2008) found that preening increased in treated birds (particularly in HBT birds) relative to C birds and suggested that beak treatment and the change in beak shape reduced the ability of the bird to effectively preen. This is supported to an extent by Sandilands and Savory

(2002) who found that birds trimmed using HBT directed more attention towards their preen gland while preening and took significantly longer to collect oil from the gland; however, the authors did not see differences in time spent preening between HBT treated and C birds. In the present study, shortening or blunting the beak by IRBT tended to increase the time spent preening during the rearing period as compared to pullets with natural, untreated beaks, although the differences were only numerical. The increased time spent preening seen in IRBT treated birds continued during the early laying period with hens that had either SHV or STP beaks spending significantly more time preening than hens with intact beaks. The increase in time spent preening seen during the early laying period in the present study could be due to a less aggressive environment in comparison to hens with intact beaks, who spent numerically more time performing aggressive behaviours and had higher cannibalism-related mortality. It is also possible that the increased time spent preening observed in the SHV and STP treatments may have been due to a reduced effectiveness of the beak as suggested by Sandilands and Savory (2002) and Marchant-Forde et al.(2008). Preening can also function as a displacement behaviour in situations where a bird may be experiencing frustration, stress, or fear (Delius, 1988).

Birds that are treated using IRBT may be less aggressive than birds with intact beaks (Gabrush, 2011) and HBT treated birds (Dennis et al., 2009). A reduction in aggressive behaviour helps improve welfare by providing a less stressful environment (Dennis et al., 2009). Less aggression also results in better feather cover and reduced damage inflicted upon the comb, which decreases pain or discomfort that could be experienced by the birds (Kajlich et al., 2016). Feather cover is important for bird welfare as it helps protect the skin (Leeson and Walsh, 2004). The removal of feathers has been associated with pain in laying hens (Gentle and Hunter, 1990) and can increase the risk of cannibalism due to skin exposure and the presence of blood (Savory, 1995; Kajlich et al., 2016).

In the present study, hens with intact beaks consistently had poorer feather cover than hens with beaks that were blunted using IRBT during the laying period. These results are similar to previous studies that have been conducted on commercial farms (Lambton et al., 2010; Damme and Urselmans, 2013; Morrissey et al., 2016; Riber and Hinrichsen, 2017). Poor feather cover in the 42 and 60 wk old C hens in the present study may have resulted in C hens directing less energy towards growth (Leeson and Walsh, 2004). This is further supported by the fact that C hens had a tendency to have higher feed intake, lower body weight, and poorer feed efficiency during the laying period. Comparison of hens with the 3 beak shapes created by adjusting IRBT settings found no differences in feather cover or comb damage indicating that regardless of the amount of tissue treated and/or sloughed, hens with shortened or blunted beaks were less able to grasp and damage the feathers and combs of conspecifics.

Comb damage is not frequently evaluated in relation to beak treatment despite its relationship to aggressive pecking (Savory, 1995). From the present study, it is evident that the removal of the sharp hook of the beak that occurs with IRBT is effective at limiting the damage that can be inflicted upon the combs of conspecifics as hens with natural, untreated beaks had significantly higher comb damage scores compared to birds with IRBT treated beaks. Overall, the results of the present study as well as the findings of previous studies indicate that leaving birds with intact beaks can have detrimental consequences for plumage and comb condition thereby negatively affecting bird welfare.

One of the major welfare concerns with leaving birds with intact beaks is an increased risk of mortality due to cannibalism as birds with intact beaks are able to inflict much greater damage towards the plumage and skin of conspecifics than their beak treated counterparts. Not only does cannibalism represent an animal welfare concern, it can also have economic consequences for producers as it results in decreased egg production and less income over feed cost (Guesdon et al., 2006; Damme and Urselmans, 2013). Data from the early to mid-laying period (18 to 42 wk of age) in the present study demonstrates that leaving birds with untreated, intact beaks, particularly LB birds, results in significantly higher overall mortality compared to birds with blunted/shortened beaks as a result of IRBT. Multiple studies have found significant increases in mortality in birds with intact beaks (Guesdon et al., 2006; Mertens et al., 2009). Riber and Hinrichsen (2017) investigated the welfare consequences of raising birds with intact beaks in commercial aviaries. The authors found that accumulated mortality over the laying period tended to be higher in flocks that were not beak treated as compared to flocks that were (Riber and Hinrichsen, 2017). Other studies using commercial flocks have also reported higher mortality in flocks with intact beaks (Weeks et al., 2016).

One of the most significant findings of the present study was the interaction between IRBT treatment and strain on mortality due to cannibalism during the early laying period. The data shows that there may be a genetic component to the behaviour and that the LB strain may be more prone to cannibalism than the LW strain, which is consistent with the findings of previous studies (Abrahamsson and Tauson, 1995). This interaction also highlights how effective IRBT, regardless of settings used and final beak shape, is at reducing cannibalism-related mortality. Cannibalism was also seen in 2 cages of LB hens with SHV beaks, with one of these cages being directly beside a cage of LB hens with intact beaks where numerous hens were culled or died due to cannibalism. This provides further evidence that cannibalism is a socially transmitted behaviour as suggested by Zeltner et al. (2000).

3.5.2 Strain

Although the primary focus of the present study was the effects of different beak shapes, including those created by altering IRBT settings compared to a natural, untreated beak shape, 2 strains of egg production birds were used to examine how different genetics are affected by IRBT. The results of this study demonstrate that strain had more of an effect on productivity, behaviour, and welfare of LW and LB pullet and hens than IRBT treatment. During the rearing and laying periods, LB birds had consistently heavier body weights compared to LW birds, which is consistent with previous studies (Tauson et al., 1999; Singh et al., 2009).

Feed intake differed between strains during the laying period, which is not surprising considering the heavier body weights of LB hens. Strain had an effect on egg production during the early to mid-laying period with LB hens having higher HDP but lower HHP than LW. Considering the higher mortality in the LB strain, the lower HHP is not surprising. The increased incidence of abnormal eggs laid by LB hens in the present study may have been due to the hens experiencing stress within their environment. The cause of this stress could be attributed to increased aggression observed in the LB strain during the laying period, although the increase was not statistically significant. This is consistent with the results of Hughes et al. (1986) who found that brown-egg layers laid more abnormal eggs when subjected to various stressors within their environment. Stress causes a release of adrenaline, which is thought to alter oviduct contractions and distort egg shape (Hughes et al., 1986). The increased incidence of broken eggs may be related to the heavier body weight and higher activity levels observed in the LB hens. LW hens had poorer shell quality (as measured by specific gravity) compared to LB. These results agree with Singh et al. (2009), who found that LB hens had better overall egg quality as compared to LW.

The 2 strains also differed somewhat in their behaviour. LB birds spent a greater percent of time performing active behaviours (standing and walking) during both the rearing and laying periods, which has been suggested to be an indication of improved welfare in poultry (Bizeray et al., 2002; Pohle and Cheng, 2009). During both periods, LB birds also spent less time preening than LW. This does not agree with the results of Singh (2008) who did not see differences between LB and LW hens in the time spent standing and walking during the laying period but found that LB hens spent more time preening. Throughout the rearing period, LW pullets spent a greater percent of time perching (classified as a low incidence behaviour). Although commercial perches were not provided in the floor pens, the drinker system, which was suspended from the ceiling, served as a makeshift perch for the birds. Singh (2008) also found that white-egg layers used perches more than brown-egg layers. The differences in the percent of time spent perching may be due in part to the differences in body weight between the LB and LW pullets. As mentioned previously, LB pullets were significantly heavier during the rearing period in the present study, which may have limited their ability to ascend onto the drinker system to perch. Laying hens are highly motivated to perch and perching may serve as means to escape aggressive pen-mates (Newberry et al., 2001). No differences in aggression were seen between the strains from 5 to 13 wk of age and is likely not the reason for increased perching in LW pullets. However, at 17 wk of age LW pullets showed significantly more aggression and this may have contributed to the increase perching in LW pullets during that time.

Feather cover was also found to be different between the 2 strains and this may partially be due in part to the fact that feather loss is easier to quantify on white-feathered birds (Damme and Urselmans, 2013). Strain only affected feather cover in the middle of the laying period, with LW hens having better feather cover on the neck and wings but poorer cover on the tail than LB hens. This agrees with data presented by Damme and Urselmans (2013), who reported less feather loss in LW hens in comparison to LB. However, Damme and Urselmans (2013) did not score individual body areas.

Similar to the work done on IRBT treated pullets reared in cages (Struthers, Chapter 2), there was a trend for higher mortality in LW pullets during the first 4 wk of the rearing period in the present study. LW pullets also had higher infectious mortality over the 16 wk rearing period; however, this mortality was due to yolk sac infection during the first 4 wk of life. During the laying period, there was a trend for LB hens to have higher mortality than LW and this was likely due to higher levels of cannibalism in the LB hens. There was also a trend for LB hens to have higher mortality due to hemorrhagic fatty liver syndrome (HFLS). This may be related to the higher body weights seen in LB hens, which would have predisposed the hens to HFLS (Leeson, 2018).

3.6 Conclusion

The results of this study indicate that IRBT and the beak shapes that were created by adjusting IRBT settings had minor effects on the productivity and behaviour of layer pullets and hens while simultaneously improving welfare when compared to birds with intact beaks. During early life, pullets with a STAN beak shape had reduced body weight as compared to pullets with intact beaks and this may have been due to the required period of adaptation as the treated beak tissue sloughed and beak shaped changed. However, this reduction was transient and as pullets reached sexual maturity, IRBT and the subsequent beaks shapes did not affect productivity.

It was hypothesized that IRBT and the change in beak shape would cause minor changes in pullet and hen behaviour. During both the rearing and laying periods some differences in behaviour were observed, however, they were short-term and disappeared as the birds aged. An improvement in bird well-being was demonstrated by the improvement in feather cover and reductions in both comb damage and mortality due to cannibalism seen during the laying period in IRBT treated hens. Cannibalism-related mortality was reduced by almost 20 percent by beak treating birds using IRBT, providing support for the continued use of IRBT, as it is one of the most effective methods of controlling injurious pecking and cannibalism within egg production flocks. The results of the present study demonstrate that any effects of the IRBT treatments and subsequent beaks shapes on production and behaviour are short-term and are clearly outweighed by the improvement in welfare by the reduction in cannibalism-related mortality.

3.7 Acknowledgements

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Table 3. 1. Scoring criteria for feather cover (adapted from Davami et al. (1987) and Sarica et al. (2008)) and comb damage (adapted from Ali and Cheng, 1985) of hens.

	Score	Description
Feather Cover	1	No feather cover
	2	More than 50% of the plumage is missing
	3	50% or less of the plumage is missing
	4	Full, intact plumage
Comb Damage	0	No sign of pecking damage
	1	A single mark of pecking damage
	2	2 to 3 marks of pecking injuries on both sides of the comb
	3	More than 3 marks of pecking on the comb
	4	Severe injuries, bleeding, extensive damage to the comb

Table 3. 2. Effect of infrared beak treatments and strain on the body weight (kg) of Experiment 2a Lohmann LSL-Lite and Lohmann Brown pullets housed in floor pens from 1 d to 18 wk of age.

Age	Beak Treatment					Strain			Interaction	SEM
	SHV	STP	STAN	C	*P*-value	LB	LW	*P*-value	*P*-value	
1 d	0.036	0.036	0.036	0.036	0.546	0.036	0.036	0.667	0.292	0.0000
4 wk	0.300^{ab}	0.301^{ab}	0.295^{b}	0.303^{a}	0.043	0.303^{a}	0.297^{b}	0.008	0.396	0.0016
8 wk	0.710	0.706	0.699	0.715	0.085	0.736^{a}	0.679^{b}	<0.001	0.492	0.0080
12 wk	1.089	1.095	1.075	1.092	0.268	1.182^{a}	0.994^{b}	<0.001	0.565	0.0246
16 wk	1.296	1.305	1.292	1.307	0.735	1.445^{a}	1.155^{b}	<0.001	0.212	0.0378

[a, b] Means within a main effect with different superscripts are significantly different ($P \leq 0.05$)

SHV = large difference between top and bottom beak lengths

STP = intermediate difference between top and bottom beak lengths

STAN = small difference between top and bottom beak lengths

C = sham untreated control

LB = Lohmann Brown

LW = Lohmann LSL-Lite

Table 3. 3. Effect of infrared beak treatments and strain on the behaviour (% of time) of Experiment 2a Lohmann LSL-Lite and Lohmann Brown pullets over a 24-h period at 5, 9, 13, and 17 wk of age.

Behaviour	Beak Treatment					Strain			Interaction	SEM
	SHV	STP	STAN	C	*P*-value	LB	LW	*P*-value	*P*-value	
<u>5 wk of age</u>										
Nutritive	7.33	7.39	7.36	6.90	0.890	6.86	7.63	0.610	0.812	0.227
Active	9.55	9.25	9.32	8.55	0.660	10.55^{a}	7.78^{b}	0.002	0.402	0.513
Rest	69.85	70.19	69.78	70.60	0.807	68.91^{b}	71.30^{a}	0.008	0.690	0.441
Preen	3.41	3.47	3.61	3.28	0.998	3.62	3.27	0.522	0.215	0.22
Comfort	0.30	0.30	0.30	0.21	0.346	0.28	0.27	0.278	0.074	0.022
Exploratory	7.32^{ab}	6.62^{b}	6.55^{b}	8.13^{a}	0.049	7.28	7.03	0.170	0.597	0.315
Aggression	0.01	0.00	0.01	0.01	0.709	0.02	0.00	0.253	0.665	0.005
Low incidence	2.23^{bc}	2.78^{ab}	3.07^{a}	2.31^{c}	0.011	2.48^{b}	2.71^{a}	0.004	0.008	0.169
<u>9 wk of age</u>										
Nutritive	4.91	5.52	5.49	4.27	0.552	4.97	5.12	0.835	0.728	0.197
Active	11.57	11.00	11.03	10.42	0.481	11.71^{a}	10.29^{b}	0.012	0.614	0.353
Rest	65.12	65.04	62.55	66.71	0.653	68.77	60.94	0.192	0.849	1.213
Preen	4.34	5.20	4.95	4.64	0.379	4.70	4.86	0.203	0.368	0.168
Comfort	0.19	0.27	0.33	0.21	0.269	0.22	0.28	0.467	0.217	0.029
Exploratory	6.35	6.55	6.04	7.15	0.617	7.15	5.90	0.065	0.318	0.297
Aggression	0.04	0.03	0.09	0.03	0.776	0.04	0.05	0.269	0.416	0.016
Low incidence	7.48	6.41	9.52	6.58	0.313	2.43^{b}	12.56^{a}	<0.001	0.733	1.450
<u>13 wk of age</u>										
Nutritive	4.07	4.45	4.51	3.72	0.517	3.97	4.41	0.226	0.595	0.142
Active	13.39	13.54	13.29	13.49	0.522	14.33	12.52	0.897	0.298	0.365
Rest	60.87	58.85	58.78	61.03	0.675	66.55	53.23	0.122	0.134	1.838
Preen	6.23	7.41	7.01	6.09	0.090	6.53^{b}	6.84^{a}	0.001	0.104	0.234
Comfort	0.05	0.07	0.05	0.12	0.119	0.07	0.07	0.966	0.796	0.009
Exploratory	6.58	6.50	6.30	7.06	0.468	6.36	6.86	0.203	0.306	0.211
Aggression	0.01	0.03	0.01	0.03	0.630	0.01	0.03	0.404	0.943	0.007

Low incidence	8.80	9.14	10.05	8.46	0.386	2.18[b]	16.04[a]	<0.001	0.501	1.875
<u>17 wk of age</u>										
Nutritive	3.52	3.99	3.92	3.27	0.147	3.35[b]	4.00[a]	<0.001	0.118	0.162
Active	14.64	15.11	14.66	15.72	0.966	15.03[a]	15.02[b]	0.002	0.641	0.272
Rest	57.63	58.20	58.69	58.96	0.304	66.39	50.35	0.139	0.141	2.101
Preen	6.45	6.46	6.36	5.88	0.878	5.99[b]	6.58[a]	0.003	0.672	0.202
Comfort	0.21	0.17	0.17	0.13	0.593	0.25[a]	0.09[b]	0.002	0.704	0.026
Exploratory	6.42	6.17	6.50	5.88	0.457	6.25	6.24	0.641	0.114	0.202
Aggression	0.02	0.02	0.03	0.01	0.372	0.00[b]	0.04[a]	0.011	0.096	0.008
Low incidence	11.11	9.88	9.67	10.15	0.134	2.74[b]	17.67[a]	<0.001	0.137	1.967

[a, b] Means within a main effect with different superscripts are significantly different ($P \leq 0.05$)
SHV = large difference between top and bottom beak lengths
STP = intermediate difference between top and bottom beak lengths
STAN = small difference between top and bottom beak lengths
C = sham untreated control
LB = Lohmann Brown
LW = Lohmann LSL-Lite
Nutritive = time at feeder + time at drinker
Active = standing + walking
Rest = resting
Preen = preening
Comfort = dustbathing + feather ruffling + leg stretching + wing stretching
Exploratory = gentle pecking + object pecking
Aggression = aggressive pecking
Low incidence = perching + head shaking + head scratching + beak wiping + wing flapping + unknown

Table 3. 4. Interaction between infrared beak treatments and strain on low incidence[1] behaviours (% of time) of Experiment 2a Lohmann LSL-Lite and Lohmann Brown pullets over a 24-h period at 5 wk of age.

Strain	Beak Treatment			
	SHV	STP	STAN	C
LB	2.69[bc]	2.32[c]	2.56[c]	2.36[c]
LW	1.76[c]	3.23[ab]	3.59[a]	2.26[c]

[a,b,c] Means with different superscripts are significantly different ($P \leq 0.05$)
[1]Perching + head shaking + head scratching + beak wiping + wing flapping + unknown
SHV = large difference between top and bottom beak lengths
STP = intermediate difference between top and bottom beak lengths
STAN = small difference between top and bottom beak lengths
C = sham untreated control
LB = Lohmann Brown
LW = Lohmann LSL-Lite

Table 3. 5. Effect of infrared beak treatments and strain on the total mortality (as a % of birds placed) of Experiment 2a Lohmann LSL-Lite and Lohmann Brown pullets housed in floor pens from 1 d to 16 wk of age.

Age	Beak Treatment					Strain			Interaction	SEM
	SHV	STP	STAN	C	*P*-value	LB	LW	*P*-value	*P*-value	
1 d – 4 wk	1.25	1.88	2.50	2.50	0.784	0.63	3.44	0.053	0.549	0.654
5 – 8 wk	0.00	0.00	0.00	1.25	0.161	0.31	0.31	1.000	1.000	0.213
9 – 12 wk	0.00	0.63	0.00	0.00	0.447	0.31	0.00	0.351	0.447	0.156
13 – 16 wk	0.63	0.00	0.00	0.00	0.447	0.31	0.00	0.351	0.447	0.156
1 d – 16 wk	1.88	2.50	2.50	3.75	0.724	1.56	3.75	0.357	0.622	0.738

[a,b] Means within a main effect with different superscripts are significantly different ($P \leq 0.05$)
SHV = large difference between top and bottom beak lengths
STP = intermediate difference between top and bottom beak lengths
STAN = small difference between top and bottom beak lengths
C = sham untreated control
LB = Lohmann Brown
LW = Lohmann LSL-Lite

Table 3. 6. Effect of infrared beak treatments and strain on cause of mortality (as a % of birds placed) of Experiment 2a Lohmann LSL-Lite and Lohmann Brown pullets housed in floor pens from 1 d to 16 wk of age.

Cause[1]	Beak Treatment					Strain			Interaction	SEM
	SHV	STP	STAN	C	*P*-value	LB	LW	*P*-value	*P*-value	
Infectious	0.63	0.63	2.50	0.63	0.512	0.00[b]	2.19[a]	0.016	0.512	0.509
Mechanical	0.00	0.63	0.00	0.63	0.596	0.63	0.00	0.195	0.596	0.213
Other	0.00	0.63	0.00	1.25	0.363	0.31	0.63	0.580	0.802	0.252
Unknown	1.25	0.63	0.00	1.25	0.561	0.63	0.94	0.667	0.150	0.376

[a,b] Means within a main effect with different superscripts are significantly different ($P \leq 0.05$)

[1] Infectious: enteritis, pericarditis, yolk sac infection; Mechanical: broken wing, broken leg; Unknown: no visible lesion; Other: impacted large intestine, dehydration

SHV = large difference between top and bottom beak lengths

STP = intermediate difference between top and bottom beak lengths

STAN = small difference between top and bottom beak lengths

C = sham untreated control

LB = Lohmann Brown

LW = Lohmann LSL-Lite

Table 3. 7. Effect of infrared beak treatments and strain on the body weight (kg), productivity, and egg quality of Experiment 2b Lohmann LSL-Lite and Lohmann Brown hens from 18 to 42 wk of age and Lohmann LSL-Lite hens from 42 to 60 wk of age.

	Beak Treatment					Strain			Interaction	SEM
	SHV	STP	STAN	C	*P*-value	LB	LW	*P*-value	*P*-value	
Body weight, kg										
18 wk	1.40	1.42	1.40	1.41	0.289	1.57^{a}	1.25^{b}	<0.001	0.002	1.407
42 wk	2.02	2.01	2.00	1.96	0.142	2.18^{a}	1.81^{b}	<0.001	0.138	1.996
60 wk	1.90	1.82	1.86	1.81	0.322	-	1.85	-	-	1.847
18 to 42 wk of age										
Feed intake, g/bird/d	115.58	114.28	115.38	117.24	0.239	117.72^{a}	113.52^{b}	<0.001	0.167	0.6037
Total feed per egg mass	2.149	2.125	2.321	2.180	0.301	2.181	2.207	0.747	0.327	0.0392
Total feed per dozen eggs	1.500	1.480	1.611	1.533	0.357	1.520	1.542	0.686	0.376	0.0273
Egg production (HDP[1]), %	88.87	89.07	88.50	88.85	0.841	89.72^{a}	87.92^{b}	<0.001	0.704	0.2619
Egg production (HHP[1]), %	88.24	87.91	87.88	84.01	0.512	86.69	87.32	0.068	0.170	0.8555
Total saleable eggs, %	99.14^{a}	99.29^{a}	98.81^{ab}	98.54^{b}	0.006	98.79^{b}	99.10^{a}	0.048	0.036	0.0916
Total unsaleable eggs[2], %	0.86^{b}	0.71^{b}	1.19^{ab}	1.46^{a}	0.006	1.21	0.90	0.117	0.051	0.0916
Double yolk eggs, %	0.55	0.35	0.45	0.72	0.057	0.47	0.57	0.258	0.189	0.0528
Soft-shelled eggs, %	0.09	0.13	0.11	0.20	0.123	0.15	0.11	0.362	0.211	0.0198
Cracked eggs, %	0.06^{b}	0.04^{b}	0.14^{a}	0.10^{ab}	0.001	0.13^{a}	0.04^{b}	<0.001	0.308	0.0122
Broken eggs, %	0.08^{c}	0.10^{bc}	0.27^{ab}	0.25^{a}	0.028	0.27^{a}	0.08^{b}	0.002	0.041	0.0343
Abnormal eggs, %	0.09^{b}	0.09^{b}	0.22^{a}	0.19^{ab}	0.044	0.19^{a}	0.10^{b}	0.020	0.059	0.0225
Egg weight, g	58.37	58.01	57.83	58.53	0.308	58.06	58.32	0.367	0.341	0.1518
Specific gravity	1.088	1.088	1.088	1.088	0.716	1.089^{a}	1.088^{b}	0.040	0.695	0.0001
42 to 60 wk of age										
Feed intake, g/bird/d	123.04	123.52	128.26	128.56	0.308	-	125.84	-	-	1.3374
Total feed per egg mass	2.150	2.120	2.184	2.242	0.109	-	2.174	-	-	0.0187
Total feed per dozen eggs	1.654	1.617	1.680	1.750	0.054	-	1.675	-	-	0.0182
Egg production (HDP[1]), %	93.82	96.13	96.24	93.39	0.107	-	94.90	-	-	0.5296
Egg production (HHP[1]), %	92.58	92.19	89.07	90.00	0.703	-	90.96	-	-	1.2268

Total saleable eggs, %	99.62	99.40	99.40	99.22	0.191	-	99.41	-	-	0.0655
Total unsaleable eggs[2], %	0.38	0.60	0.60	0.78	0.286	-	0.59	-	-	0.0655
Double yolk eggs, %	0.05	0.05	0.11	0.05	0.680	-	0.07	-	-	0.0192
Soft-shelled eggs, %	0.02	0.07	0.09	0.13	0.262	-	0.08	-	-	0.0224
Cracked eggs, %	0.22	0.37	0.31	0.30	0.342	-	0.30	-	-	0.0330
Broken eggs, %	0.09	0.09	0.07	0.07	0.986	-	0.08	-	-	0.0224
Abnormal eggs, %	0.00[b]	0.02[b]	0.02[b]	0.23[a]	<0.001	-	0.07	-	-	0.0248
Egg weight, g	64.39	63.66	64.26	64.92	0.086	-	64.31	-	-	0.1809
Specific gravity	1.082	1.082	1.082	1.083	0.307	-	1.082	-	-	0.0002

[a, b, c] Means within a main effect with different superscripts are significantly different ($P \leq 0.05$)

[1]HDP = hen-day production; HHP = hen-housed production

[2]Total unsaleable eggs = double yolk eggs + soft-shelled eggs + cracked eggs + broken eggs + abnormal eggs

SHV = large difference between top and bottom beak lengths

STP = intermediate difference between top and bottom beak lengths

STAN = small difference between top and bottom beak lengths

C = sham untreated control

LB = Lohmann Brown

LW = Lohmann LSL-Lite

Table 3. 8. Interaction between infrared beak treatments and strain on the body weight (kg) at 18 wk of Experiment 2b Lohmann LSL-Lite and Lohmann Brown hens housed in conventional cages from 18 to 42 wk of age.

Strain	Beak Treatment			
	SHV	STP	STAN	C
LB	1.56[a]	1.59[a]	1.57[a]	1.55[a]
LW	1.25[bc]	1.24[bc]	1.22[c]	1.28[b]

[a, b, c] Means with different superscripts are significantly different ($P \leq 0.05$)

SHV = large difference between top and bottom beak lengths

STP = intermediate difference between top and bottom beak lengths

STAN = small difference between top and bottom beak lengths

C = sham untreated control

LB = Lohmann Brown

LW = Lohmann LSL-Lite

Table 3. 9. Interaction between infrared beak treatments and strain for the percent of total saleable and broken eggs laid by Experiment 2b Lohmann LSL-Lite and Lohmann Brown hens from 18 to 42 wk of age.

	Beak Treatment x Strain							
	LB SHV	LW SHV	LB STP	LW STP	LB STAN	LW STAN	LB C	LW C
Total saleable eggs, %	99.23^{ab}	99.04^{ab}	99.19^{ab}	99.39^{a}	98.27^{b}	99.34^{a}	98.47^{b}	98.62^{b}
Broken eggs, %	0.09^{b}	0.06^{b}	0.12^{b}	0.08^{b}	0.50^{a}	0.05^{b}	0.37^{ab}	0.13^{ab}

$^{a, b}$ Means within a row with different superscripts are significantly different ($P \leq 0.05$)
SHV = large difference between top and bottom beak lengths
STP = intermediate difference between top and bottom beak lengths
STAN = small difference between top and bottom beak lengths
C = sham untreated control
LB = Lohmann Brown
LW = Lohmann LSL-Lite

Table 3. 10. Effect of infrared beak treatments and strain on the behaviour (% of time) of Experiment 2b Lohmann LSL-Lite and Lohmann Brown hens over a 24-h period at 23 and 39 wk of age.

Behaviour	Beak Treatment					Strain			Interaction	SEM
	SHV	STP	STAN	C	*P*-value	LB	LW	*P*-value	*P*-value	
23 wk of age										
Nutritive	14.49	15.39	15.96	15.65	0.434	14.71	16.04	0.527	0.448	0.430
Active	26.78	24.14	24.03	25.66	0.346	28.85^{a}	21.45^{b}	0.001	0.990	1.105
Rest	43.53	44.49	44.31	44.25	0.115	43.43^{b}	44.86^{a}	0.001	0.411	0.284
Preen	6.36^{a}	6.83^{a}	6.20^{ab}	5.43^{b}	0.022	5.04^{b}	7.38^{a}	<0.001	0.173	0.399
Comfort	0.16	0.14	0.10	0.12	0.568	0.13	0.13	0.820	0.571	0.017
Exploratory	2.47	2.18	2.35	2.23	0.913	1.88	2.74	0.057	0.111	0.235
Aggression	0.05	0.14	0.10	0.20	0.444	0.17	0.08	0.105	0.554	0.030
Low incidence	6.15	6.68	6.96	6.46	0.772	5.80^{b}	7.33^{a}	0.015	0.400	0.329
39 wk of age										
Nutritive	15.76	15.01	15.54	15.04	0.402	14.08^{b}	16.60^{a}	0.044	0.924	0.489
Active	28.15	25.12	25.01	25.64	0.208	29.49	22.47	0.120	0.559	1.125
Rest	43.46	45.59	44.71	45.58	0.834	43.77^{b}	45.89^{a}	<0.001	0.867	0.461
Preen	4.91	5.35	5.45	6.70	0.342	5.18^{b}	6.03^{a}	0.009	0.446	0.347
Comfort	0.10	0.06	0.24	0.07	0.358	0.12	0.12	0.991	0.348	0.038
Exploratory	1.54	1.66	1.78	1.53	0.874	1.55	1.71	0.563	0.912	0.140
Aggression	0.03	0.06	0.07	0.07	0.710	0.08	0.03	0.106	0.315	0.012
Low incidence	6.05	7.15	7.20	5.37	0.455	5.73	7.15	0.092	0.561	0.471

[a, b] Means within a main effect with different superscripts are significantly different ($P \leq 0.05$)
SHV = large difference between top and bottom beak lengths
STP = intermediate difference between top and bottom beak lengths
STAN = small difference between top and bottom beak lengths
C = sham untreated control
LB = Lohmann Brown
LW = Lohmann LSL-Lite
Nutritive = time at feeder + time at drinker
Active = standing + walking
Rest = resting

Preen = preening
Comfort = dustbathing + feather ruffling + leg stretching + wing stretching
Exploratory = gentle pecking + object pecking
Aggression = aggressive pecking
Low incidence = perching + head shaking + head scratching + beak wiping + wing flapping + unknown

Table 3. 11. Effect of infrared beak treatments and strain on the feather cover score (scale 1-4)[1] and comb damage score (scale 0-4)[2] of Experiment 2b Lohmann LSL-Lite and Lohmann Brown hens at 18 and 42 wk of age and Lohmann LSL-Lite hens at 60 wk of age.

Body Area	Age (wk)	Beak Treatment					Strain			Interaction	SEM
		SHV	STP	STAN	C	*P*-value	LB	LW	*P*-value	*P*-value	
Neck	18	4.0	4.0	4.0	4.0	1.000	4.0	4.0	1.000	1.000	0.00
	42	3.4^{ab}	3.4^{b}	3.6^{a}	2.8^{c}	<0.001	3.2^{b}	3.4^{a}	<0.001	0.017	0.03
	60	3.1^{a}	3.0^{a}	3.0^{a}	2.6^{b}	<0.001	-	2.9	-	-	0.03
Back	18	4.0	4.0	4.0	4.0	1.000	4.0	4.0	1.000	1.000	0.00
	42	3.9^{a}	3.9^{a}	3.9^{a}	3.5^{b}	<0.001	3.8	3.8	0.568	<0.001	0.02
	60	3.8^{a}	3.5^{a}	3.7^{a}	2.8^{b}	<0.001	-	3.4	-	-	0.05
Breast	18	4.0	4.0	4.0	4.0	1.000	4.0	4.0	1.000	1.000	0.00
	42	3.6^{a}	3.6^{a}	3.7^{a}	3.1^{b}	<0.001	3.5	3.5	0.284	<0.001	0.03
	60	3.2^{a}	3.2^{a}	3.2^{a}	2.6^{b}	<0.001	-	3.0	-	-	0.05
Wings	18	4.0	4.0	4.0	4.0	1.000	4.0	4.0	1.000	1.000	0.00
	42	3.9^{a}	3.9^{a}	3.9^{a}	3.7^{b}	<0.001	3.8^{b}	3.9^{a}	0.022	0.742	0.02
	60	3.9^{a}	3.8^{a}	3.9^{a}	3.3^{b}	<0.001	-	3.7	-	-	0.03
Tail	18	4.0	4.0	4.0	4.0	1.000	4.0	4.0	1.000	1.000	0.00
	42	3.8^{a}	3.7^{a}	3.9^{a}	3.3^{b}	<0.001	3.8^{a}	3.5^{b}	<0.001	<0.001	0.03
	60	2.9^{a}	3.1^{a}	3.1^{a}	2.1^{b}	<0.001	-	2.8	-	-	0.05
Comb	18	-	-	-	-	-	-	-	-	-	-
	42	1.5^{b}	1.2^{b}	1.3^{b}	1.9^{a}	<0.001	1.4	1.5	0.680	0.410	0.05
	60	2.1	1.9	1.9	2.2	0.133	-	2.0	-	-	0.06

[a,b,c] Means within a main effect with different superscripts are significantly different ($P \leq 0.05$)

[1]Score of 1=no feather cover, 2=greater than 50% of plumage missing, 3=50% or less of the plumage missing, and 4=full, intact plumage (Davami et al., 1987 and Sarica et al., 2008)

[2]Score of 0=no comb damage, 1=single mark of pecking damage, 2=2 to 3 marks of pecking damage, 3=greater than 3 marks of pecking damage, and 4=extensive damage, presence of blood (Ali and Cheng, 1985)

SHV = large difference between top and bottom beak lengths
STP = intermediate difference between top and bottom beak lengths
STAN = small difference between top and bottom beak lengths
C = sham untreated control
LB = Lohmann Brown
LW = Lohmann LSL-Lite

Table 3. 12. Interaction between infrared beak treatments and strain on the feather scores of Experiment 2b Lohmann LSL-Lite and Lohmann Brown hens at 42 wk of age.

Body area	Strain x Beak Treatment							
	LB SHV	LW SHV	LB STP	LW STP	LB STAN	LW STAN	LB C	LW C
Neck	3.3^{bc}	3.6^{a}	3.2^{cd}	3.6^{ab}	3.4^{abc}	3.7^{a}	2.9^{de}	2.8^{e}
Back	3.8^{abc}	3.9^{ab}	3.9^{abc}	3.9^{abc}	3.7^{bc}	4.0^{a}	3.6^{c}	3.3^{d}
Breast	3.4^{c}	3.8^{ab}	3.5^{abc}	3.6^{abc}	3.5^{abc}	3.8^{a}	3.4^{bc}	2.9^{d}
Tail	3.8^{a}	3.7^{a}	3.8^{a}	3.6^{a}	3.8^{a}	3.9^{a}	3.7^{a}	3.0^{b}

^{a,b,c,d,e} Means within a row with different superscripts are significantly different ($P \leq 0.05$)

SHV = large difference between top and bottom beak lengths

STP = intermediate difference between top and bottom beak lengths

STAN = small difference between top and bottom beak lengths

C = sham untreated control

LB = Lohmann Brown

LW = Lohmann LSL-Lite

Table 3. 13. Effect of infrared beak treatments and strain on the total mortality (as a % of birds placed) of Experiment 2b Lohmann LSL-Lite and Lohmann Brown hens from 18 to 42 wk of age and Lohmann LSL-Lite hens from 42 to 60 wk of age.

Age (wk)	Beak Treatment					Strain			Interaction	SEM
	SHV	STP	STAN	C	*P*-value	LB	LW	*P*-value	*P*-value	
18 – 21	0.00	0.69	0.69	0.00	0.567	0.35	0.35	1.000	0.267	0.243
22 – 25	0.00	0.69	0.00	0.00	0.403	0.00	0.35	0.324	0.403	0.174
26 – 29	0.00	0.00	0.00	4.86	0.098	2.43	0.00	0.142	0.098	1.052
30 – 33	0.69	0.00	0.00	3.47	0.220	2.08	0.00	0.076	0.220	0.729
34 – 37	0.69	0.00	0.00	0.69	0.567	0.69	0.00	0.160	0.567	0.243
38 – 41	1.39	0.00	0.00	2.08	0.326	1.74	0.00	0.073	0.326	0.568
42 – 45	1.39	1.39	6.94	2.78	0.436	-	3.13	-	-	1.100
46 – 49	0.00	0.00	0.00	1.39	0.414	-	0.35	-	-	0.347
50 – 53	0.00	0.00	1.39	0.00	0.414	-	0.35	-	-	0.347
54 – 60	0.00	0.00	0.00	0.00	-	-	0.00	-	-	0.000
18 – 42	2.78	1.39	0.69	11.11	0.354	7.29[a]	0.69[b]	0.048	0.026	1.938
42 – 60	1.39	1.39	8.33	4.17	0.346	-	3.82	-	-	1.325

[a,b] Means within a main effect with different superscripts are significantly different ($P \leq 0.05$)

SHV = large difference between top and bottom beak lengths

STP = intermediate difference between top and bottom beak lengths

STAN = small difference between top and bottom beak lengths

C = sham untreated control

LB = Lohmann Brown

LW = Lohmann LSL-Lite

Table 3. 14. Interaction between infrared beak treatments and strain on total mortality (as a % of birds placed) of Experiment 2b Lohmann LSL-Lite and Lohmann Brown hens from 18 to 42 wk of age.

Strain	Beak Treatment			
	SHV	STP	STAN	C
LB	5.56^{ab}	0.00^{b}	1.39^{b}	22.22^{a}
LW	0.00^{b}	2.78^{ab}	0.00^{b}	0.00^{b}

^{a,b} Means with different superscripts are significantly different ($P \leq 0.05$)

SHV = large difference between top and bottom beak lengths

STP = intermediate difference between top and bottom beak lengths

STAN = small difference between top and bottom beak lengths

C = sham untreated control

LB = Lohmann Brown

LW = Lohmann LSL-Lite

Table 3. 15. Effect of infrared beak treatments and strain on cause of mortality (as a % of birds placed) of Experiment 2b Lohmann LSL-Lite and Lohmann Brown hens from 18 to 42 wk of age and Lohmann LSL-Lite hens from 42 to 60 wk of age.

Cause[1]	Beak Treatment					Strain			Interaction	SEM
	SHV	STP	STAN	C	*P*-value	LB	LW	*P*-value	*P*-value	
<u>18 to 42 wk of age</u>										
Cannibalism	1.39^{ab}	0.00^{b}	0.00^{b}	9.72^{a}	0.031	5.56^{a}	0.00^{b}	0.009	0.031	1.671
Metabolic	0.69	0.00	0.00	1.39	0.228	1.04	0.00	0.062	0.228	0.294
Infectious	0.69	0.69	0.69	0.00	0.778	0.69	0.35	0.557	0.292	0.294
Other	0.00	0.69	0.00	0.00	0.403	0.00	0.35	0.324	0.403	0.174
<u>42 to 60 wk of age</u>										
Infectious	0.00	0.00	1.39	1.39	0.582	-	0.69	-	-	0.480
Skeletal	1.39	1.39	1.39	0.00	0.801	-	1.04	-	-	0.575
Mechanical	0.00^{b}	0.00^{b}	5.56^{a}	0.00^{b}	0.011	-	1.39	-	-	0.819
Other	0.00	0.00	0.00	1.39	0.414	-	0.35	-	-	0.347
Unknown	0.00	0.00	0.00	1.39	0.414	-	0.35	-	-	0.347

^{a,b} Means within a main effect with different superscripts are significantly different ($P \leq 0.05$)

[1]Cannibalism: physical damage to the body from another bird's pecking; Metabolic: hemorrhagic fatty liver syndrome; Infectious: hepatitis, osteomyelitis, pericarditis, peritonitis, salpingitis; Skeletal: osteoporosis; Mechanical: broken wing, broken leg; Unknown: no visible lesion; Other: vent prolapse, ovarian cyst

SHV = large difference between top and bottom beak lengths

STP = intermediate difference between top and bottom beak lengths

STAN = small difference between top and bottom beak lengths

C = sham untreated control

LB = Lohmann Brown

LW = Lohmann LSL-Lite

Table 3. 16. Interaction between infrared beak treatments and strain on mortality due to cannibalism[1] (as a % of birds placed) of Experiment 2b Lohmann LSL-Lite and Lohmann Brown hens from 18 to 42 wk of age.

Strain	Beak Treatment			
	SHV	STP	STAN	C
LB	2.78^{ab}	0.00^{b}	0.00^{b}	19.44^{a}
LW	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}

^{a,b} Means with different superscripts are significantly different ($P \leq 0.05$)

[1]Cannibalism = physical damage to the body from another bird's pecking

SHV = large difference between top and bottom beak lengths

STP = intermediate difference between top and bottom beak lengths

STAN = small difference between top and bottom beak lengths

C = sham untreated control

LB = Lohmann Brown

LW = Lohmann LSL-Lite

4.0 Chapter 4: Overall Discussion

4.1 Introduction

Consumer attitudes with regards to how poultry are raised and their well-being are changing and because of this, long-standing management practices used in poultry production, such as beak treatment, are coming under scrutiny. This increase in consumer concern for animal welfare has resulted in a number of countries (primarily European) banning or phasing out all beak treatment methods. The current Canadian National Farm Animal Care Council Codes of Practice for Hatching Eggs, Breeders, Chickens and Turkeys requires that beak treatment is performed only by competent persons and that beak treatment methods are regularly evaluated to determine the impacts on welfare (NFACC, 2016a). Although not required, it is recommended that infrared beak treatment (IRBT) is used instead of hot-blade trimming (HBT) and that producers adopt more humane methods of beak treatment as they become available (NFACC, 2016a).

Beak treatment of laying hens is an important management practice as it is one of the most effective methods of controlling or eliminating injurious pecking and cannibalism within egg production flocks (Glatz, 1990). The factors which influence the levels of cannibalism that occurs in laying hens are not well understood and the presence of this behaviour in a flock often results in high mortality over a very short period of time (Guesdon et al., 2006). The behaviour can spread through a flock quickly and is often more prevalent in more extensive housing systems such as furnished cages or aviaries (Guesdon et al., 2006). This makes banning beak treatment problematic, especially since Egg Farmers of Canada has committed to requiring producers to transition housing away from conventional systems to other designs including extensive systems such as free run or even free range by 2036 (EFC, 2016). Beak treatment methods are continually improving and the IRBT system is reflective of this. However, research that has been conducted on the different methods of beak treatment often link IRBT to more traditional methods such as HBT despite evidence that IRBT does not result in the same pain responses, changes in behaviour, or reductions in production that are sometimes seen with HBT (Marchant-Forde et al., 2008; Dennis et al., 2009; Marchant-Forde and Cheng, 2010).

The purpose of this research was to determine the effects of 4 specific beak shapes on the beak length, production, behaviour, and welfare of layer pullets and hens, with a particular emphasis during early life when the beak tissue is sloughing. Three of the beak shapes were created by adjusting IRBT settings (shovel beak (SHV), step beak (STP), and standard beak (STAN)), and the fourth was an untreated natural beak (control (C)). The effects of the IRBT treatments and subsequent change in beak shape on pullet beak length and growth were determined by taking beak photographs and assessing beak sloughing. The effects on pullet and hen production performance were determined using body weight, feed intake, feed efficiency, water disappearance, egg production, and egg quality. The effects on pullet and hen well-being were determined using behaviour, pecking force, feather cover, comb damage, mortality rate, and cause of mortality. Behaviour was evaluated using whole pen or cage observations at 15-minute instantaneous scan sampling intervals over either 8 or 24 h periods.

4.2 Objectives

The primary objective of this research was to examine how different beak shapes, including those created by adjusting IRBT settings and untreated beaks, affect the beak length, productivity, pecking force, behaviour, and welfare of Lohmann LSL-Lite and Lohmann Brown layer pullets. A secondary objective was to follow birds with these beak shapes through to the end of the egg production cycle and determine the effects on the production, behaviour, and welfare of Lohmann LSL-Lite and Lohmann Brown hens.

4.3 Discussion

The natural, untreated shape of a chicken beak resembles that of a hook, with the sharp tip of the upper beak tip extending out beyond the bottom beak. It is this hook-like shape that allows birds to easily grab and tear the feathers and tissues of other birds during cannibalism outbreaks in egg-production systems (Glatz, 2000). The goal of beak treatment is to remove the beak tip and cause the beak to have a blunter, shortened appearance. By removing the beak tip and therefore, the sharp hook-like structure, birds are less effective at grasping and damaging the feathers and tissues of other birds (Dennis and Cheng, 2012).

Beak treatment, regardless of the method, results in changes to beak shape (Carruthers et al., 2012). The beak shapes used in the present work are similar to ones that have been observed in HBT or IRBT treated birds in commercial or research settings (Craig et al., 1992; Lunam et al., 1996; Sandilands and Savory, 2002; Carruthers et al., 2012; Yamauchi et al., 2017). Some of the more prevalent beak shapes that have been observed in egg production flocks following beak treatment include shovel and step beaks. These beak shapes are characterized by the elongation of the lower beak extending out beyond the top beak. With HBT, the creation of a shovel (SHV) or step (STP) beak has often been intentional (Bell and Kuney, 1991; Glatz and Runge, 2017) as it is believed that the slight elongation of the lower beak may reduce the bird's ability to grasp and damage the feathers and tissues of conspecifics. However, some studies have suggested that this slight elongation may result in difficulty grasping and consuming feed (Gentle et al., 1982; Prescott and Bonser, 2004). With IRBT, these beak shapes are not purposely created but rather represent variations from the standard treatment setting (STAN) which results in equal top and bottom beak lengths (beak shape is symmetrical).

In the present work, the different beak shapes (SHV, STP, and STAN) were intentionally created by adjusting the guard-plate, mirror shape, mirror material, and infrared intensity. In commercial settings, standard operating procedures written by the equipment manufacturer are provided to hatchery personnel to help ensure that specific IRBT settings are used based on bird species, strain, housing system, etc. However, if treatment efficacy is not monitored, large variations in beak shape and length can occur due to inappropriate IRBT settings and/or tissue growth. Since the goal of beak treatment is to reduce damage inflicted on birds from feather pecking, aggression, and cannibalism, the amount of tissue growth post-IRBT is very important to monitor. If too much tissue growth occurs, birds could still be successful in removing the feathers or damaging the tissues of other birds, even with shortened or blunted beaks. This has obvious welfare implications as the removal of feathers and tissue damage causes pain, exposed skin, and increases the risk of cannibalism (Gentle and Hunter, 1990; Gentle et al., 1997). It also has economic implications as feather removal and exposed skin can result in lower egg production and poor feed efficiency, leading to high feed costs for producers and lower income (Glatz, 1998; Honaker and Ruszler, 2004; Yamak and Sarica, 2012). Cannibalism can result in high levels of mortality in egg production flocks (Guesdon et al., 2006).

It has been suggested that following beak treatment, the lengths of the upper and lower beaks should resemble those of untreated beaks with the lower beak being slightly shorter than the upper one (Marchant-Forde et al., 2008). However, beyond stating that this would ensure normal beak function, the authors did not provide any science-based evidence for this suggestion. Some within the poultry industry have classified deviations from the standard (i.e. symmetrical) beak shape created by IRBT as severe beak "abnormalities" (Blatchford et al., 2016; Kajlich et al., 2016). Kajlich et al. (2016) classified severe beak "abnormalities" as a difference of length between the upper and lower beaks greater than 0.5 cm (not specified whether top or bottom beak was longer) and/or beaks that were abnormally shaped (curled, twisted, or improperly aligned) and found that 40 percent of the hens that were examined had severe beak "abnormalities". Blatchford et al. (2016) did not define what they considered severe "abnormalities" but reported that as much as 60 percent of birds sampled from 3 different housing systems had severely abnormal beaks. In a survey of beak "abnormalities" in layer and broiler chickens brought to a processing plant in Japan, Yamauchi et al. (2017) found that elongation of the lower beak (resulting in a shovel beak) accounted for almost 65 percent of all observed "abnormalities". The incidence of "abnormalities" in birds that came from beak treated flocks was almost 14 percent; however, details of the beak treatments including age at treatment, severity of treatment, and method were not provided in the study.

The viewpoint that any detectable difference between the top and bottom beak lengths is "abnormal" undermines the value of any amount of beak treatment especially since the classification has primarily been based off of visual observation of the physical appearance of the beak. Very little research has been conducted examining whether these beak shapes termed severe "abnormalities" negatively affect bird welfare, behaviour, and productivity. Previous studies have suggested that shovel beaks (which have been classified as a severe "abnormality") may negatively impact bird welfare by affecting their ability to grasp and consume feed (Gentle et al., 1982; Glatz, 2003), especially when feed is presented as a single layer (Prescott and Bonser, 2004). More recent research has reported that IRBT results in fewer beak "abnormalities" as compared to HBT (Marchant-Forde et al., 2008; Carruthers et al., 2012) and Hughes et al. (2017) found no differences in productivity and minor differences in behaviour between laying hens that had shovel beaks of varying lengths.

Another limitation is the fact that the majority of previous studies have not reported the specific IRBT settings used within their study or discussed the beak shapes that were observed post-treatment. The ideal IRBT-created beak shape would be one that causes no change in production and behaviour by allowing the bird to successfully grasp and consume feedstuffs and manipulate drinker systems while still maximizing bird welfare by improving feather cover, minimizing pain, and reducing mortality due to cannibalism. With regards to the parameters studied in the present work (summarized in Tables 4.1-4.4), very few differences were noted between the 3 beaks shapes that were created by adjusting IRBT settings (SHV, STP, and STAN). This suggests that the amount of beak tissue that was treated and subsequently sloughed off had minimal effects on production, behaviour, or welfare as determined by the parameters studied in this work. It also suggests that even if some minor variation in beak shape does occur, birds are still able to consume feed and water and perform normal behaviours. The beak shapes, particularly the SHV beak (which had the greatest elongation of the lower beak), did not appear to hinder the bird's ability to consume feed and water; however, during both the rearing and the laying period, feed was presented as a deep multilayer.

As previously discussed in Chapter 1, Kuenzel (2007) highlighted some of the major welfare concerns regarding beak treatment. The first of these was the reduced ability of the bird to perform normal behaviors such as feeding and drinking. Reductions in these behaviours would most certainly influence nutritive intake, growth, and bird welfare. The results of this research suggest that the change in beak shape or the sloughing of the beak tissue did not affect the expression of these behaviours or alter the bird's ability to eat or drink as compared to birds with natural, untreated beaks (Table 4.1). This supports data presented by Honaker and Ruszler (2004), who found that as birds matured, IRBT did not impede their ability to eat or drink. However, unlike in the present study, Honaker and Ruszler (2004) reported that IRBT treated birds had consistently lower body weights compared to birds with intact beaks throughout the rearing period. The authors suggested the reason for this slower rate of growth seen in IRBT treated birds was due to age at treatment (1 d). Since IRBT is only performed on day of hatch, it is not known whether treating birds using IBRT at older ages would cause the same reductions in body weight and growth. Other studies conducted using HBT have found that the younger the birds are trimmed, the less negative effects on body weight (Gentle et al., 1997; Schwean-Lardner et al., 2016).

During the rearing and laying periods in the present work, no differences in feed intake were found between birds with shortened beaks as a result of IRBT and birds with intact beaks. The effects of the IRBT treatments on body weight were not consistent with differences noted for pullets reared in floor pens but not pullets reared in cages. At 4 wk of age, floor-reared pullets with STAN beaks (small difference between the top and bottom beak length) were lighter than floor-reared pullets with intact beaks. The majority of previous research has reported an initial reduction in body weight and feed intake following IRBT in comparison to birds with intact beaks (Gentle and McKeegan, 2007; Marchant-Forde et al., 2008; Marchant-Forde and Cheng, 2010; Damme and Urselmans, 2013); however, these reductions were only seen until 3 to 4 wk post-treatment. From these studies, it is evident that IRBT treated birds undergo compensatory weight gain as they age (Honaker and Ruszler, 2004; Damme and Urselmans, 2013) and as the birds reach sexual maturity, any effects of IRBT are no longer apparent. This was clearly demonstrated in the present research as very few differences were seen between the IRBT treatments during the laying period, suggesting that IRBT treatment, regardless of settings and subsequent beak shape, does not result in long-term detrimental effects.

In terms of egg production and quality, previous research has demonstrated that beak treating egg production birds using IRBT can confer significant advantages. Damme and Urselmans (2013) found that IRBT treated laying hens had significantly higher egg production and lower mortality as compared to hens that were left with intact beaks. IRBT treated hens also had better feed conversion and higher egg income compared to control hens (Damme and Urselmans, 2013). In the present work, no differences in egg production were noted throughout the laying period; however, hens with SHV and STP beak shapes laid significantly less unsaleable eggs than C hens. Unsaleable egg production, particularly the production of soft-shelled and abnormally shaped eggs, is related to stress (Hughes et al., 1986; North, 2002) and the lower percentage of unsaleable eggs laid by SHV and STP hens in the present research may have been due to the fact that there was less aggression and cannibalism observed in treated hens during the laying period.

The second concern highlighted by Kuenzel (2007) was that beak treatment results in acute pain and stress. The results of the present research provide no evidence that birds experienced acute pain as a result of the IRBT treatment and this was clearly demonstrated during the sloughing period in this work. To the best of the author's knowledge, the present work is the first to directly examine how the beak sloughing that occurs because of IRBT affects various parameters during the early life of young layer pullets. One of the benefits of the IRBT system is that it allows birds to more easily adapt to the change in beak shape because the change is gradual rather than abrupt like with HBT. Despite being a gradual process, it is still possible that sloughing of the tissue may cause temporary reductions in feed intake and body weight due to either acute pain or the bird having to adapt to the new beak shape (Honaker and Ruszler, 2004; Marchant-Forde et al., 2008; Marchant-Forde and Cheng, 2010). However, these studies did not assess sloughing directly. During the period of sloughing in the present work, it was seen that nutritive intake and growth steadily increased with age suggesting that, in addition to being able to consume feed and water, beak treated birds were not experiencing pain or sensitivity from the IRBT treatments.

Sloughing and the subsequent change in beak shape also did not appear to affect the force with which birds used to peck, suggesting a lack of pain because birds were not hesitant to peck or use their beaks (Table 4.2). This differs somewhat from previous literature (Freire et al., 2008; Jongman et al., 2008; Dennis and Cheng, 2010b; Freire et al., 2011); however, the majority of these studies used HBT rather than IRBT, limiting the comparisons that can be made. Dennis and Cheng (2010b) reported that birds treated using HBT at 2 d of age pecked with less force until 3 wk post-treatment. Research in mammals has shown that after a nerve injury, animals require a period during which they relearn natural movement patterns by adjusting force and timing (Vanswearingen, 2008). Dennis and Cheng (2010b) suggested that this was the reason for why HBT treated birds pecked with less force initially. This period of relearning is not likely as noticeable with IRBT because of the gradual, rather than immediate loss of the beak tissue.

The behaviour that was observed during both the rearing and laying periods lends support to this and overall, there were few differences in behavioural expression (summarized in Table 4.3). When pullets were reared in cages, pullets with STAN beaks were more active (standing and walking) than pullets with untreated beaks. When pullets were reared in floor pens during early life, C pullets spent more time performing exploratory behaviours than pullets with STP or STAN beak shapes. Reduced exploratory behaviours could indicate a reluctance to use the beak due to pain or sensitivity. Increased time spent standing has also been interpreted as evidence of acute pain in IRBT treated birds (Marchant-Forde et al., 2008). However, considering that pecking force was not affected by IRBT treatment throughout the entire rearing period and that the differences in behaviour were short-term and were not seen after 5 wk of age, it is more likely that the differences in exploratory behaviour were because of altered sensory feedback in the treated beak tissue. This altered sensory feedback would make pecking at objects in the physical environment less rewarding (Jongman et al., 2008; Freire et al., 2011).

The other concerns discussed by Kuenzel (2007) include the formation of neuromas in the remaining beak tissue and chronic pain. Neuromas have only been reported with HBT and their formation is largely dependent on the age of the bird and the severity of trim (Lunam et al., 1996; Gentle et al., 1997; Schwean-Lardner et al., 2016). Histological samples of beaks were not collected for this study; however, previous research has indicated that IRBT does not result in neuroma formation (Gabrush, 2011; McKeegan and Philbey, 2012). Chronic pain has yet to be reported for IRBT (McKeegan and Philbey, 2012; Janczak and Riber, 2015) and in the present research, there was no indication that birds were in chronic pain (if any pain) as there were no long-term reductions in production, pecking force, or behaviour.

4.4 Conclusion

The beak shapes that were created by adjusting IRBT settings as well as the sloughing of the treated tissue had minor effects on production and behaviour during both the rearing and laying periods while simultaneously improving bird welfare in comparison to birds that had natural, untreated beaks. The amount of beak tissue treated and sloughed also did not appear to impact these parameters as very few differences were noted between the 3 beak shapes created by IRBT (summarized in Tables 4.1-4.4). Transient effects were seen on productivity during the rearing period. When pullets had an intermediate difference between the top and bottom beak length (resulting in a STP beak shape), water disappearance was lower than birds with untreated beaks. However, this did not translate into a reduction in feed intake or growth. When pullets had a small difference between the top and bottom beak length (resulting in a STAN beak shape), body weight was lighter than birds with untreated beaks; however, differences were no longer apparent after 4 wk of age. These differences may be due to the pullets having to adapt to the change in beak shape as the beak tissue sloughed rather than pain as there was no effect of IRBT treatment on pecking force. During the rearing and laying periods, minor differences in behaviour were observed after the beak tissue had sloughed; however, none of the behaviours where differences were noted were indicative of pain. During the laying period, hens with a STP beak had better feed efficiency compared to hens with untreated natural beaks, likely as a result of better feather cover and less feed wastage. The IRBT treatments, regardless of beak shape, improved feather cover and helped reduce damage inflicted upon the comb, resulting in better bird well-being by reducing aggressive behaviours and pain.

Finally, and perhaps most important, the IRBT treatments, regardless of final beak shape, significantly reduced mortality due to cannibalism. Preventing or reducing cannibalism is important because the behaviour can result in fear, pain, and mortality, all of which are detrimental to bird welfare (Hughes and Duncan, 1972; Glatz, 2000; Jendral and Robinson, 2004). The data from the present work demonstrates that when birds are left with untreated, intact beaks, they are more successful at damaging tissues and killing other birds, even if they are housed in conventional cages where the risk of cannibalism is typically lower than in more extensive housing systems (Lay Jr. et al., 2011). It has also been suggested that cannibalism may be strain related (Hughes and Duncan, 1972; Glatz, 2000) and the data from the present work strongly supports this. However, these previous studies found that cannibalism was higher in white-feathered strains as compared to brown-feathered strains, which is in disagreement with the results of the present work. In the present work, no incidences of cannibalism were observed for LW hens in any of the beak treatment groups; however, leaving LB hens with intact beaks resulted in almost 20 percent of birds dying due to cannibalism. Regardless of whether or not there is a genetic component to cannibalism, it is evident that by beak treating laying hens using IRBT, producers can reduce mortality, improve production, and optimize bird well-being.

This research is important because it provides science-based evidence and information on the impact that variations in beak shape post-IRBT can have on the productivity and welfare of layer pullets and hens. This research benefits the Canadian poultry industry as it helps further establish the importance of the beak treatment of laying hens. As commercial egg production systems begin to switch from conventional cages to more extensive forms of housing, the need for IRBT to help prevent and control cannibalism within laying hen flocks becomes even more important. Various alternative practices such as varying light intensity, using low feather pecking strains, and the use of enrichments have been studied as replacements for beak treatment (Jendral and Robinson, 2004). However, very few of these alternatives are currently as effective as beak treatment and it is clear that they should supplement beak treatment rather than replace it.

In conclusion, the data outlined in this thesis provide a better understanding of how the different beak shapes that result from altering IRBT settings and the subsequent sloughing of the treated tissue affect layer pullet and hen productivity, behaviour, and welfare. It illustrates how during early life, pullets are able to adapt to the change and maintain their ability to feed, drink, and peck. These data suggest that the IRBT treatments do not cause pain and that temporary changes in nutritive intake and behaviour during early life reported in previous studies are due more to the adaptation process than pain. These data also suggests that by shortening or blunting the beak, bird welfare can be improved substantially without compromising production. However, there is still limited research on the effects of IRBT and different IRBT treatments on beak anatomy, histology, and neurophysiology. Understanding these would help further substantiate that IRBT is an improved method of beak treatment. How IRBT stimulates the beak tissue as well as its influence on short-term pain (if any) and stress also warrants further investigation.

Table 4. 1. Summary of the effects of infrared beak treatments on the production performance of Lohmann LSL-Lite and Lohmann Brown pullets and hens.

<table>
<tr><th rowspan="2">Parameter</th><th colspan="4">Beak Treatment</th></tr>
<tr><th>SHV</th><th>STP</th><th>STAN</th><th>C</th></tr>
<tr><td><u>Rearing period (cages, 1 – 28 d)</u></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Body weight</td><td colspan="4">No effect</td></tr>
<tr><td>Feed intake</td><td colspan="4">No effect</td></tr>
<tr><td>Feed-to-gain, mortality corrected</td><td colspan="4">No effect</td></tr>
<tr><td>Water disappearance</td><td>-</td><td>Less than C
from 8 – 28 d</td><td>-</td><td>More than STP
from 8 – 28 d</td></tr>
<tr><td>Mortality</td><td colspan="4">No effect</td></tr>
<tr><td><u>Rearing period (floor pens, 1 d – 16 wk)</u></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Body weight</td><td>-</td><td>-</td><td>Lighter than C
at 4 wk only</td><td>Heavier than STAN
at 4 wk only</td></tr>
<tr><td>Mortality</td><td colspan="4">No effect</td></tr>
<tr><td><u>Laying period (18 – 42 wk)</u></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Body weight</td><td colspan="4">No effect</td></tr>
<tr><td>Feed intake</td><td colspan="4">No effect</td></tr>
<tr><td>Total feed per egg mass</td><td colspan="4">No effect</td></tr>
<tr><td>Total feed per dozen eggs</td><td colspan="4">No effect</td></tr>
<tr><td>Hen-day production</td><td colspan="4">No effect</td></tr>
<tr><td>Hen-housed production</td><td colspan="4">No effect</td></tr>
<tr><td>Saleable egg production</td><td>Higher than C</td><td>Higher than C</td><td>-</td><td>Less than SHV/STP</td></tr>
<tr><td>Unsaleable egg production</td><td>Less than C</td><td>Less than C</td><td>-</td><td>Higher than
SHV/STP</td></tr>
<tr><td>Egg weight</td><td colspan="4">No effect</td></tr>
<tr><td>Specific gravity</td><td colspan="4">No effect</td></tr>
<tr><td>Mortality</td><td>-</td><td>Less than C</td><td>Less than C</td><td>Higher than
STP/STAN</td></tr>
</table>

Mortality due to cannibalism	-	Less than C	Less than C	Higher than STP/STAN
<u>Laying period (42 – 60 wk)</u>				
Body weight		No effect		
Feed intake		No effect		
Total feed per egg mass		No effect		
Total feed per dozen eggs		No effect		
Total hen-day production		No effect		
Total hen-housed production		No effect		
Saleable egg production		No effect		
Unsaleable egg production		No effect		
Egg weight		No effect		
Specific gravity		No effect		
Mortality		No effect		
Mortality due to cannibalism		No effect		

SHV = large difference between top and bottom beak lengths
STP = intermediate difference between top and bottom beak lengths
STAN = small difference between top and bottom beak lengths
C = sham untreated control

Table 4. 2. Summary of the effects of infrared beak treatments on the beak characteristics and pecking force of Lohmann LSL-Lite and Lohmann Brown pullets.

Parameter	Beak Treatment			
	SHV	STP	STAN	C
Top beak length				
28 d	Shorter than C	Shorter than C	Shorter than C	Longer than SHV/STP/STAN
56 d	Shorter than C, longer than STAN	Shorter than C	Shorter than SHV/C	Longer than SHV/STP/STAN
84 d	Shorter than C, longer than STAN	Shorter than C	Shorter than SHV/C	Longer than SHV/STP/STAN
112 d	Shorter than C, longer than STAN	Shorter than C	Shorter than SHV/C	Longer than SHV/STP/STAN
Bottom beak length				
28 d	Shorter than C, longer than STP/STAN	Shorter than SHV/C	Shorter than SHV/C	Longer than SHV/STP/STAN
56 d	Longer than STP/STAN	Shorter than SHV/C	Shorter than SHV/C	Longer than STP/STAN
84 d	Longer than STP/STAN	Shorter than SHV/C	Shorter than SHV/C	Longer than STP/STAN
112 d	Longer than STP/STAN	Shorter than SHV	Shorter than SHV/C	Longer than STAN
Beak length ratio				
28 d	Lower than STAN/C	Lower than C	Higher than SHV	Higher than SHV/STP
56 d	Lower than STP/C	Lower than C	Lower than C	Higher than SHV/STP/STAN
84 d	Lower than C	Lower than C	Lower than C	Higher than SHV/STP/STAN
112 d	Lower than C	Lower than C	Lower than C	Higher than SHV/STP/STAN
Top beak growth (1 – 112 d)	Less than C, more than STAN	Less than C	Less than SHV and C	More than SHV/STP/STAN
Bottom beak growth (28 – 112 d)	More than C	-	-	Less than SHV
Pecking force	No effect			

SHV = large difference between top and bottom beak lengths
STP = intermediate difference between top and bottom beak lengths
STAN = small difference between top and bottom beak lengths
C = sham untreated control

Table 4. 3. Summary of the effects of infrared beak treatments on the behaviour (% of time) of Lohmann LSL-Lite and Lohmann Brown pullets and hens.

Parameter	Beak Treatment			
	SHV	STP	STAN	C
Rearing period (cages, 1 – 28 d)				
Nutritive	No effect			
Active	-	-	More than C	Less than STAN
Rest	No effect			
Preen	No effect			
Comfort	No effect			
Exploratory	No effect			
Aggression	No effect			
Low incidence	No effect			
Rearing period (floor pens, 1 d – 16 wk)				
Nutritive	No effect			
Active	No effect			
Rest	No effect			
Preen	No effect			
Comfort	No effect			
Exploratory	-	Less than C at 5 wk only	Less than C at 5 wk only	More than STP/STAN at 5 wk only
Aggression	No effect			
Low incidence	-	More than C at 5 wk only	More than C at 5 wk only	Less than STP/STAN at 5 wk only
Laying period (18 – 60 wk)				
Nutritive	No effect			
Active	No effect			
Rest	No effect			
Preen	More than C at 23 wk only	More than C at 23 wk only	-	Less than SHV/STP at 23 wk only
Comfort	No effect			
Exploratory	No effect			
Aggression	No effect			
Low incidence	No effect			

SHV = large difference between top and bottom beak lengths
STP = intermediate difference between top and bottom beak lengths
STAN = small difference between top and bottom beak lengths
C = sham untreated control

Table 4. 4. Summary of the effects of infrared beak treatments on the physical condition of Lohmann LSL-Lite and Lohmann Brown hens.

Parameter	Beak Treatment			
	SHV	STP	STAN	C
Feather cover	Better than C	Better than C	Better than C	Worse than SHV/STP/STAN
Comb damage	Less than C	Less than C	Less than C	More than SHV/STP/STAN

SHV = large difference between top and bottom beak lengths
STP = intermediate difference between top and bottom beak lengths
STAN = small difference between top and bottom beak lengths
C = sham untreated control

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6.0 Appendices

Table 6. 1. Ingredients and nutrient composition of diets fed to Lohmann LSL-Lite and Lohmann Brown pullets and hens from 1 d to 60 wk of age.

Ingredients (%)	Starter (1 d–6 wk)	Grower (6–10 wk)	Developer (10–16 wk)	Pre-lay (16–18 wk)	Layer (18–60 wk)
Barley	10.00	0.00	18.00	0.00	0.00
Wheat	42.90	57.24	56.43	53.08	51.98
Soybean meal	0.00	6.74	2.50	5.36	145.00
Corn	12.00	0.00	0.00	5.00	10.00
Peas/Lentils	10.00	18.88	6.05	8.72	0.00
Meat meal restricted	9.50	0.00	0.00	0.0	5.00
Canola meal	7.00	9.08	10.00	10.0	0.00
Corn distillers' dried grains with solubles	5.52	3.74	1.61	0.00	5.00
Extruded pea canola	0.00	0.00	0.00	9.59	0.00
Tallow	1.00	0.00	0.00	0.00	2.50
Oat hulls	0.00	0.00	1.50	0.00	0.00
Canola Oil	0.00	1.00	1.00	1.00	0.00
Di-calcium phosphate (21%)	0.00	0.00	0.00	0.00	0.00
Mono-calcium phosphate	0.00	0.49	0.36	0.74	0.74
Limestone	0.79	1.68	1.68	5.72	9.50
Salt	0.00	0.00	0.23	0.24	0.27
Sodium bicarbonate	0.00	0.21	0.14	0.12	0.40
Choline chloride	0.08	0.00	0.00	0.00	0.00
Endofeed[1]	0.02	0.02	0.02	0.03	0.00
Ronozyme P-CT[2]	0.00	0.03	0.03	0.03	0.00
DL-Methionine	0.08	0.08	0.07	0.08	0.20
L-Lysine HCL	0.16	0.00	0.03	0.00	0.13
L-Threonine	0.00	0.02	0.00	0.00	0.00
Mono-calcium carbonate	0.28	0.00	0.00	0.00	0.00
Potassium chloride	0.08	0.00	0.00	0.00	0.00
Biotin	0.02	0.00	0.00	0.00	0.00
Amprolium 25%[3]	0.05	0.03	0.03	0.00	0.00
DG-200mg Selenium	0.04	0.14	0.14	0.15	0.00
V8V[4]	0.08	0.08	0.08	0.07	0.62
M2M[5]	0.06	0.07	0.08	0.08	0.75
Termin-8[6]	0.00	0.15	0.00	0.00	0.00

Nutrients	**Starter (1 d–6 wk)**	**Grower (6–10 wk)**	**Developer (10–16 wk)**	**Pre-lay (16–18 wk)**	**Layer (18–60 wk)**
ME (kcal/kg)	2738	2750	2725	2750	2634
Crude protein (%)	19.20	19.10	16.00	17.70	19.10
Calcium (%)	0.96	0.92	0.88	2.45	3.92
Chloride (mg/kg)	0.70	0.20	0.20	0.20	949.90
Non-phytate phosphorus (%)	0.43	0.40	0.36	0.44	0.38
Sodium (%)	0.17	0.16	0.15	0.15	0.17
Arg (%)	1.13	1.03	0.78	0.91	1.09
Ile (%)	0.66	0.61	0.49	0.56	0.69
Lys (%)	0.99	0.97	0.56	0.69	0.93
Met (%)	0.39	0.37	0.29	0.31	0.49
Met + Cys (%)	0.73	0.72	0.66	0.59	0.81
Thr (%)	0.64	0.55	0.43	0.50	0.63
Trp (%)	0.18	0.19	0.16	0.22	0.22

[1]β-glucanase, 700 activity units/g and xylanase enzymes 2,250 activity units/g (GNC Bioferm Inc., Bradwell, Canada)
[2]Phytase enzyme, 2500 FYT/g (DSM Nutritional Products, Heerlen, the Netherlands)
[3]Coccidiostat
[4]Supplied per kilogram of diet: vitamin A (retinyl acetate + retinyl palmitate), 11000 IU; vitamin D3, 2200 IU; vitamin E (dl-α-topheryl acetate), 30 IU; menadione, 2.0 mg; thiamine, 1.5 mg; riboflavin, 6.0 mg; niacin, 60 mg; pyridoxine, 4 mg; vitamin B12, 0.02 mg; pantothenic acid, 10.0 mg; folic acid, 0.6 mg; and biotin, 0.15 mg; ethoxyquin, 0.625 mg; calcium carbonate, 500 mg.
[5]Supplied per kilogram of feed: iron, 80 mg; zinc, 80 mg; manganese, 80 mg; copper, 10 mg; iodine, 0.8 mg; and selenium, 0.3 mg.
[6]Pathogen control (*Salmonella spp*., molds) (Anitox, Lawrenceville, USA)

Table 6. 2. Effect of infrared beak treatments and strain on the pecking force (N) of Lohmann LSL-Lite and Lohmann Brown pullets housed in cages from 1 to 28 d of age and floor pens from 28 to 112 d of age.

Age (d)	Beak Treatment					Strain			Interaction	SEM
	SHV	STP	STAN	C	*P*-value	LB	LW	*P*-value	*P*-value	
7	7	7	8	7	0.775	7	7	0.921	0.938	0.3
14	11	12	11	10	0.136	12[a]	10[b]	0.001	0.265	0.4
21	11	10	12	12	0.768	12	11	0.191	0.555	0.5
28	18	20	19	19	0.132	20[a]	18[b]	0.001	0.025	0.4
56	24	22	24	23	0.622	23	23	0.881	0.582	0.6
84	33	31	33	36	0.623	35	32	0.263	0.873	1.1
112	39	33	37	34	0.206	36	36	0.794	0.272	1.1

[a, b] Means within a main effect with different superscripts are significantly different ($P \leq 0.05$)

SHV = large difference between top and bottom beak lengths

STP = intermediate differentiation

STAN = small differentiation

C = untreated control

LB = Lohmann Brown

LW = Lohmann LSL-Lite

Table 6. 3. Interaction between infrared beak treatments and strain for the pecking force (N) at 28 d of age of Lohmann LSL-Lite and Lohmann Brown pullets.

Strain	Beak Treatment			
	SHV	STP	STAN	C
LB	19^{ab}	22^{a}	22^{a}	19^{ab}
LW	17^{b}	19^{ab}	17^{b}	19^{ab}

$^{a, b}$ Means with different superscripts are significantly different ($P \leq 0.05$)
SHV = large difference between top and bottom beak lengths
STP = intermediate differentiation
STAN = small differentiation
C = untreated control
LB = Lohmann Brown
LW = Lohmann LSL-Lite

Table 6. 4. Effect of infrared beak treatments and strain on the individual behaviours (% of time) of Experiment 1c Lohmann LSL-Lite and Lohmann Brown pullets over an 8-h period from 9 to 27 d of age.

Behaviour	Beak Treatment					Strain			Interaction	SEM
	SHV	STP	STAN	C	*P*-value	LB	LW	*P*-value	*P*-value	
Feeding	18.56	19.26	17.67	23.85	0.073	18.37	21.30	0.833	0.633	0.897
Drinking	4.49	5.24	4.88	4.11	0.735	3.99	5.37	0.068	0.697	0.322
Resting	10.31	10.89	10.06	10.49	0.962	11.03^{a}	9.85^{b}	0.035	0.645	0.442
Perching	2.62	2.24	2.36	1.52	0.373	3.78^{a}	0.59^{b}	<0.001	0.533	0.464
Preening	6.82	7.24	6.74	7.31	0.773	6.76	7.30	0.942	0.551	0.265
Standing	36.95^{a}	36.55^{a}	35.80^{ab}	31.10^{b}	0.026	36.76^{a}	33.44^{b}	0.009	0.270	1.007
Walking	4.41	4.08	5.91	5.36	0.325	5.05	4.83	0.058	0.627	0.348
Head Shaking	0.05	0.03	0.00	0.08	0.359	0.07	0.01	0.065	0.331	0.016
Head Scratching	0.45	0.55	0.57	0.62	0.503	0.55	0.55	0.297	0.096	0.039
Sham Dustbathing	0.06	0.11	0.15	0.21	0.355	0.14	0.12	0.625	0.828	0.026
Beak Wiping	0.58	0.47	0.48	0.63	0.759	0.45	0.63	0.228	0.420	0.054
Feather Ruffle	0.08	0.12	0.03	0.06	0.073	0.06	0.08	0.468	0.008	0.018
Leg Stretch	0.56	0.39	0.47	0.58	0.384	0.46	0.54	0.613	0.617	0.038
Wing Flap	0.27^{b}	0.59^{ab}	0.28^{b}	0.65^{a}	0.049	0.46	0.44	0.388	0.889	0.051
Wing Stretch	0.17^{a}	0.14^{ab}	0.05^{b}	0.16^{ab}	0.021	0.14	0.11	0.087	0.033	0.019
Gentle Peck	1.14	1.08	1.26	0.78	0.238	0.79^{b}	1.34^{a}	0.035	0.736	0.121
Aggressive Peck	0.03	0.00	0.03	0.03	0.415	0.02	0.02	0.658	0.185	0.009
Object Peck	2.09	2.47	3.53	3.40	0.495	1.66^{b}	4.09^{a}	0.010	0.723	0.465
Unknown	10.36	8.56	9.73	9.07	0.775	9.46	9.40	0.921	0.987	0.375

$^{a, b}$ Means within a main effect with different superscripts are significantly different ($P \leq 0.05$)
SHV = large difference between top and bottom beak lengths
STP = intermediate differentiation
STAN = small differentiation
C = untreated control
LB = Lohmann Brown
LW = Lohmann LSL-Lite

Table 6. 5. Interaction between infrared beak treatments and strain on the behaviour (% of time) of Experiment 1c Lohmann LSL-Lite and Lohmann Brown pullets from 9 to 27 d of age.

Behaviour	Strain x Beak Treatment							
	LB SHV	LW SHV	LB STP	LW STP	LB STAN	LW STAN	LB C	LW C
Feather ruffling	0.12^{ab}	0.03^{b}	0.03^{b}	0.21^{a}	0.06^{ab}	0.00^{b}	0.03^{b}	0.08^{ab}
Wing stretching	0.24^{a}	0.09^{ab}	0.18^{ab}	0.09^{ab}	0.03^{b}	0.08^{b}	0.12^{ab}	0.19^{ab}

$^{a, b}$ Means within a row with different superscripts are significantly different ($P \leq 0.05$)
SHV = large difference between top and bottom beak lengths
STP = intermediate differentiation
STAN = small differentiation
C = untreated control
LB = Lohmann Brown
LW = Lohmann LSL-Lite

Table 6. 6. Effect of infrared beak treatments and strain on the individual behaviours (% of time) of Experiment 2a Lohmann LSL-Lite and Lohmann Brown pullets over a 24-h period at 5 wk of age.

Behaviour	Beak Treatment					Strain			Interaction	SEM
	SHV	STP	STAN	C	*P*-value	LB	LW	*P*-value	*P*-value	
Feeding	5.17	5.43	5.29	4.97	0.892	5.21	5.21	0.336	0.783	0.15
Drinking	2.16	1.96	2.07	1.94	0.759	1.65^{b}	2.41^{a}	0.008	0.493	0.13
Resting	69.85	70.19	69.78	70.60	0.807	68.91^{b}	71.30^{a}	0.007	0.690	0.44
Perching	0.84^{b}	1.35^{ab}	1.69^{a}	0.96^{b}	0.018	0.83^{b}	1.60^{a}	0.001	0.004	0.20
Preening	3.41	3.47	3.61	3.28	0.998	3.62	3.27	0.522	0.215	0.22
Standing	7.18	6.38	6.86	5.73	0.446	7.88^{a}	5.19^{b}	0.001	0.253	0.53
Walking	2.37	2.87	2.46	2.82	0.162	2.67	2.59	0.362	0.489	0.12
Head Shaking	0.01	0.00	0.01	0.01	0.690	0.02	0.00	0.066	0.690	0.00
Head Scratching	0.13	0.08	0.07	0.09	0.251	0.08	0.10	0.200	0.075	0.01
Dustbathing	0.23	0.24	0.19	0.11	0.140	0.19	0.19	0.701	0.312	0.02
Beak Wiping	0.07^{a}	0.06^{a}	0.06^{a}	0.02^{b}	0.015	0.02^{b}	0.08^{a}	<0.001	0.015	0.01
Feather Ruffle	0.03	0.05	0.03	0.05	0.255	0.05	0.03	0.287	0.220	0.01
Leg Stretch	0.03	0.02	0.05	0.05	0.272	0.04	0.04	0.749	0.293	0.01
Wing Flap	0.07	0.02	0.06	0.05	0.283	0.05	0.05	0.550	0.207	0.01
Wing Stretch	0.01	0.00	0.03	0.01	0.195	0.01	0.07	0.446	0.059	0.01
Gentle Peck	0.41^{b}	0.42^{b}	0.62^{a}	0.33^{b}	0.002	0.48	0.41	0.073	0.412	0.03
Aggressive Peck	0.01	0.00	0.01	0.01	0.709	0.02	0.00	0.253	0.665	0.00
Object Peck	6.91^{ab}	6.20^{b}	5.93^{b}	7.80^{a}	0.049	6.80	6.63	0.185	0.686	0.33
Unknown	1.11	1.26	1.18	1.17	0.898	1.48^{a}	0.88^{b}	0.007	0.576	0.11

$^{a, b}$ Means within a main effect with different superscripts are significantly different ($P \leq 0.05$)
SHV = large difference between top and bottom beak lengths
STP = intermediate differentiation
STAN = small differentiation
C = untreated control
LB = Lohmann Brown
LW = Lohmann LSL-Lite

Table 6. 7. Effect of infrared beak treatments and strain on the individual behaviours (% of time) of Experiment 2a Lohmann LSL-Lite and Lohmann Brown pullets over a 24-h period at 9 wk of age.

Behaviour	Beak Treatment					Strain			Interaction	SEM
	SHV	STP	STAN	C	*P*-value	LB	LW	*P*-value	*P*-value	
Feeding	3.23	3.60	3.55	2.59	0.275	3.32	3.17	0.705	0.935	0.153
Drinking	1.68	1.92	1.94	1.67	0.749	1.65	1.95	0.651	0.618	0.080
Resting	65.12	65.04	62.55	66.72	0.653	68.77	60.94	0.192	0.849	1.213
Perching	6.66	5.66	8.93	5.75	0.248	1.72^{b}	11.78^{a}	<0.001	0.660	1.445
Preening	4.34	5.20	4.95	4.64	0.379	4.70	4.86	0.203	0.368	0.168
Standing	9.29	8.94	8.77	8.48	0.470	9.27^{a}	8.47^{b}	0.013	0.728	0.309
Walking	2.28	2.06	2.25	1.94	0.225	2.45^{a}	1.82^{b}	0.001	0.410	0.102
Head Shaking	0.04	0.05	0.07	0.05	0.610	0.06	0.04	0.408	0.972	0.009
Head Scratching	0.17	0.17	0.13	0.13	0.192	0.15	0.15	0.561	0.013	0.013
Dustbathing	0.10	0.15	0.20	0.12	0.435	0.13	0.16	0.629	0.602	0.022
Beak Wiping	0.02	0.03	0.03	0.02	0.763	0.01	0.04	0.060	0.208	0.007
Feather Ruffle	0.03	0.04	0.04	0.03	0.702	0.03^{b}	0.05^{a}	0.005	0.010	0.005
Leg Stretch	0.03	0.05	0.07	0.03	0.179	0.04	0.05	0.729	0.161	0.008
Wing Flap	0.03	0.04	0.06	0.04	0.904	0.07	0.02	0.120	0.352	0.013
Wing Stretch	0.03	0.02	0.02	0.01	0.639	0.03	0.02	0.402	0.262	0.006
Gentle Peck	0.33^{ab}	0.54^{a}	0.49^{ab}	0.22^{b}	0.016	0.48^{a}	0.31^{b}	0.043	0.270	0.048
Aggressive Peck	0.04	0.03	0.09	0.03	0.776	0.04	0.05	0.269	0.416	0.016
Object Peck	6.03	6.00	5.55	6.92	0.505	6.66	5.59	0.080	0.326	0.281
Unknown	0.56	0.45	0.30	0.59	0.074	0.42	0.53	0.130	0.551	0.048

$^{a, b}$ Means within a main effect with different superscripts are significantly different ($P \leq 0.05$)
SHV = large difference between top and bottom beak lengths
STP = intermediate differentiation
STAN = small differentiation
C = untreated control
LB = Lohmann Brown
LW = Lohmann LSL-Lite

Table 6. 8. Effect of infrared beak treatments and strain on the individual behaviours (% of time) of Experiment 2a Lohmann LSL-Lite and Lohmann Brown pullets over a 24-h period at 13 wk of age.

Behaviour	Beak Treatment					Strain			Interaction	SEM
	SHV	STP	STAN	C	*P*-value	LB	LW	*P*-value	*P*-value	
Feeding	2.86	3.18	2.93	2.33	0.346	2.64	3.01	0.223	0.491	0.137
Drinking	1.21	1.28	1.59	1.39	0.225	1.33	1.40	0.371	0.360	0.081
Resting	60.87	58.85	58.78	61.03	0.675	66.55	53.23	0.122	0.134	1.838
Perching	8.07	8.33	9.39	7.84	0.313	1.39[b]	15.42[a]	<0.001	0.481	1.896
Preening	6.23	7.41	7.01	6.09	0.090	6.53[b]	6.84[a]	0.001	0.104	0.234
Standing	11.49	11.80	11.71	11.54	0.709	12.45	10.82	0.806	0.308	0.370
Walking	1.89	1.74	1.58	1.95	0.090	1.88	1.70	0.319	0.177	0.068
Head Shaking	0.05	0.07	0.05	0.04	0.553	0.06	0.04	0.198	0.162	0.008
Head Scratching	0.11	0.14	0.13	0.11	0.639	0.10	0.15	0.089	0.441	0.012
Dustbathing	0.00[b]	0.00[b]	0.00[b]	0.05[a]	<0.001	0.02[a]	0.01[b]	0.027	0.012	0.006
Beak Wiping	0.01	0.01	0.01	0.02	0.601	0.01	0.02	0.080	0.097	0.004
Feather Ruffle	0.01	0.03	0.03	0.05	0.364	0.03	0.03	0.929	0.348	0.007
Leg Stretch	0.03	0.03	0.02	0.02	0.913	0.02	0.03	0.506	0.790	0.006
Wing Flap	0.01	0.03	0.03	0.03	0.844	0.03	0.02	0.846	0.986	0.006
Wing Stretch	0.01	0.01	0.00	0.00	0.073	0.01	0.00	0.356	0.021	0.003
Gentle Peck	0.20	0.21	0.26	0.13	0.246	0.24	0.16	0.075	0.041	0.028
Aggressive Peck	0.01	0.03	0.01	0.03	0.630	0.01	0.03	0.404	0.943	0.007
Object Peck	6.38	6.29	6.04	6.94	0.407	6.12	6.70	0.142	0.421	0.216
Unknown	0.53	0.56	0.44	0.42	0.665	0.59[a]	0.39[b]	0.029	0.922	0.043

[a, b] Means within a main effect with different superscripts are significantly different ($P \leq 0.05$)
SHV = large difference between top and bottom beak lengths
STP = intermediate differentiation
STAN = small differentiation
C = untreated control
LB = Lohmann Brown
LW = Lohmann LSL-Lite

Table 6. 9. Effect of infrared beak treatments and strain on the individual behaviours (% of time) of Experiment 2a Lohmann LSL-Lite and Lohmann Brown pullets over a 24-h period at 17 wk of age.

Behaviour	Beak Treatment					Strain			Interaction	SEM
	SHV	STP	STAN	C	*P*-value	LB	LW	*P*-value	*P*-value	
Feeding	2.38	2.46	2.41	2.14	0.570	1.96^{b}	2.74^{a}	<0.001	0.296	0.122
Drinking	1.14	1.52	1.51	1.14	0.123	1.39	1.27	0.687	0.307	0.103
Resting	57.63	58.20	58.69	58.96	0.304	66.39	50.35	0.139	0.141	2.101
Perching	10.58	9.42	9.27	9.63	0.093	2.12^{b}	17.34^{a}	<0.001	0.082	2.002
Preening	6.45	6.46	6.36	5.88	0.878	5.99^{b}	6.58^{a}	0.003	0.672	0.202
Standing	13.11	13.53	12.96	14.07	0.917	13.49^{a}	13.34^{b}	0.003	0.513	0.276
Walking	1.53	1.57	1.70	1.64	0.915	1.54	1.68	0.247	0.036	0.083
Head Shaking	0.06	0.07	0.07	0.03	0.206	0.05	0.07	0.230	0.231	0.009
Head Scratching	0.07	0.09	0.11	0.07	0.765	0.08	0.09	0.682	0.433	0.012
Dustbathing	0.15	0.09	0.09	0.06	0.317	0.16^{a}	0.03^{b}	0.002	0.228	0.024
Beak Wiping	0.01	0.01	0.01	0.00	0.555	0.00	0.02	0.054	0.555	0.004
Feather Ruffle	0.03	0.04	0.07	0.04	0.381	0.06	0.03	0.135	0.574	0.007
Leg Stretch	0.01	0.01	0.00	0.02	0.504	0.01	0.01	0.499	0.922	0.004
Wing Flap	0.02	0.02	0.01	0.03	0.479	0.03	0.01	0.121	0.794	0.006
Wing Stretch	0.01	0.03	0.01	0.01	0.481	0.01	0.02	0.719	0.058	0.005
Gentle Peck	0.24	0.36	0.31	0.20	0.130	0.36^{a}	0.19^{b}	0.004	0.376	0.034
Aggressive Peck	0.02	0.02	0.03	0.01	0.372	0.00^{b}	0.04^{a}	0.011	0.096	0.008
Object Peck	6.18	5.82	6.20	5.69	0.399	5.89	6.05	0.400	0.099	0.189
Unknown	0.38	0.27	0.20	0.39	0.500	0.47^{a}	0.14^{b}	0.007	0.288	0.061

[a, b] Means within a main effect with different superscripts are significantly different ($P \leq 0.05$)

SHV = large difference between top and bottom beak lengths

STP = intermediate differentiation

STAN = small differentiation

C = untreated control

LB = Lohmann Brown

LW = Lohmann LSL-Lite

Table 6. 10. Interactions between infrared beak treatments and strain on the individual behaviours (% of time) of Experiment 2a Lohmann LSL-Lite and Lohmann Brown pullets over 24-h.

Age (wk)	Behaviour	Strain x Beak Treatment							
		LB SHV	LW SHV	LB STP	LW STP	LB STAN	LW STAN	LB C	LW C
5	Perching	1.05^{b}	0.63^{b}	0.62^{b}	2.09^{a}	0.73^{b}	2.65^{a}	0.91^{b}	1.01^{b}
	Beak wiping	0.01^{c}	0.12^{a}	0.01^{c}	0.11^{ab}	0.04^{bc}	0.08^{abc}	0.01^{c}	0.03^{c}
9	Feather ruffling	0.04^{ab}	0.03^{b}	0.03^{b}	0.05^{ab}	0.01^{b}	0.07^{a}	0.03^{b}	0.04^{ab}
	Head scratching	0.22^{a}	0.11^{ab}	0.17^{ab}	0.16^{ab}	0.08^{b}	0.18^{ab}	0.12^{ab}	0.14^{ab}
13	Dustbathing	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.07^{a}	0.03^{b}
	Wing stretching	0.00^{b}	0.01^{ab}	0.03^{a}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}
	Gentle pecking	0.24^{ab}	0.16^{b}	0.16^{b}	0.26^{ab}	0.42^{a}	0.09^{b}	0.14^{b}	0.12^{b}
17	Walking	1.29^{b}	1.77^{ab}	1.87^{ab}	1.27^{b}	1.72^{ab}	1.67^{ab}	1.28^{b}	2.00^{a}

^{a,b,c} Means within a row with different superscripts are significantly different ($P \leq 0.05$)
SHV = large difference between top and bottom beak lengths
STP = intermediate differentiation
STAN = small differentiation
C = untreated control
LB = Lohmann Brown
LW = Lohmann LSL-Lite

Table 6. 11. Effect of infrared beak treatments and strain on the feed consumption (g/bird/d) of Experiment 2b Lohmann LSL-Lite and Lohmann Brown hens from 18 to 42 wk of age and Lohmann LSL-Lite hens from 42 to 60 wk of age.

Age (wk)	Beak Treatment					Strain			Interaction	SEM
	SHV	STP	STAN	C	*P*-value	LB	LW	*P*-value	*P*-value	
18 – 22	95.9^{ab}	93.1^{b}	93.0^{b}	98.4^{a}	<0.001	100.2^{a}	90.0^{b}	<0.001	0.006	0.93
22 – 26	113.1^{ab}	111.8^{b}	112.1^{b}	116.1^{a}	0.018	115.8^{a}	110.8^{b}	<0.001	0.180	0.66
26 – 30	121.3	120.4	121.7	123.3	0.409	124.6^{a}	118.8^{b}	<0.001	0.117	0.77
30 – 34	120.3	119.4	120.6	122.0	0.519	122.7^{a}	118.5^{b}	0.001	0.105	0.68
34 – 38	120.6	120.6	122.4	122.1	0.626	122.2	120.7	0.243	0.405	0.64
38 – 42	122.2	120.4	122.5	121.6	0.849	121.0	122.3	0.448	0.669	0.86
42 – 46	126.2	125.1	128.1	125.9	0.793	-	126.3	-	-	1.03
46 – 50	127.6	129.1	136.2	131.2	0.510	-	131.0	-	-	2.17
50 – 54	120.6	121.6	125.0	128.6	0.306	-	123.9	-	-	1.63
54 – 58	124.9	123.9	127.7	130.3	0.358	-	126.7	-	-	1.38
58 – 60	116.0^{b}	117.9^{ab}	124.3^{ab}	126.8^{a}	0.033	-	121.2	-	-	1.57
18 – 60	117.7	117.3	118.7	120.0	0.390	117.7	119.1	0.245	0.273	0.60

$^{a,\,b}$ Means within a main effect with different superscripts are significantly different ($P \leq 0.05$)

SHV = large difference between top and bottom beak lengths

STP = intermediate differentiation

STAN = small differentiation

C = untreated control

LB = Lohmann Brown

LW = Lohmann LSL-Lite

Table 6. 12. Interaction between infrared beak treatments and strain on the feed consumption (g/bird/d) at 22 wk of Experiment 2b Lohmann LSL-Lite and Lohmann Brown hens housed in conventional cages from 18 to 42 wk of age.

Strain	Beak Treatment			
	SHV	STP	STAN	C
LB	101.11^{a}	100.56^{a}	97.31^{ab}	101.76^{a}
LW	90.68^{cd}	85.68^{d}	88.64^{d}	95.08^{bc}

$^{a, b, c, d}$ Means with different superscripts are significantly different ($P \leq 0.05$)

SHV = large difference between top and bottom beak lengths

STP = intermediate differentiation

STAN = small differentiation

C = untreated control

LB = Lohmann Brown

LW = Lohmann LSL-Lite

Table 6. 13. Effect of infrared beak treatments and strain on the individual behaviours (% of time) of Experiment 2b Lohmann LSL-Lite and Lohmann Brown hens over a 24-h period at 23 wk of age.

Behaviour	Beak Treatment					Strain			Interaction	SEM
	SHV	STP	STAN	C	*P*-value	LB	LW	*P*-value	*P*-value	
Feeding	12.08	12.29	13.04	12.04	0.526	11.74	12.99	0.698	0.522	0.434
Drinking	2.41	3.10	2.92	3.61	0.092	2.97	3.05	0.762	0.797	0.164
Resting	43.53	44.49	44.31	44.25	0.115	43.43^{b}	44.86^{a}	0.001	0.411	0.284
Perching	0.00	0.00	0.00	0.00	-	0.00	0.00	-	-	0.000
Preening	6.36^{a}	6.83^{a}	6.20^{ab}	5.43^{b}	0.022	5.04^{b}	7.38^{a}	<0.001	0.173	0.399
Standing	26.29	23.34	23.07	24.82	0.305	28.39^{a}	20.37^{b}	0.001	0.961	1.183
Walking	0.48	0.80	0.96	0.83	0.576	0.46^{b}	1.08^{a}	0.013	0.587	0.136
Head Shaking	0.00	0.00	0.02	0.01	0.562	0.02	0.00	0.216	0.562	0.006
Head Scratching	0.02	0.02	0.11	0.02	0.175	0.04	0.05	0.708	0.735	0.016
Dustbathing	0.14	0.09	0.07	0.06	0.227	0.08	0.09	0.694	0.515	0.015
Beak Wiping	0.00	0.00	0.00	0.00	-	0.00	0.00	-	-	0.000
Feather Ruffle	0.00	0.00	0.03	0.03	0.193	0.01	0.02	0.439	0.193	0.008
Leg Stretch	0.00	0.02	0.00	0.00	0.447	0.01	0.00	0.351	0.447	0.005
Wing Flap	0.00	0.05	0.00	0.00	0.122	0.03	0.00	0.141	0.122	0.011
Wing Stretch	0.02	0.03	0.00	0.03	0.648	0.03	0.02	0.601	0.710	0.009
Gentle Peck	0.80	0.52	0.57	0.59	0.344	0.36^{b}	0.88^{a}	0.001	0.018	0.102
Aggressive Peck	0.05	0.14	0.10	0.20	0.444	0.17	0.08	0.105	0.554	0.030
Object Peck	1.67	1.67	1.78	1.64	0.996	1.52	1.86	0.385	0.372	0.175
Unknown	6.13	6.60	6.83	6.43	0.812	5.71^{b}	7.28^{a}	0.016	0.437	0.329

$^{a, b}$ Means within a main effect with different superscripts are significantly different ($P \leq 0.05$)
SHV = large difference between top and bottom beak lengths
STP = intermediate differentiation
STAN = small differentiation
C = untreated control
LB = Lohmann Brown
LW = Lohmann LSL-Lite

Table 6. 14. Interaction between infrared beak treatments and strain on gentle pecking behaviour (% of time) of Experiment 2b Lohmann LSL-Lite and Lohmann Brown hens at 23 wk of age.

Strain	Beak Treatment			
	SHV	STP	STAN	C
LB	0.30^{bc}	0.35^{bc}	0.65^{abc}	0.13^{c}
LW	1.30^{a}	0.68^{abc}	0.49^{abc}	1.04^{ab}

^{a,b,c} Means with different superscripts are significantly different ($P \leq 0.05$)

SHV = large difference between top and bottom beak lengths

STP = intermediate differentiation

STAN = small differentiation

C = untreated control

LB = Lohmann Brown

LW = Lohmann LSL-Lite

Table 6. 15. Effect of infrared beak treatments and strain on the individual behaviours (% of time) of Experiment 2b Lohmann LSL-Lite and Lohmann Brown hens over a 24-h period at 39 wk of age.

Behaviour	Beak Treatment					Strain			Interaction	SEM
	SHV	STP	STAN	C	*P*-value	LB	LW	*P*-value	*P*-value	
Feeding	14.25	13.35	13.81	12.66	0.129	12.47	14.56	0.062	0.842	0.478
Drinking	1.51	1.66	1.74	2.38	0.336	1.61	2.04	0.131	0.827	0.155
Resting	43.46	45.59	44.71	45.58	0.834	43.77^{b}	45.89^{a}	<0.001	0.867	0.461
Perching	0.00	0.00	0.00	0.00	-	0.00	0.00	-	-	0.000
Preening	4.91	5.35	5.45	6.70	0.342	5.18^{b}	6.03^{a}	0.009	0.446	0.347
Standing	27.63	24.81	24.78	25.32	0.226	29.12	22.15	0.129	0.529	1.118
Walking	0.52	0.31	0.23	0.32	0.312	0.38	0.31	0.971	0.640	0.067
Head Shaking	0.00	0.00	0.00	0.00	-	0.00	0.00	-	-	0.000
Head Scratching	0.02	0.04	0.12	0.06	0.084	0.03^{b}	0.09^{a}	0.037	0.242	0.019
Dustbathing	0.07	0.04	0.18	0.05	0.397	0.09	0.09	0.964	0.586	0.028
Beak Wiping	0.00	0.00	0.00	0.00	-	0.00	0.00	-	-	0.000
Feather Ruffle	0.00	0.01	0.02	0.00	0.519	0.01	0.01	0.647	0.313	0.006
Leg Stretch	0.03	0.00	0.01	0.02	0.731	0.02	0.01	0.387	0.421	0.008
Wing Flap	0.00	0.00	0.01	0.02	0.560	0.02	0.00	0.217	0.560	0.006
Wing Stretch	0.00	0.00	0.02	0.00	0.447	0.00	0.01	0.351	0.447	0.006
Gentle Peck	0.33	0.45	0.44	0.61	0.658	0.58	0.33	0.099	0.445	0.065
Aggressive Peck	0.03	0.06	0.07	0.07	0.710	0.08	0.03	0.106	0.315	0.012
Object Peck	1.21	1.21	1.34	0.92	0.781	0.96	1.38	0.190	0.825	0.142
Unknown	6.02	7.11	7.07	5.29	0.477	5.68	7.07	0.097	0.555	0.469

$^{a, b}$ Means within a main effect with different superscripts are significantly different ($P \leq 0.05$)
SHV = large difference between top and bottom beak lengths
STP = intermediate differentiation
STAN = small differentiation
C = untreated control
LB = Lohmann Brown
LW = Lohmann LSL-Lite

Presentations

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