AUSTRALIAN POULTRY CRC

FINAL REPORT

Program (3)

PROJECT LEADERS: Dr Phil Glatz and Assoc Prof Geoff Hinch

DATE OF COMPLETION: 12/06/2008

Minimise cannibalism using innovative beak trimming methods

ISBN 1 921010 28 2

Project No. 04-20: **Minimise cannibalism using innovative beak-trimming methods**

The information contained in this publication is intended for general use to assist public knowledge and discussion and to help improve the development of sustainable industries. The information should not be relied upon for the purpose of a particular matter. Specialist and/or appropriate legal advice should be obtained before any action or decision is taken on the basis of any material in this document. The Australian Poultry CRC, the authors or contributors do not assume liability of any kind whatsoever resulting from any person's use or reliance upon the content of this document.

Researcher Contact Details

Dr Phil Glatz

SARDI-PPPI, Davies Building,
Roseworthy Campus,
Roseworthy, SA 5371

Phone: (08) 83037786
Fax: (08) 83037689
Email: glatz.phil@saugov.sa.gov.au

Assoc Prof Geoff Hinch

School of Rural Science and Agriculture,
University of New England,
Armidale, NSW 2351

Phone (02) 67732202
Fax: (02) 67733922
Email: ghinch@une.edu.au

In submitting this report, the researcher has agreed to the Australian Poultry CRC publishing this material in its edited form.

Australian Poultry CRC Contact Details

PO Box U242
University of New England
ARMIDALE
NSW 2351

Phone: 02 6773 3767
Fax: 02 6773 3050
Email: info@poultrycrc.com.au
Website: http://www.poultrycrc.com.au

Published in October 2008

Executive Summary

What the report is about? This report is about research undertaken at the University of New England (UNE) and the South Australia Research and Development Institute (SARDI) to assess the effect of the hot blade (HB) and infrared (IR) beak trimming methods on production, beak condition, pain and mortality of laying hens. On-farm trials were also undertaken in South Australia to assess beak condition and across Australia to monitor the mortality of flocks beak trimmed with the IR method. Flinders University Neuroscience Centre conducted anatomical studies to evaluate neuromas in beaks of birds trimmed using the IR and HB beak trimming methods. The University of Adelaide's Physics laboratory used laser technology to investigate a laser method of beak trimming.

i) Trials conducted at SARDI's Pig and Poultry Production Institute (PPPI): Beak condition was superior for IR treated birds in the rearing period but by mid-lay was similar to HB trimmed birds, irrespective of treatment. The upper beak of IR trimmed birds was longer (4mm) than HB trimmed birds throughout the laying period. While beak trimming method had no effect on egg production, the IR treatment resulted in higher body weight throughout lay and lower egg weight. In South Australia, Industry flocks were monitored to compare beak trimming quality with the research trial at the PPPI. There was a significant variation in beak condition and length of beak birds across farms for both trimming methods. Consistency needs to be improved in Industry for both methods of trimming. Across Australia mortality of birds beak trimmed with an IR machine was assessed in 46 flocks (1m birds total) housed in cage and free range systems. Mortality (corrected to 50 weeks of age) was 1.27% for caged birds and 2.37% for free-range birds.

ii) Trials conducted at UNE: Pain was assessed by examining self-administration of an analgesic (carprofen) and pecking behaviour in pullets beak-trimmed by the hot-blade or infra-red method compared to birds with intact beaks. Birds trimmed at 10 weeks of age pecked more gently at a disc attached to a force-displacement transducer than birds trimmed at 1 day of age with the IR, HB and intact birds when measured at 11 weeks of age. However, the pecking force in birds trimmed at 10 weeks of age was not increased by providing them with analgesic-treated feed, though birds that ate more carprofen had a higher maximum force of peck. There was no evidence that beak trimmed pullets consumed more carprofen-treated feed than pullets with an intact beak.

In a large layer trial mortality was lower ($p<0.05$) for IR trimming compared to HB trimming after 20 weeks. Non-re-trimmed treatments had higher ($p<0.01$) average cumulative mortality compared to re-trimmed treatments from week 26. Hen day egg production (HDEP) was significantly lower ($p<0.01$) for the control birds for the short period and there were no significant differences between HB and IR treated birds. Re-trimmed birds had a slightly lower HDEP for most of the laying period. There was no significant difference in egg quality and egg shell thickness between treatments. There were minimal differences in bird weights between treatments over the laying period. Feather scores increased (poorer covering) significantly ($p<0.01$) over time particularly from mid lay. The IR group exhibited significantly lower pecking force ($p<0.01$) than the control or HB birds. HB birds also had a peck force greater than the controls. There were no significant differences between re-trim and control treatments applied at 10 weeks with mean force values of 1.59 vs 1.64 newtons. It is apparent that IR and HB treatment at 1 day old increases the level of aggression/pecking activity relative to other treatments and that fearfulness appears significantly higher in the birds treated by IR at day 1 than other trim treatments except the double HB trim. The IR treatment at day old had long lasting effects on fear and aggression behaviours.

iii) At the University of Adelaide: A series of experiments using different lasers were conducted to determine the practical viability of laser beak trimming (LBT), following the initial promising trials on live birds. A number of available and scalable continuous wave (cw) lasers ranging from the deep IR to visible laser wavelengths were used. Experiments were performed on fresh, but detached chicken beaks. The lasers used included a CO_2 laser, wavelength 10.6μm, a semiconductor diode laser, wavelength 808nm, and an Nd:YAG laser, wavelength 1.06μm, all in the 5-10W power regime. All lasers investigated were successful in making a hole in the beak at the zone of ossification in the upper

beak. Tests were made to determine if the beak can transmit significant power through the outer layers to damage the growth point without burning a hole in the outside of the beak. This was found to be limited by excess scatter. However the use of a laser as a cutting tool is viable, and this can reduce both the blood loss and pain due to its ability to seal blood vessels and nerve endings during cutting.

iv) At Flinders University: The histopathology of upper beaks of HB and IR trimmed birds were assessed at 32, 144 and 420 days. At 32 days of age scattered microneuromas were found in some beaks. These were found in the ventral dermis adjacent to the roof of the palate. The presence of the microneuromas was independent of the type of trimming as they were found in three beaks trimmed by HB and two beaks trimmed by the IR method. Receptors were not identified in any of these beaks. At 144 days of age all beaks, irrespective of whether they were trimmed by HB or IR procedures, neuromas were present. These appeared as either extensive traumatic neuromas or small fascicles of microneuromas. At 420 days of age extensive traumatic neuromas and scar tissue were clearly present in both the HB and IR trimmed beaks. The histopathology suggests, based on the current literature (for review see Lunam 2005) that excessive tissue was removed for the HB method and excessive heat was used for the IR method for the age at which the birds were trimmed. This resulted in the formation of traumatic neuromas which persisted to adulthood.

Who is the report targeted at? This report is targeted at Australian and overseas egg farmers, scientists, students, welfare groups, policy makers and poultry industry leaders.

Background: Layer mortality (about 10%) is considered to be a major cost to the egg industry in Australia. Currently, cannibalism is the main contributor to mortality during the rearing and laying period in cage, barn and free-range systems. Associated with the cannibalism is a reduction in farm income from lost productivity, disposal of birds and flock morbidity. Mortality from cannibalism in some strains can be greater than 20% when beak trimming is not used and efforts are required to minimise cannibalism to ensure that the egg industry remains sustainable. The increasing public knowledge of poultry welfare issues means that any improvements in the control of cannibalism are perceived by the community as being welfare friendly. Public perception can be influenced by the knowledge of the welfare status of birds subject to existing practices and new practices that might be introduced to control cannibalism. Currently the most effective method for controlling cannibalism is HB beak-trimming, but the negative long-term effects of the procedure are a welfare concern. Many European Union countries have banned trimming or intend to ban it. Attempts have been made to develop better methods of beak-trimming. The IR method of trimming developed by Nova-Tech in the USA is an innovative procedure and is gaining popularity. The method uses an IR energy source to treat the beak. Immediately following treatment, the beak looks physically the same as it did before and the bird is able to continue to use its beak. Welfare and production aspects of the IR process were examined to determine if the method was sustainable compared to HB beak trimming. Previous work conducted by SARDI indicates potential for using lasers to beak trim poultry. Research focused on determining the best method of beak trimming in Australia, which minimises welfare concerns for poultry. One of the concerns associated with the conventional HB method is the inability of operators to achieve a consistent level of trimming.

Aims/Objectives:

- Establish if IR beak trimming minimises cannibalism and reduces development of neuromas and pain compared to HB trimming.
- Determine the beak length, beak step, beak condition, production, feather pecking and physiological status of poultry beak-trimmed using the IR and HB methods.
- Develop a laser method of beak trimming.

Methods:
i) *Work conducted at the PPPI* (*Measurement of beak length, beak step, beak condition and production of IR and HB trimmed layers*): Fifty IR trimmed Hyline Brown chicks were treated at day old in the hatchery using an IR beak treatment machine developed by Nova-Tech engineering. Another 50 chicks were trimmed at 10 days of age by an experience beak trimmer using a Lyon beak

trimming machine to remove one half of the upper beak and one third of the lower beak from chickens. Beak length, beak step, beak condition, body weight, egg production and egg weight were determined monthly throughout the growing and laying period. Beak length and beak step was measured using a digital electronic vernier calliper. Upper beak length was measured from the edge of the external nare to the tip of the beak and beak step from the edge of the top beak to the edge of bottom beak. Beak condition was assessed using a grading system as Grade 1 (no imperfections, splitting, chapping or swelling; good keratin layer on beak; beak is not too short); Grade 2 (beak shows minor imperfections in appearance and beak is too short) and Grade 3 (beak shows major imperfections and is very short).

ii) *Work conducted on 3 egg farms in South*: Beak length, beak step and beak condition were measured on Hyline Brown layers on 3 commercial layer farms in South Australia. For the 3 industry farms data was assessed on 100 birds at 45 and 60 weeks of age. Farm 1 and 2 used only one of the trimming methods while farm 3 used both methods of trimming.

iii) *Mortality of layers trimmed with the IR method for birds housed in cage and free range barn systems across Australia*: Mortality was measured for 32 flocks of hens housed in cages (Hi-rise, multi-tier and conventional) with natural ventilation or controlled environment and compared with 14 free range barn systems (slats or slats/litter) with natural ventilation. Total number of birds housed in the 46 sheds was approximately 1m birds with an age range from 20-80 weeks of age. Mortality of birds from each production system was corrected to 50 weeks of age.

iv) *Work conducted at the University of Adelaide Physics laboratory* (*Testing of laser devices for their potential as a beak trimming machine*): Experiments were performed on fresh, but detached chicken beaks with a CO_2 laser, wavelength 10.6μm, a semiconductor diode laser, wavelength 808nm, and an Nd: YAG laser, wavelength 1.06μm, all in the 5–10W power regime. The lasers were set up to focus on a small point after a certain propagating distance by the use of lenses or focusing mirrors. The beaks from day-old male chickens were placed at the focal point of the setup (inside a fume box) and burnt a small distance below the nostrils. The time taken for the laser beam to pass through the beak was measured at different power densities.

v) *Work conducted at UNE:* An experiment aimed to identify if the IR and HB beak trimming methods cause pain by examining self-administration of an analgesic (carprofen) and pecking behaviour. In addition a large layer trial was conducted at UNE to examine pecking behaviour, cannibalism, productivity and egg characteristics at 4-6 weekly intervals during lay of birds trimmed with the IR and HB method. Interactions between rearing and laying environment and the beak trimming methods were also evaluated. The housing treatments imposed in this trial created the variable housing conditions that can often initiate feather pecking and cannibalism.

vi) *Work conducted at Flinders University*: Upper beak samples were obtained from 5 birds for each of the IR and HB treatments from the PPPI trial at 32, 144 and 420 days of age. Beak samples were stored in plastic vials containing Zamboni's solution. The histopathology of upper beaks including incidence of neuromas were assessed.

Results/Key findings:

i) *Work conducted at the PPPI and on South Australian egg farms*

- Beak condition (a measure of its appearance and shape) was superior for IR treated birds in the rearing period but by mid lay was similar for birds whether trimmed with the HB method or the IR method.
- The upper beak length of IR trimmed birds was consistently longer (4mm) than HB trimmed birds throughout the laying period. No difference in egg production was observed throughout the production period between the beak-trimming treatments. Body weight of IR treated birds was higher throughout lay while egg weight was lower.
- There was a significant variation in beak condition and beak length of HB and IR trimmed birds monitored on South Australian egg farms. There is a need for further consistency in the application of both trimming methods.

ii) *Mortality of layers trimmed with the IR method on 46 farms across Australia*

- Barn/free range production systems had higher mortality (2.5%) compared to cage systems (1.8%) when mortality was corrected to 50 weeks of age.
- Conventional and Hi-rise cage systems had similar mortality (1.85 vs 1.79%) as did controlled environment and naturally ventilated cage systems (1.79 vs 1.83%).
- Likewise there was similar mortality (2.78%) for the flooring systems whether it was slats only or slats/litter in free range/barn production systems.

iii) *Pain, performance and behaviour studies undertaken at UNE*

- Birds monitored 1 week after being HB trimmed at 10 weeks of age pecked more (P<0.001) gently (0.6±0.06N) at a disc attached to a force-displacement transducer compared to day old IR trimmed birds (0.9±0.1N), day old HB trimmed (1.1±0.07N) and intact birds (1.2±0.1N).
- Maximum force of pecks recorded was also lower (P<0.001) in birds trimmed at 10 weeks of age compared to intact birds or birds IR and HB birds trimmed at 1 day of age.
- Carprofen has been reported to have an analgesic effect on neuromuscular pain in chickens. The pecking force in birds trimmed at 10 weeks of age was not increased by providing them with analgesic-treated feed, though birds that ate more carprofen had a higher maximum force of peck (P=0.03).
- No evidence was found that beak trimmed pullets consumed more carprofen-treated feed than pullets with an intact beak.
- The three beak trimming methods resulted in an 34% reduction in beak length, considered a light trim, and is perhaps not representative of commercial birds where greater portions of the beak are removed.
- It appears Carprofen has no analgesic effect on potential neuropathic pain arising from the nerves severed by a light beak trim.
- A large layer trial showed that IR trimmed birds had lower mortality after 20 weeks (p<0.05) compared to HB trimming. The difference in average cumulative mortality between a re-trimmed and non-re-trimmed treatments became significant (p<0.01) from week 26 with higher mortality in the trimmed group which was not re-trimmed.
- HDEP was significantly lower (p<0.01) for the control birds but there were no significant differences between HB and IR treated birds. Re-trimmed birds had a slightly lower HDEP for most of the laying period.
- There were no consistent significant differences in egg weights between treatments.
- There was no significant difference in egg quality and egg shell thickness between treatments and there were minimal differences in body weight over the laying period.
- It is apparent that IR and HB treatment at 1 day old increases the level of aggression/pecking activity relative to other treatments and that fearfulness appears significantly higher in the birds treated by IR at day 1 than other trim treatments except the double HB trim. The 1 day treatment using IR had long lasting effects on fear and aggression behaviours.

iv) Development of a laser method of beak trimming at Adelaide University:

All lasers investigated were successful in making a hole in the upper beak at the zone of ossification. Tests were made to determine if the beak can transmit significant power through the outer layers to damage the growth point without burning a hole in the outside of the beak. This was found to be limited by excess scatter. However the use of a laser as a cutting tool is viable, and this can reduce both the blood loss and pain due to its ability to seal blood vessels and nerve endings during cutting.

v) Histology work conducted in Flinders University:

Similar histopathology of the upper beaks was found for IR and HB trimming methods at 32, 144 and 420 days of age. Sensory receptors were not found in the upper beak for both trimming methods at any ages. The histopathology suggests that excessive tissue was removed for the age at which the HR birds were trimmed or excessive heat treatment was used for the IR method. This results in the formation of traumatic neuromas which persisted to adulthood.

Implications for relevant stakeholders:

- There is a need to improve the consistency of beak trimming for both the IR and HB method in Australia.
- Mortality of layers trimmed with the IR method is relatively low indicating this method is acceptable for use in Australia to control cannibalism.
- Birds trimmed with a HB at 10 days of age and those IR trimmed at day old formed traumatic neuromas which persisted to adulthood. A constraint in this study was that too much beak may have been removed as persistent neuromas in the HB trimmed birds was unexpected. There is a need to practice HB trimming at day old to overcome neuroma formation and chronic pain.
- IR and HB trimmed pullets do not consume more analgesic treated feed than pullets with an intact beak suggesting that either pain from IR and HB beak trimming is not excessive or the analgesic is ineffective for neuropathic pain.
- There is a need to continue with the development of high technology laser methods of beak trimming as an alternative to current methods of beak trimming.

Recommendations:

The IR method of trimming is suitable for use as a method to control cannibalism in layers but further development is required with this method to reduce the incidence of neuromas. HB trimming should be done at day old according to the Code of Practice to allow neuromas to resolve and reduce chronic pain.

Table of Contents

Literature review

Introduction

Feather pecking and cannibalism are serious welfare problems in laying hens. Feather pecking results in both pain and threats for the recipient and also reduces profitability. It is estimated that poorer feed conversion caused by poor feathering, increases the cost of egg production by approximately 7 to 12% (Glatz, 1998). In addition it can lead to cannibalism resulting in further economic losses (Bilcik and Keeling, 2002; Hester and Shea-Moore, 2003; McAdie and Keeling, 2000; Yngvesson and Keeling, 2001). Cannibalism is a major concern in all current poultry housing environments including cage, barn and free range systems (Lee and Craig, 1990; Appleby and Hogarth, 1991; Gleaves, 1999), and is a major cause of bird mortality in untrimmed commercial layers (Tablante *et al*., 2000). Glatz (2005) reported that without beak trimming, mortality within a flock could be as high as 25 to 30% and may be financially as disastrous as a disease outbreak. Mortality from cannibalism in some strains can be greater than 20%, depending on the production system and the management strategies. Aside from beak trimming, there are no other practical means that successfully prevents feather pecking and cannibalism in current poultry housing systems. For an average sized laying flock of 100,000 birds, a producer can save about A$200,000 annually by beak trimming (Anderson and Davis, 1997).

The increasing public knowledge of poultry welfare issues means that any improvements in the control of cannibalism are perceived by the community as being welfare friendly. Public perception can be influenced by the knowledge of the welfare of birds subject to existing practices and new practices that might be used to control cannibalism. Currently the most effective method for controlling cannibalism is HB beak-trimming, but the negative long-term effects of the procedure are a welfare concern. The major welfare issue associated with beak trimming is the loss of sensory input from the removal of receptors and acute and chronic pain from severed nerves. After severing, sprouting of axons can form disorganised tangles of nerves (neuromas). Excess sprouts can degenerate and the neuroma regresses. However neuromas may persist and discharge ectopic action potential perceived as pain. Many EU countries have banned trimming or intend to ban it. Pain sensation and neuroma formation are dependent on the type and/or severity of tissue injury sustained (Bennett, 1993; Colburn *et al*., 1999; Luo *et al*., 2002; Sheen and Chung, 1993; Zeltser *et al*., 2000). An obvious approach to overcome problems associated with traditional HB beak trimming is to develop alternative methods that prevent or limit tissue damage and inflammation and thereby result in a reduction or elimination of pain. Attempts have been made to develop better methods of beak-trimming. The IR method of trimming developed by Nova-Tech in the USA is an innovative procedure and is gaining popularity. The method uses an IR energy source to treat the beak. Immediately following treatment, the beak looks physically the same as it did before and the bird is able to continue to use its beak. However welfare aspects of the IR process need to be fully examined to determine if this method of beak trimming is sustainable. Preliminary work by South Australia Research and Development Institute indicates potential for using lasers to beak trim poultry and further work is required to develop this method.

Beak trimming methods

Beak trimming methods were reviewed by Glatz (2000; 2004). Methods include equipment powered by gas,, electric soldering iron, hot and cold blade trimming, robotic beak trimming, chemical beak trimming, bio beak trimming, freeze drying method, IR beak trimming and laser beak trimming. The majority of beak-trimming is carried out with a heated blade that cuts and cauterises the beak. The beak-trimmer holds the bird securely with its beak resting on a cutting bar. A foot pedal is then operated to bring the heated cutting blade down onto the beak. The blade cuts quickly and smoothly through the upper and lower beaks in one motion. The heat of the blade seals off the cut thus preventing bleeding and infection. Pain to the bird is minimised when the procedure is done correctly (Glatz, 2000, 2005). New beak-trimming methods are being introduced into the industry. One of these new approaches is the IR method. The process directs a strong source of heat onto the inner tissue of the beak. After a few weeks the tip of the upper and lower beak dies and drops off and the beak becomes shorter with blunt tips. Another method being investigated is laser trimming, which operates by sending energy to the target tissue; the heat is absorbed and cuts the tissue. Some problems have been reported by Industry in the USA concerning the IR method of trimming. Misshapen beaks and beak regrowth have been a concern and need to be investigated in relation to cannibalism. Likewise in Australia there has been a concern over the regrowth of beaks after day-old IR treatment. Some of these flocks have been retrimmed with the HB at 10 weeks of age. In addition welfare aspects (particularly long term pain) of the laser and IR technology need to be resolved before blanket use of these techniques can be considered in the poultry industry.

HB beak trimming

HB beak trimming is the preferred method for beak trimming birds around the world (Glatz, 2000). The method involves placing a chick's beak on a cutting bar for the beak trimmer to judge the amount of beak to cut or in a hole in a guide plate attached to a trimmer that enables different amounts of beak to be cut depending on the age of the bird. A HB (~950°F) is then activated which both cuts and cauterizes the beak stump.

The greatest concern with this method is its potential to cause chronic pain resulting from neuromas which develop after the procedure. The comparison is made that beak trimming is similar for birds after the operation as it is for human amputees. Post-amputation symptoms in man include painful and non-painful phantom sensations after the loss of limbs (Angrill and Koster, 2000; Wall, 1981; Weinstein, 1998). Phantom limb pain is severe in about 5-10% of cases (Weinstein, 1998). Persistent phantom limb pain can be treated with analgesia in patients (Bloomquist, 2001). In poultry it is not clear if the presence of neuromas do result in pain although there is data to suggest neuromas are involved with chronic pain (Breward and Gentle, 1985; Gentle, 1986; 1992; Gentle *et al*., 1997).

Beak trimming reduces mortality, improves feather cover and feed efficiency during the egg laying period (Hester, 2005). When beak trimming is performed correctly there are only short term effects on behaviour and feed intake (Jongman and Barnett, 2005). However, van Liere (1995) found that beak trimming has long lasting consequences in reducing the responsiveness to a preening stimulus. It took trimmed birds 27 seconds to start preening, only 8 seconds for intact birds after birds were trimmed using the HB method at 6 weeks of age. However the majority of birds worldwide are trimmed early in life and it is expected that the pain response of birds trimmed at 6 weeks of age would be more severe.

If birds are beak-trimmed earlier than 10 days of age both neuroma formation and pain is reduced (Megret, *et al*. 1996; Lunam, *et al.* 1996). The tip of the bone including the zone of ossification is the location where the beak is cut. Ossification of the bone continues after beak-trimming but the order of ossification is disturbed (Kawai, *et al*. 1990). Traumatic-neuromas consist of swollen tangled masses of regenerating axon sprouts. These may form as either large masses or may develop as small scattered multiple fascicles of axons to form microneuromas (Devor and Rappaport, 1990; Lunam *et al*., 1996). After several weeks, the nerve fibres regrow, the excess axon sprouts degenerate and the neuroma regresses. Occasionally, the neuroma mass persists and can discharge spontaneous action potentials that are perceived as chronic pain. Studies by Lunam, *et al*. (1996) showed neuromas were present in all beaks at 10 weeks, but neuromas were not found at 70 weeks after moderate trimming at hatch. As neuromas were not observed in adult hens that had been moderately trimmed at hatch, the results indicate that they develop and persist for at least 10 weeks, before resolving. This would explain why other workers observed neuromas in beak stumps between 15 days and 10 weeks after trimming one-third of the upper beak (Breward and Gentle, 1985; Gentle, 1986) at birds at 5 weeks-of-age. The presence of neuromas is not in itself evidence of chronic pain as neural activity may cease following resolving of neuromas and normal feeding and pecking behaviour could be restored.

Analgesics and pain

To date, animal welfare research has provided some behavioural and neurological evidence to inform the debate on the acceptability of routine beak trimming within the industry (see Cheng, 2006 for a recent review). However, there are limitations to both these lines of evidence: first, it is unclear whether the reported reduction in pecking following beak trimming, termed guarding behaviour, indicates pain or arises from the loss of sensory perception in the beak. Since the nerves have been severed, pecking with a trimmed beak will not provide the sensory feedback that an intact beak may provide, and may thus reduce the sensory stimulation achieved through exploration with the beak resulting in less pecking. Additionally, the regrown tips of the beak do not always contain afferent nerves or sensory corpuscles (Gentle *et al*., 1997); therefore the loss of sensory feedback may be long-term and may explain long-term evidence of guarding behaviour. It appears that the amount of beak removed appears critical, with some evidence that sensory receptors are still present in moderately trimmed birds (Lunam *et al*., 1996). It should also be noted that the main objective of beak trimming, a reduction in cannibalism, could arise both from a resultant reduction in the tendency of birds to peck or by reducing the amount of damage that birds can cause each other. Second, it is also unclear whether nerves that form neuromas project to the brain, and if they do whether they transmit action potentials to brain areas that may interpret these as pain. There is an urgent need for reliable and unequivocal indicators of pain in beak trimmed birds that will aid the debate as to the suitability of beak trimming.

When given a choice of feeds, rats with clinical symptoms of pain will consume more of an analgesic-containing feed than animals not in pain (e.g. Colpaert *et al*., 2001). It has been known for some time that chickens are able to select some feeds over others, even when both feeds are visually similar but differ only in nutrients, such as by consuming more feed high in selenium than feed lacking in selenium (Zuberbueher *et al*., 2002). Similarly, Danbury *et al*. (2000) found that when given a choice of feeds with and without an analgesic (carprofen), lame broiler chickens consumed more of the analgesic-treated feed than sound birds. Additionally, the consumption of carprofen in chickens was positively correlated to the severity of lameness, and consumption resulted in an improved gait (Danbury *et al*., 2000). The authors conclude that lame birds are able to select feeds with analgesics, thereby indicating that they are in pain and that they will actively seek relief from this pain. Carprofen is a non-steroidal analgesic which has previously been shown to have an effect on chickens, by improving the gait of lame broilers (McGeown *et al*, 1999). In the present experiment the method used was based on the approach described by Danbury *et al*. (2000) to investigate the potential impact of pain in beak trimmed birds. If trimmed birds are in pain and attempt to guard the beak from further pain stimulation, then it is predicted that trimmed birds should peck more gently than intact birds. This difference in pecking force should, however, be removed by administering an analgesic.

IR beak treatment

Glatz, (2005) reports IR beak trimming was developed by Nova-Tech Engineering of Willmar, Minnesota, USA. The Nova-Tech beak treatment system is a bloodless procedure and uses a non-contact, high intensity, IR energy source to treat the beak tissue. The IR penetrates the hard outer layer of the beak and the underlying basal tissue of the beak is treated, thus substantially affecting the regeneration of the corneum. Initially, the beak remains intact, protecting the treated soft basal layer tissue. Immediately following the process, the basal tissue appears white with a dot on the top of the beak. Within a week the beak softens, and by two weeks after the treatment the sharp hook of the beak erodes away as the bird uses its beak. Because the IR process initially affects mostly the basal tissue, a bird at 4 weeks of age will have a longer beak than a bird that has undergone a traditional beak cutting method. By 12 weeks of age, however, the IR treated beak will be shorter than the beak cut with the HB. A head holding fixture (specific for chickens) generated from a mould of the bird's cranium becomes the reference point to maintain consistent treatment over a range of bird sizes. Birds with a larger cranium will reference the beak back further versus smaller birds. The amount of IR energy applied to the beak is programmable allowing variations in bird size due to age and strain. Birds undergoing IR beak trimming experienced less overall stress and had less deviation in the shape of their beaks (the beaks resembled untrimmed ones, but without the bill tip). As a consequence, they performed better when eating, drinking, and preening. Such behavioural differences may be indicative of little pain and have fewer detrimental effects on well-being. The immediate advantages of IR over HB beak trimming appear to be: 1) the elimination of open wounds that contribute to bleeding, inflammation and pain and; 2) as changes in beak length and shape occur gradually over a 2 week period it may better enable chicks to alter their beak related functions since they are adapting to a progressive, rather than an instantaneous, change in beak shape.

Although IR beak treatment may represent an advance in well-being, to date very little data are available that documents its effect on pain (acute and/or chronic) and neuroma formation. Nonetheless, the few data that are published consistently find that IR treatment offers improved outcomes relative to hot-blade trimming. There is a lack of data on influence of IR trimming on pecking and cannibalism over the laying cycle. So, prior to advocating its widespread use within industry, a scientific evaluation of its benefits needs to be undertaken under research and commercial conditions.

Marchant-Forde and Cheng (2006a) compared trimming of the upper and lower beak using the HB and IR method where 1/3-1/2 of the upper and lower beak was removed. They found that HB beak length was longer than IR after two weeks. In addition there was considerably more variation in beak length for HB trimmed birds. However, at 9-10 weeks of age length of IR treated beaks was similar to HB beaks (Marchant-Forde and Cheng, 2006b). Body weight was lower for both methods of beak trimming compared to intact beak birds; with HB trimmed birds being lighter than the IR treated birds. It took longer for HB birds to approach the feed and start feeding compared to IR treated birds. Both trimming treatments performed more head flicks compared to intact birds. However HB trimmed birds did more beak scratching than IR treated birds. Marchant-Forde and Cheng (2006c) concluded that HB trimming had a greater impact on production and growth than IR trimming but by 10 weeks of age these differences had disappeared.

McKeegan and Gentle (unpublished) compared body weight, beak length and behaviour of IR and HB methods for Hyline layers trimmed at 1 day of age. There were no significant differences in body weight between the HB or IR treated birds at any age. By 16 weeks there was no significant difference in beak length between the two trimmed groups. Overall, there was no behavioural evidence such as decreased feed intake, reduced activity or less beak related behaviours at any age which might indicate there was pain or stress from the beak trimming. These findings agree with a study examining the same treatments in broiler breeder chicks which suggested that the infra-red beak treatment technique resulted in consistent beak trimming without adverse welfare consequences (McKeegan and Gentle, 2006). The Nova-Tech IR beak treatment method produced a reliable and precise removal of the tip of the beak and apart from a slight increase in the amount of beak removed, its application did not differ from HB trimming.

Problems reported with the IR treatment system

Temple Grandin, American Egg Industry QA consultant (pers. comm.) indicated she held some chickens while they were being trimmed with a HB versus IR and felt that the stress response (struggling and vocalising) of the IR treated chickens was much lower than conventionally trimmed birds. She recommended to the manufacturer that they should conduct more studies both in the field and laboratory to verify the advantages of the system in reducing cannibalism and impact on the welfare of the bird. Temple Grandin said there were field reports on IR treated birds indicating an increase in number of birds with crooked beaks. This was more prevalent in some strains than others. Dr Colin Fisher, Nutrition Consultant, Aviagen Limited has been concerned (pers. comm.) with variations in beak growth and re-growth in flocks of adult broiler breeders trimmed early in life with the IR method. Suddenly, and for no known reason, excessive beak growth is seen as a field problem and there is no clue as to why this is happening. In Australia field reports have indicated that flocks trimmed using the IR technology have resulted in variable beak length within the flock, which may predispose some birds to increased levels of feather pecking.

Problems with IR beak trimming during the procedure include effects on neighbouring chicks, birds staying too long on the rotor and some chicks needing retrimming. After the procedure there have been reports of regrowth of beak stump and distorted shape, loss of flock uniformity and pain. Solutions examined were to use to higher energy to treat the beak, which resulted in less beak regrowth and a smoother beak stump at a later age (Cheng; pers. comm.).

Laser beak trimming

Lasers are used widely in human medicine particularly for surgery. The general public and welfare groups may perceive that laser trimming is a milder, more technologically advanced method. The new laser machines on the market are smaller, more flexible and easier to transport than earlier models. Cost of lasers is falling dramatically and there is considerable potential for developing a laser machine for mass beak trimming of birds at large hatcheries and for trimming and retrimming older birds. Lasers operate by sending energy to the target tissue; the heat is absorbed and in the process if the beam is strongly directed will result in cutting of the tissue. During the procedure patients feel intense emissions of light, each pulse lasting a fraction of a second on the area being treated (www.ienhance.com). Many lasers are equipped with cooling systems to decrease temperature on the treated area, providing a mild anaesthetic effect. Patients normally feel a burning or stinging sensation. There are a number of lasers available, including ophthalmic laser, CO2 laser and the Nd:YAG laser.

An ophthalmic laser (1.5W; 4 second pulse; 50-micron spot size) were used to successfully cut through an upper beak sample from a cull chicken (Glatz, 2004). Two passes of the laser beam were required to complete the cut. There was insufficient power in the laser beam to cut the beak tissue in one action. Live bird studies with 5-day-old chickens established the spot size to enable coagulation of the tissue and prevent bleeding. When a 50-micron spot size was used for duration of 2 seconds there was insufficient energy density of the laser beam on the tissue to cause coagulation and the beak began to bleed. The spot size was increased to 200 microns with a cutting time of 2 seconds. The birds vocalised more in response to the increase in energy density indicating birds were perhaps feeling more discomfort. There was no bleeding from the wound indicating that the 200 micron spot size was effective not only in cutting the tissue but also in sealing the wound. In live birds the laser was able to cut through the outer layers of keratin, but was not able to cut the inner bone. The lack of success in being able to cut the bony portion of the beak with an ophthalmic laser was considered to be due the lack of power. There was no significant difference in the beak length and body weight of control birds, laser trimmed or trimmed with a HB. There were no apparent problems with healing of the beak stump. The cuts that were made looked cleaner and straighter than the HB cuts. As the birds aged the beak tissue sloughed off at first as the stump wound healed. Then regrowth of the beak occurred. There was one bird where the bony tip appeared to be effectively cut and cauterised. The beak regrowth of this bird was substantially less than other birds. The CO_2 laser with a 1 second pulse, 50-micron spot size and power rating of 10W was the most effective laser in cutting a beak sample. The experiments showed that there is potential to use lasers for beak trimming and demonstrated the spot size required to cauterise the beak, and the power to cut the beak.

Van Rooijen and van der Haar (1997) reported on a laser method, which cuts the beaks of day-old chickens with a laser beam. No details were provided by the authors on the type of laser used, or the severity of beak-trimming. By 16 weeks the beaks of laser trimmed birds resembled the un-trimmed beaks, but without the bill tip. Unfortunately, feather pecking and cannibalism during the laying period were highest among the laser trimmed hens. These results suggest that the severity of beak trimming by laser was insufficient, enabling regrowth of the beaks. It might be expected that use of laser beak trimming, would enable greater uniformity in beak-trimming and improved welfare because the beak would not require cauterisation. Laser beak-trimming may represent a welfare advance but further work is required with this technology before it can be applied in industry. Van Rooijen reported it might be expected that use of laser beak-trimming, would enable greater uniformity in beak-trimming and improve bird welfare.

Lasers and human surgery

The continuous wave CO_2 laser, operating at a wavelength of 10.6 µm, was found to seal blood vessels up to 0.5mm in diameter, preventing any bleeding from the wound, and also sealed lymphatics and nerve endings (Yang and Li, 2002; Zeitouni *et al*., 2001; Takac *et al*., 1998; Ries and Speyer, 1996). The pain from operations with the CO_2 laser was also found to vanish significantly faster than other methods of cutting. Although sealing both blood vessels and nerve endings, the use of the CW CO_2 laser causes excessive deeper thermal injury and subsequent scarring. This can be solved by the use of a pulsed CO_2 laser, such as the Ultrapulse mode and the Sharpulse mode CO_2 lasers, as pulsed beams can adequately confine the thermal energy to the desired location (Yang and Li, 2002; Ries and Speyer, 1996).

The CW Nd:YAG laser, a solid state laser that operates at a wavelength of 1.064µm, is quite effective in suppressing neuroma formation after amputation. Several studies have indicated that the use of Nd:YAG produced no regrowth of axons outside the coagulated proximal stump or any signs of neuromas (Konig *et al*., 1987; Menovsky *et al*., 1999). This is due to the Nd:YAG laser beam coagulating and sealing the nerve endings, allowing the perineurium to grow over the nerve stump before the regrowth of axon (Menovsky *et al*., 1999). Thus, the Nd:YAG laser is an effective suppressor of amputation neuromas.

Other lasers that also may be suitable are the Argon laser (wavelength at 488-514nm) and diode lasers (wavelength at around 830 nm) (Takac *et al*., 1998; Menovsky *et al*., 1999; Ries and Speyer, 1996). From this, it can be concluded that the use of lasers has the potential to reduce both blood loss and pain caused by the trimming process.

Alternatives to beak trimming

Alternatives to beak trimming were reviewed by Glatz (2000), including implanting hormones, blind chickens, spectacles (restricting vision of birds), contact lenses, environmental enrichment devices, bitting devices, tin pants, changing the light intensity, rearing under red light, provision of straw, grain and whey blocks, use of anti-pick compounds and genetic strategies. It is possible to rear pullets without beak-trimming if there is effective light control (Wells, 1983). Control of pecking is quite different and more problematical in the laying stage when a higher light intensity up to 5 lux needs to be provided. This approach needs to be coupled with close management of body weight. The only concern is poor feather cover, which may result from using the low light management approach. Some farms have achieved 3% mortality over 3-4 batches using this approach. Hester and Shea-Moore (2003) recommended that selecting more docile birds could minimize the need to beak trim. Feeding high-fibre diets, low energy diets, or roughages reduced feather pecking (van Krimpen *et al*., 2005). Other studies (Choct and Hartini, 2005) have indicated that fibre levels of diets correlate with cannibalism mortality in layers. It appears that the type and physical characteristics of fibre is important. There are two types of fibre; soluble (barley, rye and low-ME wheat) and insoluble (millrun, rice hulls, oat hulls and lucerne meal). Levels that are believed to be effective are >4% crude fibre. Diets high in insoluble fibre are effective in controlling cannibalism, even after the onset of cannibalism. High insoluble fibre diets shorten digesta transit time, whereas soluble fibre has the opposite effect. A faster food transit rate may increase the feeding frequency and reduce boredom. Providing a complete ration to meet the nutrient needs for age and type of flock is also very important. Cannibalism has been linked to deficiencies in protein, sodium and phosphorus. Protein requirements change as the chicks grow and should be adjusted based on a recommended feeding schedule. Adequate feeder space for all birds to eat simultaneously helps prevent underweight birds that are frequently victims of cannibalism. However, dietary manipulation is not a total answer to cannibalism problems in non beak-trimmed layers.

Remedies can be used to stop cannibalism. Hanging cabbages or sugar beets in the pen, putting pine boughs on the floor, painting windows red, applying tar to picked birds, using no pick salves, using repellent sprays, adding salt to the feed and water, feeding oats have all been remedies used to stop cannibalism. Likewise feeding vitamin preparations or including vitamin B complex in drinking water, feeding DL methionine (Neal, 1956), manganese sulphate and horn meal (Kull, 1948) have all also been suggested as remedies for cannibalism. Vicks vapour rub on applied on the wound (Grigor, *et al*. 1995) may stop cannibalism. Including DL methionine (Shaver Focus, 1982) in drinking water (1.5g/L for first 4 days; 1.0 g/L for next 3 days) and feeding whole grain diets (Foster and Taha, 1978) can also minimise pecking attacks.

It is possible to rear pullets without beak-trimming provided there is effective light control. However once an outbreak has occurred it is difficult to control cannibalism. Under some conditions it might be possible to manage laying hens without beak-trimming, but for most producers, the risk of such a policy is too high (Glatz, 2000). Bell (1996) reports that care must be taken when considering the 'no trim" form of management. He states "elimination of beak-trimming may seem to be an attractive goal but it must be done with caution and careful consideration of all the consequences".

Alternative production systems and beak-trimming (Glatz, 2000)

It is not possible to ban beak-trimming due to the risk of damage caused by pecking activity especially in alternative systems or in open sided houses where light intensity is high. Feather pecking and cannibalism amongst birds kept in virtually all of the alternative systems remains unpredictable and a major problem yet to be solved (Petersen, 1994; Blokhuis and Wiepkems, 1998; Tauson and Abrahamsson, 1992; Blokhuis and Metz, 1996; Kathle and Kolstad, 1996; Elson, 1990; Engstrom and Schaller, 1993 and Norgaard-Nielsen, *et al*., 1993). A no trim approach was used in barn birds and 6% mortality was noted compared to 1% in trimmed flocks (P Bell, pers comm.). However a comparative analysis revealed that aviary hens consumed 3.0% more food than caged hens, but food conversion was 6.7% higher in aviaries than in cages. Beak trimming reduced prevalence of cannibalism rates but had no effect on overall mortality (Aerni *et al*., 2005). Increased pecking and cannibalism is considered to be caused by the larger group sizes. Losses of up to 13% of a flock of laying hens have been reported in an aviary (Hill, 1886) and of up to 15% in both a strawyard (Gibson, *et al.* 1988) and a free range system (Keeling, *et al.* 1988). Gibson, *et al.* (1985) found persistent high mortality in a covered strawyard system despite being temporarily abated by beak-trimming at 28 weeks-of-age. Industry would take up the method if it can be assured that there will be no outbreaks of cannibalism. More work is required on methods to reduce feather pecking in barn and free-range systems. Michie and Wilson (1985) found it necessary to beak-trim five of the six pens because of cannibalism after housing untrimmed birds in a perchery. The policy was that all birds in a pen were beak-trimmed after two birds had been pecked. In a second trial however no cannibalism was observed. Cannibalism seems to be much worse in some aviary systems than birds kept in cages for the same strain although the problem is not consistent. Under these circumstances, Norgaard-Nielsen, *et al*. (1993) suggests that it may be essential to beak-trim laying hens in alternative systems on welfare grounds. On the other hand Appleby and Hughes (1991) report that where flocks in alternative systems have been compared directly with cages and no cannibalism problems occurred, mortality was similar. However when cannibalism did occur it was disturbingly high in an aviary (14.6 %) and a strawyard (13.3%). The presence of males has been important factor in reducing this behaviour problem in females.

Appleby, *et al.* (1988) found that mortality was low in a deep litter system for 2 years but in the third year birds, which had not been beak-trimmed, suffered from cannibalism. In a comparison of deep litter with cages, outbreaks of cannibalism occurred in both systems in flocks which had not been beak-trimmed, but not in flocks trimmed at one day of age. In welfare terms current alternative systems housing large flocks of laying hens remain at risk of an outbreak of cannibalism providing a major argument against the system. No strategy guarantees that feather pecking will not develop in practical poultry keeping and beak-trimming may be required in specific cases to prevent the greater risk of welfare problems caused by cannibalism.

Implications of not beak-trimming (Glatz, 2000)

The most obvious advantage of beak-trimming is a reduction in cannibalism although the extent of the reduction in cannibalism depends on the strain, season, and type of housing, flock health and other factors. Beak-trimming also improves feed conversion by reducing food wastage. A further advantage of beak-trimming is a reduction in the chronic stress associated with dominance interactions in the flock.

Economic analyses revealed that beak-trimmed flock had a 24c/bird hen-housed advantage. Glatz (1990) also found that layers that were not trimmed consumed significantly more food but in contrast to results of Bell (1996) laid fewer eggs, had poorer food efficiency and higher mortality (25% v 8%) than beak-trimmed hens. Over the period 20-40 weeks-of-age Maizama and Adams (1994) also observed that mortality of untrimmed birds was high (6.3 % v 1.2 %) compared to trimmed birds. Guesdon *et al*. (2006) compared different cage and rearing systems and concluded that beak trimming is the most effective way to prevent cannibalism (Guesdon *et al*., 2006).

Hens, which had 10, 20, 30 40 and 50 % of the upper and lower beak-trimmed at 10 days-of-age using the non-precision method were reared under low light conditions and no cannibalism was observed. During the laying period birds were housed in cages in a naturally ventilated shed. At 32 weeks-of-age the experiment was terminated because of severe outbreaks of cannibalism in the lightly trimmed groups as a result of the regrowth of beaks (Glatz, unpublished data).

Objectives

- Establish if IR beak trimming minimises cannibalism and reduces development of neuromas and pain compared to HB trimming.
- Determine the beak length, beak step, beak condition, production, feather pecking and physiological status of poultry beak-trimmed using the IR and HB methods.
- Develop a laser method of beak trimming.

Results
Reports on trials conducted at the partner institutions

1. Work conducted at the PPPI

1.1 Comparison of HB beak trimming and IR treatment in laying hens

SUMMARY

In Australia two methods of beak trimming are used to prevent cannibalism in laying hens; HB and IR beak trimming. Work was undertaken to evaluate the two trimming methods by comparing the production performance and beak characteristics of Hyline Brown layers. Beak parameters of layers trimmed with the IR and HB method were monitored throughout the production cycle. Beak condition (a measure of its appearance and shape) was superior for IR treated birds in the rearing period but by mid lay was similar for birds whether trimmed with the HB method or the IR method. The upper beak length of IR trimmed birds was consistently longer (4mm) than HB trimmed birds throughout the laying period. No difference in egg production was observed throughout the production period between the beak-trimming treatments. Body weight of IR treated birds was higher throughout lay while egg weight was lower. Industry flocks were also monitored to provide a basis for comparison with the research trial. There was a significant variation in beak condition and beak length of birds on industry farms between both methods. The results indicate there is a need for further consistency in the application of both trimming methods.

I. INTRODUCTION

Cannibalism is a significant problem for layers in Australia. It is a source of production loss and reduced welfare of birds with mortality ranging from 25-30% for non beak trimmed birds (Glatz, 2000). There are a number of strategies to reduce cannibalism, but the most effective method to prevent cannibalism in layers is beak trimming (Glatz and Bourke, 2005; Kuenzel, 2007). HB beak trimming involves the partial removal of the upper and lower beak by using an electrically heated blade that cuts and cauterises the beak (Glatz, 2005). The HB method has been the most popular method of beak trimming since the 1940's. However, the IR method was recently introduced and involves the use of an IR beam to treat the bird's beak (Glatz, 2005; Gentle and McKeegan, 2007). The procedure involves exposing part of the beak to an intense IR beam, which kills the underlying beak tissue. The treated tissue erodes after a few weeks resulting in a partially trimmed beak (Glatz, 2004; Gentle and McKeegan, 2007). The aim of the study was to compare the production performance and beak condition of bird's beak trimmed using the HB and IR method.

II. MATERIALS AND METHODS

Fifty IR trimmed Hyline Brown chicks were treated at day old in the hatchery using an IR beak treatment machine developed by Nova-Tech engineering. Another 50 chicks were trimmed at 10 days of age by an experience beak trimmer using a Lyon beak trimming machine to remove one half of the upper beak and one third of the lower beak from chickens. Pullets from both treatments were wing banded and housed in rearing cages until 18 weeks. During the layers stage a randomised design was used for allocation of treatments with 10 replicates per treatment. A single replicate comprised 4 birds per cage in Harrison 'Welfare' back-to-back, single tier cages (each 500 mm wide by 545 deep; 545 cm^2/bird) in a fan ventilated insulated laying shed with louvered windows. The layer shed was equipped with evaporative coolers linked to a thermostat. The cooling operated when shed temperature at bird level reached 25^{o}C. The temperature range in the shed during the experiment from March 2006 to April 2007 was approximately 12-28^{0}C. IR trimmed birds were treated day old at the hatchery using an IR beak treatment machine developed by Nova-Tech engineering. Birds were fed *ad libitum* on a commercial chick starter diet from 0- 6 weeks, a grower diet from 7-18 weeks and a layer diet from

19-66 weeks. Beak length, beak step, beak condition, body weight, egg production and egg weight were determined monthly throughout the growing and laying period. Beak length and beak step was measured using a digital electronic vernier calliper. Upper beak length was measured from the edge of the external nare to the tip of the beak and beak step from the edge of the top beak to the edge of bottom beak. Beak condition was assessed using a grading system as Grade 1, no imperfections, splitting, chapping or swelling; good keratin layer on beak; beak is not too short; Grade 2 (beak shows minor imperfections in appearance and beak is too short) and Grade 3 (beak shows major imperfections and is very short).

<u>Beak Grades Guide</u>

Grade 1

- No imperfections, splitting, chapping or swelling;
- Good keratin layer on beak;
- Beak is not too short

Grade 2

- Beak shows minor imperfections in appearance and beak is too short

Grade 3

- Beak shows major imperfections and is very short

Hyline layers housed in cages were monitored for the same beak variables at 45 and 60 weeks on 3 commercial egg farms in South Australia.

III. STATISTICAL ANALYSIS

The birds were selected at random for each treatment in the Roseworthy trial and for birds monitored on farm. Comparisons were analysed over the period 0-60 weeks for the Roseworthy trial. For the 3 industry farms data were assessed on 100 birds at 45 and 60 weeks of age. Farm 1 and 2 used only one of the trimming methods while farm 3 used both methods of trimming. Trimming method and age were the main factors in the analyses. Treatment effects were analysed using the ANOVA in the Systat software (Wilkinson, 1996).

IV. RESULTS

a. Roseworthy trial

Beak length, beak step, beak growth and beak condition: Beak length was significantly ($P<0.01$) longer for IR trimmed birds than HB trimmed birds over the whole experimental period (Table 1 and Figure 1). However, the beak step (gap between top and bottom beak) was significantly ($P<0.01$) larger for HB trimmed birds compared to the IR trimmed birds except for the first week. IR trimmed beaks regrew more ($P<0.01$) than HB trimmed birds in weeks 1, 6, 8, 12, 36 except for weeks 4, 14, 24. Beak regrowth declined as the birds aged. Birds trimmed with the HB had significantly ($P<0.01$) poorer beak condition than IR trimmed birds up to 40 weeks age but thereafter there was no significant difference in beak condition with a score of 2.01 for IR trimmed birds and 2.11 for HB trimmed birds (Figure 2).

Table 1. The beak length, beak step, beak gain, bird body weight and weight gain at different weeks of age for different treatments at the Roseworthy farm.

Treatment	Age (week)	Beak length (mm)	Beak steps	Beak gain	Body Weight	Weight gain	Beak score
IR	1	7.094	0.428	1.415	89.4	56.5	
HB	1	3.261	0.196	-2.380	88.3	57.4	
	P	*0.000*	*0.166*	*0.000*	*0.73*	*0.75*	
	SEM	*0.216*	*0.084*	*0.216*	*1.51*	*1.45*	
IR	4	6.746	0.154	-0.348	342.2	252.8	
HB	4	5.410	2.064	2.084	324.5	234.4	
	P	*0.000*	*0.000*	*0.000*	*0.06*	*0.012*	
	SEM	*0.128*	*0.123*	*0.162*	*4.66*	*3.68*	
IR	6	7.748	0.269	0.864	582.1	232.9	
HB	6	4.979	1.729	-0.325	509.9	191.8	
	P	*0.000*	*0.000*	*0.008*	*0.08*	*0.28*	
	SEM	*0.275*	*0.112*	*0.227*	*20.34*	*19.14*	
IR	8	10.097	0.612	1.468	853.9	205.6	1.205
HB	8	6.296	2.896	0.653	773.133	195.2	2.089
	P	*0.000*	*0.000*	*0.000*	*0.000*	*0.104*	*0.000*
	SEM	*0.220*	*0.169*	*0.099*	*9.49*	*3.20*	*0.064*
IR	10	10.643	0.452	0.546	1069.7	215.9	1.727
HB	10	6.722	3.172	0.425	973.1	199.9	2.133
	P	*0.000*	*0.000*	*0.442*	*0.00*	*0.016*	*0.000*
	SEM	*0.221*	*0.193*	*0.078*	*10.71*	*3.33*	*0.047*
IR	12	11.660	0.499	1.017	1311.5	241.7	1.591
HB	12	7.250	3.464	0.675	1162.4	210.5	2.043
	P	*0.000*	*0.000*	*0.032*	*0.00*	*0.002*	*0.000*
	SEM	*0.264*	*0.212*	*0.080*	*18.32*	*5.19*	*0.054*
IR	14	11.926	0.590	0.266	1458.4	147.0	1.591
HB	14	7.902	3.938	0.652	1282.0	119.6	2.152
	P	*0.000*	*0.000*	*0.017*	*0.00*	*0.001*	*0.000*
	SEM	*0.252*	*0.237*	*0.082*	*20.39*	*4.07*	*0.061*
IR	16	12.109	0.665	0.183	1588.9	130.4	1.750
HB	16	8.036	4.271	0.133	1377.6	95.6	2.174
	P	*0.000*	*0.000*	*0.766*	*0.00*	*0.00*	*0.000*
	SEM	*0.256*	*0.248*	*0.082*	*23.17*	*4.91*	*0.058*
IR	18	11.885	0.673	-0.224	1730.7	141.8	1.818
HB	18	8.116	4.407	-0.098	1495.8	87.5	2.311
	P	*0.000*	*0.000*	*0.455*	*0.00*	*0.03*	*0.000*
	SEM	*0.232*	*0.270*	*0.084*	*21.34*	*12.78*	*0.057*
IR	20	11.924	0.559	0.040	1832.7	102.0	1.682
HB	20	8.076	3.927	-0.040	1635.8	140.0	2.067
	P	*0.000*	*0.000*	*0.643*	*0.00*	*0.23*	*0.000*
	SEM	*0.224*	*0.235*	*0.086*	*19.22*	*15.61*	*0.050*
IR	24	11.959	0.450	-0.001	1995.9	159.0	1.795
HB	24	8.359	4.118	0.450	1811.2	202.7	2.073
	P	*0.000*	*0.000*	*0.038*	*0.003*	*0.19*	*0.006*
	SEM	*0.253*	*0.294*	*0.109*	*31.71*	*16.80*	*0.051*
IR	28	12.112	0.464	0.153	2114.3	118.5	2.000
HB	28	8.801	3.476	0.234	1974.2	117.7	2.150
	P	*0.000*	*0.000*	*0.743*	*0.004*	*0.98*	*0.031*
	SEM	*0.209*	*0.224*	*0.122*	*24.52*	*17.56*	*0.035*
IR	32	12.223	0.759	0.111	2129.2	14.9	2.051
HB	32	8.466	3.865	-0.120	1964.1	38.0	2.146
	P	*0.000*	*0.000*	*0.153*	*0.02*	*0.51*	*0.301*
	SEM	*0.259*	*0.242*	*0.081*	*36.5*	*17.43*	*0.046*

IR	36	12.189	0.862	0.275	2215.6	150.8	2.231
HB	36	8.476	4.037	-0.202	2070.0	56.7	2.000
	P	*0.000*	*0.000*	*0.018*	*0.06*	*0.003*	*0.014*
	SEM	*0.287*	*0.252*	*0.101*	*39.14*	*16.29*	*0.048*
IR	40	12.593	0.689	0.084	2296.8	22.9	2.026
HB	40	8.663	4.515	0.187	2139.0	69.0	2.150
	P	*0.000*	*0.000*	*0.556*	*0.004*	*0.06*	*0.208*
	SEM	*0.251*	*0.284*	*0.087*	*27.86*	*12.11*	*0.049*
IR	47	12.686	0.704	0.092	2314.7	17.9	2.053
HB	47	8.882	5.101	0.218	2168.2	29.2	2.100
	P	*0.000*	*0.000*	*0.463*	*0.01*	*0.60*	*0.621*
	SEM	*0.253*	*0.321*	*0.085*	*28.8*	*10.73*	*0.047*
IR	50	13.212	0.898	0.526	2343.7	28.9	2.026
HB	50	9.073	4.749	0.192	2097.7	-70.5	2.175
	P	*0.000*	*0.000*	*0.208*	*0.00*	*0.01*	*0.140*
	SEM	*0.264*	*0.297*	*0.132*	*32.62*	*19.72*	*0.050*
IR	54	13.281	0.798	0.069	2369.7	26.0	1.895
HB	54	9.523	4.796	0.450	2215.0	117.2	2.050
	P	*0.000*	*0.000*	*0.188*	*0.003*	*0.005*	*0.056*
	SEM	*0.256*	*0.305*	*0.144*	*26.50*	*16.61*	*0.041*
IR	58	13.288	0.840	0.008	2399.7	30.0	2.026
HB	58	9.815	4.977	0.293	2250.5	35.5	2.075
	P	*0.000*	*0.000*	*0.361*	*0.003*	*0.74*	*0.586*
	SEM	*0.233*	*0.302*	*0.155*	*25.83*	*8.09*	*0.044*

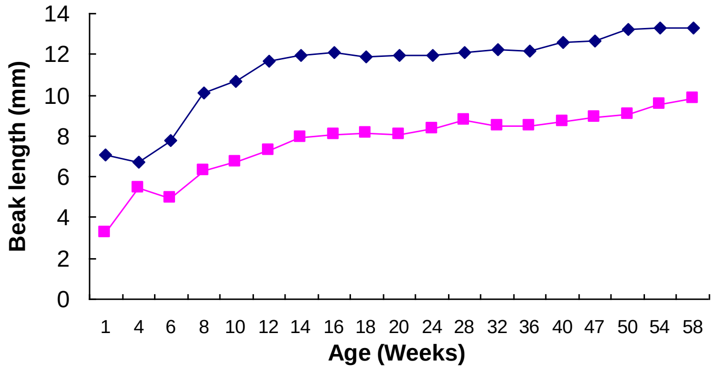


Figure 1. Beak length at different ages for IR (ω) and HB (♣) treatments.

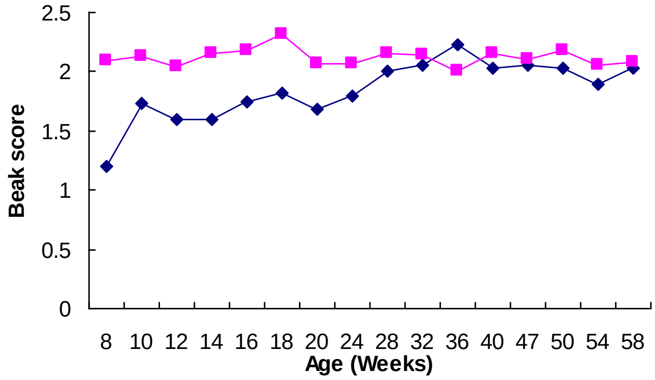


Figure 2. Beak score at different ages for IR (ω) and HB (♣) treatments.

Body weight: Generally, body weight of birds that were IR trimmed were heavier than the birds trimmed with the HB method. No significant (P>0.05) difference in body weight was found for weeks 1, 4, 6 and 36 between treatments, but there were significant (P<0.05) differences in weeks 8, 10, 12, 14, 16, 18, 20, 24, 28, 32, 40, 47, 50, 54 and 58. Birds that were IR trimmed gained more (P<0.05) weight in Week 4, 10, 12, 14, 16, 18, 36, 50 and 54 compared to birds on HB trimming (Figure 3).

Egg production: There was no significant (P>0.05) difference in numbers of eggs laid/week (Figure 6) between treatments, but HB birds laid heavier (P<0.05) eggs (63.7g) than the IR birds (62.0g) (Figure 3 and 4).

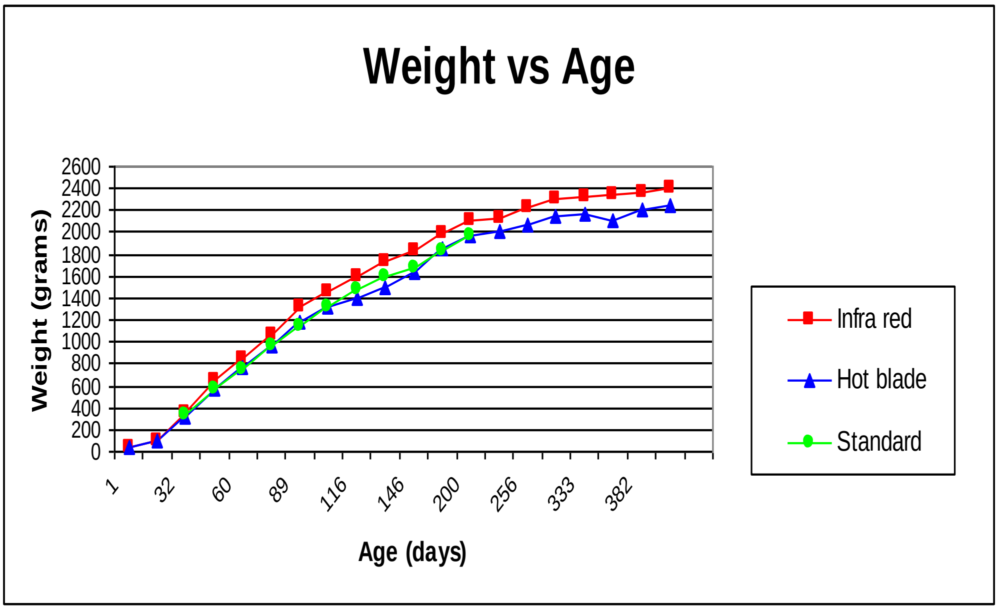


Figure 3. The body weight of birds on different treatments vs standard.

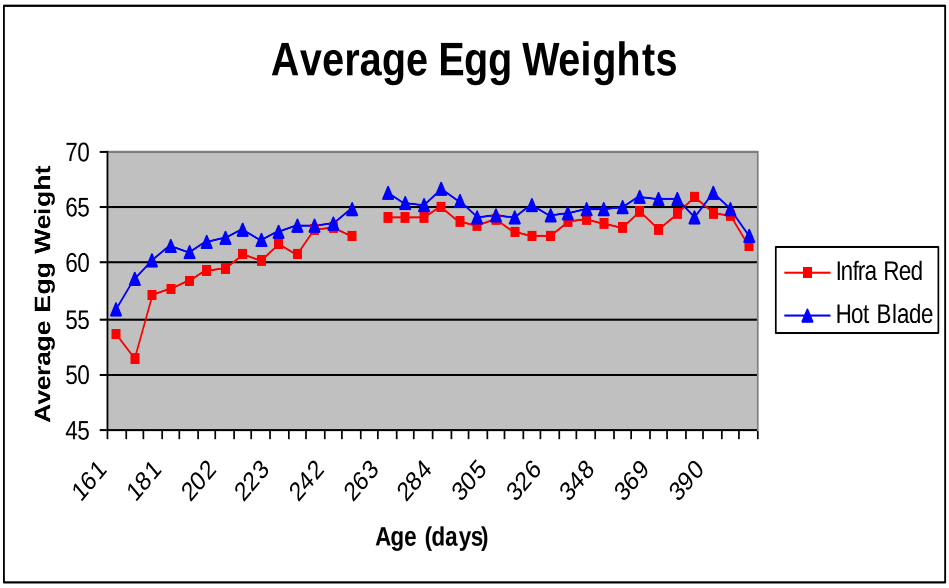


Figure 4. The average egg weight for birds trimmed by IR or HB methods.

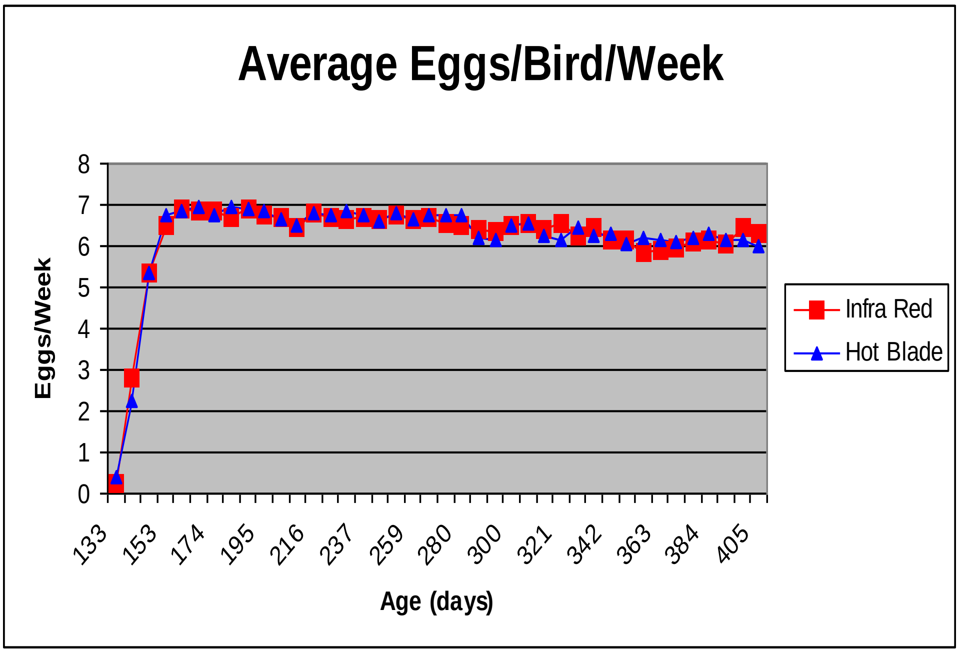


Figure 5. Eggs/week laid by the birds trimmed by the IR or HB method.

b. Industry egg farms

Beak length of layers at 45 and 60 weeks was longer (P<0.001) for IR trimmed birds compared to HB trimmed birds (Table 2) except for farm 3 at 60 weeks. However, the beak step was significantly (P<0.001) larger for HB trimmed birds than IR trimmed birds at week 45 (4.01 vs. 1.46mm) and week 60 (4.17 vs. 1.60mm) for birds on farms 1 and 2 but no differences were observed for farm 3. Beak condition was better (P<0.05) for IR trimmed birds compared to HB trimmed birds at week 45 and 60 for birds on farms 1 and 2. This difference was significant on farm 3. There was no difference in beak regrowth for both trimming treatments at week 60.

Table 2. Beak characteristics at week 45 and 60 weeks on 3 industry egg farms

Farm	Age (weeks)	Beak length (mm)	Beak step (mm)	Beak condition
Farm 1 (IR)	45	11.526[a]	1.462[a]	1.955
Farm 2 (HB)	45	9.602[b]	4.012[b]	1.840
	P	0.000	0.000	0.245
	SEM	0.177	0.225	0.049
Farm 1 (IR)	60	11.172[a]	1.602[a]	2.119
Farm 2 (HB)	60	9.402[b]	4.166[b]	2.091
	P	0.000	0.000	0.814
	SEM	0.175	0.236	0.059
Farm 3 (IR)	45	9.859 [a]	1.739	2.000[a]
Farm 3 (HB)	45	10.561[b]	1.474	1.280[b]
	P	0.001	0.339	0.000
	SEM	0.107	0.138	0.059
Farm 3 (IR)	60	9.640	1.241[a]	2.024
Farm 3 (HB)	60	9.508	1.872[b]	1.684
	P	0.810	0.035	0.016
	SEM	0.272	0.150	0.071

[a, b] Indicates significant difference for paired comparisons between farm 1 and 2 at 45 or 60 weeks and for farm 3 at 60 weeks.

V. DISCUSSION

Beak length from 0-60 weeks ranged from 3.26-9.82mm for HB trimmed birds and from 6.75-13.29mm for IR trimmed. However, for the first 6 weeks after trimming there was less variation in beak length for both trimming methods. This was also noted by Gentle and McKeegan (2007) in their 6 week experiment comparing IR and HB trimming methods. In our trial there was continual regrowth of the beak from week 1-60 after trimming for both methods. At the end of the trial the HB trimmed birds had a shorter beak (9.82mm) compared to IR trimmed beaks (13.29mm). The level of HB beak trimming at 10 days of age was greater than recommended in the Code of Practice. The upper beak remaining at 20 weeks was 8 mm compared to recommended levels of 10 mm (Bourke *et al*, 2002).

Beak step of birds on HB trimming ranged from 0.20mm at birds week of age to 5.10mm at 47 weeks of age. A smaller beak step was found for IR trimmed, ranging from 0.15mm at 4 weeks of age to 0.90mm at 50 weeks of age. Glatz and Bourke (2005) reported that most producers aim to have a blunt beak with a beak step of 3mm at 30 weeks of age to prevent feather pecking and cannibalism. Beak step for birds on HB trimming at 28 and 32 weeks of age was 3.48 and 3.87mm respectively and for birds on IR trimming was 0.46 and 0.76mm respectively. These results may indicate that IR trimmed birds have a greater capacity to engage in feather pecking and cannibalism by having a longer beak and a shorter beak step.

IR trimmed birds had a heavier body weight and a superior weight gain than the birds trimmed with the HB when compared at the same age. This result was similar to Gentle and McKeegan's (2007), who found body weight of HB trimmed birds was lower than IR trimmed birds over a 6 week experiment. Egg production for both trimming methods were similar, but HB trimmed birds laid heavier eggs (63.7g) compared to the IR trimmed birds (62.0g). This could be due to a greater ability of HB trimmed birds to consume smaller particles of feed. No significant effects on bird behaviour for the two trimming methods were found after trimming up to 6 weeks of age (Gentle and McKeegan, 2007). In terms of beak condition it was clear (particularly early in the production phase) those birds trimmed with the HB method had a poorer beak appearance than the IR trimming method. However the ability of IR trimmed birds to engage in more feather pecking and cannibalism due to a longer beak and better beak condition needs to be evaluated. The results indicate there is variation in beak length and regrowth on farms for birds trimmed with both methods. This suggests that further work is required to ensure beak trim methods are practiced consistently.

1.2 Mortality of layers trimmed with the IR method for birds housed in cage and free range barn systems in Australia

SUMMARY

In Australia IR beak trimming has recently been introduced as an alternative method of beak trimming. Although IR beak treatment may represent an advance little data is available that documents whether the method is effective in reducing cannibalism. IR beak treatment at the hatchery was used on about 1m layers in the Australian egg industry. Mortality from 32 flocks of hens housed in cages (Hi-rise, multi-tier and conventional) with natural ventilation or controlled environment were compared with 14 free range barn systems (slats or slats/litter) with natural ventilation. The flocks had an age range from 20-80 weeks and mortality of birds from each flock was corrected to 50 weeks of age.

Free-range/barn systems had higher (P<0.05) mortality (2.58%) compared to birds housed in cages (1.81%). There was no significant difference in bird mortality for birds housed in cage systems or provided with different ventilation methods. For the free-range/barn system there was no difference in layer mortality when comparing slats with the slats/litter flooring system. The relatively low mortality of birds in all production systems indicates the IR method is a suitable method of beak trimming despite higher levels of mortality in free range barn systems.

I. INTRODUCTION

In Australia IR beak trimming has been used more recently as an alternative to HB beak trimming. While IR beak treatment may represent an advance in beak trimming technology, very little data is available that documents whether the method is effective in reducing cannibalism. There have been anecdotal reports from overseas of variations in beak growth and re-growth in flocks trimmed early in life with the IR method. Excessive beak regrowth is seen as a field problem and there is no clue as to why this is happening. Solutions examined were to use higher energy to treat the beak, which resulted in less beak regrowth and a smoother beak stump at a later age (Cheng Per. Comm.). In Australia field reports have indicated that flocks trimmed using the IR technology have resulted in variable beak length within the flock, which may predispose some birds to increased levels of feather pecking. The aim of the study was to document the mortality of birds trimmed with the IR method for about 1m birds housed in cage and free-range barn systems.

II. MATERIALS AND METHODS

Mortality was measured in IR trimmed birds for 32 flocks of hens housed in cages (Hi-rise (7 flocks), multi-tier (15 flocks) and conventional (10 flocks)) and provided natural ventilation or controlled environment. The mortality from these flocks was compared with 14 free range barn systems (slats (6 flocks) or slats/litter (8 flocks)) with natural ventilation. Total number of birds housed in the 46 sheds was approximately 1m birds with an age range from 20-80 weeks of age. Mortality of birds from each flock was corrected to 50 weeks of age.

III. STATISTICAL ANALYSIS

Comparisons of birds mortality between housing, ventilation and flooring system systems were analysed using the ANOVA in the Systat software (Wilkinson, 1996).

IV. RESULTS

Free-range/barn systems had higher (P<0.05) mortality (2.5%) when corrected to 50 weeks of age (Table 3) compared to cage systems (1.8%). There was no significant difference in bird mortality (Table 4) between the conventional cage (1.9%), Hi-rise (1.80%) and the multi tier system (1.80%). Likewise no difference in bird mortality (Table 5) was observed in cage systems whether the birds were ventilated with the controlled environment method (1.8%) or naturally ventilated (1.8%). Furthermore birds housed on slats (2.8%) showed no differences in mortality (Table 6) with birds housed on slats/litter (2.5%). Figure 7 shows the comparison between all production systems in bird mortality.

Table 3. Layer mortality (%) in different rearing systems

Treatment	Mortality at 50 weeks of age
Cage	1.811
Free-range/Barn	2.508
P	*0.024*
SEM	*0.142*

Table 4. Layer mortality in different cage systems

Treatment	Mortality at 50 weeks of age
Conventional	1.852
Hi-rise	1.792
Multi-tier	1.793
P	*0.982*
SEM	*0.141*

Table 5. Layer mortality for different ventilation systems in cage systems

Treatment	Mortality at 50 weeks of age
CE	1.793
Natural	1.827
P	*0.905*
SEM	*0.141*

Table 6. Layer mortality for different floor systems in free-range/barn production systems

Treatment	Mortality at 50 weeks of age
Slats	2.773
Slats/litter	2.456
P	*0.635*
SEM	*0.313*

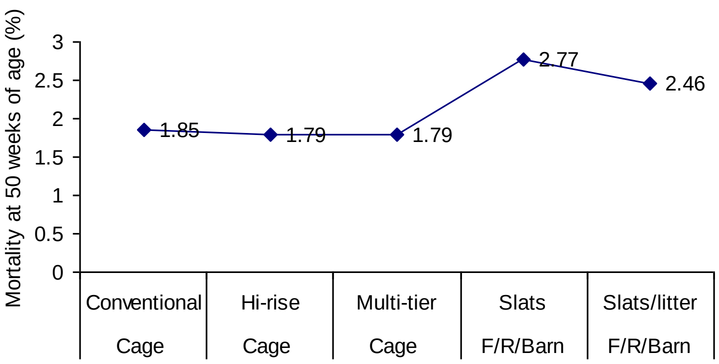


Figure 6. Bird mortality in different housing systems.

V. DISCUSSION

The results from this field assessment of mortality indicate that the reports from overseas and Australia of variations in beak growth and re-growth in flocks trimmed early in life with the IR method are not being translated into increases in mortality for the flocks assessed in Australia. The mortality levels reported are well within industry standards and provide evidence that the IR method is suitable for use in Industry and does not lead to excessive levels of cannibalism. The power settings on the IR trimming machine have an important bearing on whether extensive beak regrowth occurs (H. Cheng, pers. comm.). In this study it is likely that the settings on IR machine were appropriate and prevented beak regrowth and subsequent cannibalism. The Industry in Australia should then be confident that the new beak trimming technology is suitable for use and prevents excessive mortality from cannibalism.

2. Work conducted at Flinders University

Histology work was conducted by Dr. Christine Lunam at Flinders University.

SUMMARY

- The method of trimming, that is HB versus IR resulted in a similar histopathology of the upper beaks. Neuromas were present at 32 days of age and persisted to 420 days of age.
- Sensory receptors were not observed in beaks from either method of trimming at any age examined.
- The histopathology suggests, based on the current literature (for review see Lunam, 2005) and from the beak lengths remaining on birds assessed that excessive tissue was removed for the age at which the birds were HB trimmed. IR trimming has a significant impact on histopathology despite the level of beak remaining. This resulted in the formation of traumatic neuromas which persisted to adulthood.
- Birds trimmed with a HB at 10 days of age formed traumatic neuromas which persisted to adulthood. There is a need to practice HB trimming at day old instead of 10 days according to the Code of Practice to overcome neuroma formation and chronic pain
- There is a need to continue with the development of new technology methods of beak trimming such as laser and phyto agglutination as an alternative to current methods of beak trimming.

II. MATERIALS AND METHODS

Fifty IR trimmed Hyline Brown chicks were treated at day old in the hatchery using an IR beak treatment machine developed by Nova-Tech engineering. Another 50 chicks were trimmed at 10 days of age by an experienced beak trimmer using a Lyon beak trimming machine to remove one half of the upper beak and one third of the lower beak from chickens Upper beak samples were obtained from birds at 32, 144 and 420 days of age. The beaks were placed in Zamboni's fixative (prepared in Dr. Lunam's laboratory) and then sent to PPPI. Upper beaks from both HB and IR treatments were fixed for several weeks in the Zamboni's solution and returned to Flinders University. After fixation the beaks were decalcified over a period ranging from two weeks to three months, the time required to decalcify the tissue being directly dependent on the age of the beak. To aid histological sectioning of the beaks excess keratin was removed from the tomial margins and beak tips. Following decalcification, the beaks were processed for wax embedding and sagittal consecutive sections of seven micrometres in thickness were then collected from each beak. To ensure any microneuromas present within the tissue were not missed, the entire beaks were sectioned. These sections were then stained with haematoxylin and eosin for histological assessment. To determine the effects of HB versus IR trimming on the histopathology of the upper beaks over time, treatments were compared as shown in Table 7.

Table 7. Treatment groups showing number of beaks examined per group.

	Treatment	
Age of bird (days)	HB	IR
32	5	5
144	5	5
420	6	6

III. RESULTS AND DISCUSSION

General comment on tissue sections

The upper beaks at both 32 and 144 days of age were well fixed and therefore allowed readily discernable architectural features. In contrast all beaks at 420 days of age were poorly fixed. It was still possible however in many of these beaks to identify any gross histopathology. Some of the beaks at both 32 days and 144 days of age had excess keratin removed at the tips therefore no assessment could be made with respect to the presence of any receptors or extent of neural innervation in the most distal tissue of these beaks.

Presence of traumatic neuromas

- *32 days of age*

A few scattered microneuromas were found in some beaks at 32 days of age. These were found in the ventral dermis adjacent to the roof of the palate. The presence of the microneuromas was independent of the type of trimming as they were found in three beaks trimmed by HB and two beaks trimmed by the IR method. Receptors were not identified in any of these beaks. This is possibly because the tissue, in which these receptors would normally be found, had been accidentally removed during preparation of the beaks. An alternative explanation is that a significant amount of tissue was removed at the time of trimming with either method, thereby inducing scar tissue in conjunction with the complete absence of receptors in the regrown beaks (Lunam 2005). In support of this theory, some scar tissue was observed in these beaks.

- *144 days of age*

In all beaks, irrespective of whether they were trimmed by HB or IR procedures, neuromas were present. These appeared as either extensive traumatic neuromas or small fascicles of microneuromas. They were observed in the ventral dermis as well as in the distal tissue near the beak tip. Some scar tissue was observed in these beaks. In most of these beaks the distal dermis had been accidentally removed during preparation, and thus it was not possible to determine the presence or absence of receptors or nerve fibres at the actual tips of the regrown beaks.

- *420 days of age*

Of the twelve total beaks examined two from HB and three from IR was poorly fixed. Consequently the histopathology of these sections was very difficult to determine. However in the remainder of the beaks extensive traumatic neuromas and scar tissue were clearly present. These neuromas were present in both the HB and IR trimmed beaks. It was clear that the level of HB beak trimming practiced at 10 days of age for the birds assessed was greater than recommended in the Code of Practice to minimise neuromas. The upper beak remaining was approximately 2 mm less than recommended (Bourke *et al* .2002) throughout lay. In the case of IR trimming it is clear the treatment has a significant impact on histopathology resulting in chronic neuromas despite the level of beak remaining.

3. Work conducted at UNE

3.1 Self-administration of an analgesic does not alleviate pain in beak trimmed chickens

SUMMARY

Beak trimming in laying hens is a routine practice in which about ⅓ – ½ of the upper and lower beak is removed with the aim of reducing cannibalism. This experiment aimed to identify if this procedure causes pain by examining self-administration of an analgesic (carprofen) and pecking behaviour in 80 laying pullets beak-trimmed by two different methods; at one day of age using hot-blade cauterisation or infra-red cauterisation. We also tested a control treatment, pullets with intact beaks, and a positive control treatment of pullets beak trimmed at 10 weeks of age which were expected to experience some pain due to recent severing of the underlying nerves in the beak. At 11 weeks of age birds trimmed at 10 weeks of age pecked more ($P<0.001$) gently (0.6±0.06N) at a disc attached to a force-displacement transducer than birds trimmed at 1 day of age with an infra-red machine (0.9±0.1N) or a HB (1.1±0.07N) and intact birds (1.2±0.1N). Maximum force of pecks recorded was also lower ($P<0.001$) in birds trimmed at 10 weeks of age than birds trimmed at 1 day of age with an infra-red method or a HB and intact birds. However, the pecking force in birds trimmed at 10 weeks of age was not increased by providing them with analgesic-treated feed, though birds that ate more carprofen had a higher maximum force of peck ($P=0.03$). Pecking force in birds beak trimmed at 1 day of age was the same as the pecking force of intact birds, and was unaffected by feeding pullets carprofen. A method of self-administration of an analgesic had previously revealed that chickens in neuromuscular pain arising from lameness consumed more of a feed containing carprofen than healthy chickens. However, we found no evidence that beak trimmed pullets consumed more carprofen-treated feed than pullets with an intact beak. It should be noted that the three beak trimming methods resulted in an average 34% reduction in beak length, considered a light trim, and is perhaps not representative of commercial birds where greater portions of the beak are removed. We conclude that although carprofen has been reported to have an analgesic effect on neuromuscular pain in chickens, it appears to have no analgesic effect on potential neuropathic pain arising from the nerves severed by a light beak trim.

I. INTRODUCTION

There is a pressing need to develop reliable and unequivocal indicators of pain in farm animals to identify the welfare implications of various routine industry procedures. Beak trimming in laying hens is the removal of about ⅓ – ½ of the upper and lower beak of the young chicken, commonly using a hot-blade which simultaneously amputates and cauterizes. This routine industry practice is undertaken because it reduces the extent of cannibalism and vent pecking during rearing and in adulthood (Glatz, 1990). Within the industry, beak trimming is also often considered to improve feed efficiency and this has been supported by some studies (e.g. Glatz, 2000; Davis *et al*., 2004), though others have failed to find any improvement in feed conversion following beak trimming (e.g. Carey and Lassiter, 1995). The beak of the chicken is a complex functional organ with an extensive nerve supply that is used for food manipulation, exploration of the environment, preening and social interaction. Objections to beak trimming have centred on the possibilities that this practice causes acute and/or chronic pain and that trimming deprives the chicken of sensory feedback and impairs the function of the beak (Glatz, 2000).

To date, animal welfare research has provided some behavioural and neurological evidence to inform the debate on the acceptability of routine beak trimming within the industry (see Cheng, 2006 for a recent review). However, there are limitations to both these lines of evidence: first, it is unclear whether the reported reduction in pecking following beak trimming, termed guarding behaviour, indicates pain or arises from the loss of sensory perception in the beak. Since the nerves have been severed, pecking with a trimmed beak will not provide the sensory feedback that an intact beak may provide, and may thus reduce the sensory stimulation achieved through exploration with the beak resulting in less pecking. Additionally, the regrown tips of the beak do not always contain afferent nerves or sensory corpuscles (Gentle *et al*., 1997); therefore the loss of sensory feedback may be long-term and may explain long-term evidence of guarding behaviour. It appears that the amount of beak removed appears critical, with some evidence that sensory receptors are still present in moderately trimmed birds (Lunam *et al*., 1996). It should also be noted that the main objective of beak trimming, a reduction in cannibalism, could arise both from a resultant reduction in the tendency of birds to peck or by reducing the amount of damage that birds can cause each other. Second, it is also unclear whether nerves that form neuromas project to the brain, and if they do whether they transmit action potentials to brain areas that may interpret these as pain. Animal welfare research therefore urgently needs reliable and unequivocal indicators of pain in beak trimmed birds that will aid the moral debate as to the suitability of this routine procedure.

When given a choice of feeds, rats with clinical symptoms of pain will consume more of an analgesic-containing feed than animals not in pain (e.g. Colpaert *et al*., 2001). It has been known for some time that chickens are able to select some feeds over others, even when both feeds are visually similar but differ only in nutrients, such as by consuming more feed high in selenium than feed lacking in selenium (Zuberbueher *et al*., 2002). Similarly, Danbury *et al*. (2000) found that when given a choice of feeds with and without an analgesic (carprofen), lame broiler chickens consumed more of the analgesic-treated feed than sound birds. Additionally, the consumption of carprofen in chickens was positively correlated to the severity of lameness, and consumption resulted in an improved gait (Danbury *et al*., 2000). The authors conclude that lame birds are able to select feeds with analgesics, thereby indicating that they are in pain and that they will actively seek relief from this pain. Carprofen is a non-steroidal analgesic which has previously been shown to have an effect on chickens, by improving the gait of lame broilers (McGeown *et al*, 1999). In the present experiment we used a method based on the approach described by Danbury *et al*. (2000) to investigate the potential impact of pain in beak trimmed birds. If trimmed birds are in pain and attempt to guard the beak from further pain stimulation, then we predicted that trimmed birds should peck more gently than intact birds. This difference in pecking force should however be removed by administering an analgesic. We also trained chickens using colour cues to distinguish between carprofen-treated feed and untreated feed as undertaken by Danbury *et al*. (2000). We predicted that beak trimmed birds should consume more analgesic-treated feed than intact beak birds when both feeds were presented simultaneously.

Chickens were beak trimmed at one day of age by either a HB or an IR method by a commercial hatchery as is common commercial practice. We also tested intact beak birds as a control condition and birds that had been beak trimmed at 10 weeks of age using a HB as a positive control; behavioural and neurological evidence (Megret *et al*., 1996; Gentle *et al*., 1997) indicates that birds trimmed at 10 weeks of age are likely to experience pain in the two weeks following trimming.

II. MATERIALS AND METHODS

Eighty Hyline Brown laying pullets were housed in pairs in cages measuring 50 x 55cm (wxd) x 50cm high at the front of the cage at 10 weeks of age in an open sided layer shed. Pullets were *ad lib* fed with pullet grower crumbles (Ridley Agriproducts, Victoria), and water was available from nipple drinkers. Fluorescent lights were on a 14h light: 10h dark cycle and temperature was 21 ± 5^0C. Four groups of twenty chickens had been subjected to one of 4 beak trimming methods as follows: 1) hot-blade trimming at 1 day of age, 2) infra-red beak trimming at 1 day of age, 3) hot-blade beak trimming at 10 weeks of age and 4) intact beaks. Trimming at one day of age was undertaken by staff at a commercial hatchery (Kean's Poultry, Huntley, Victoria), and trimming at 10 weeks by an experienced technician, and in both cases about ⅓rd of the upper and lower beak was removed which is a light trim.

At 11 weeks of age chickens were given experience of two different feeds on alternate days for 6 days. The feeds consisted of grower crumbles which were coloured either red or blue using food dye (Queen's blue and red food colouring, Queen fine foods, Queensland, Australia) at a concentration of 125ml/20kg crumbles. Feed was provided in individual metal feeders 20 x 14 x 10cm at front (20 cm at the back and sides) and sprayed with the food dye colour. One of these coloured feeds was treated with an analgesic, carprofen (Pfizer animal health, rimadyl injection) at a dose of 80mg/kg of feed. Mixing of the feed with the colouring (and carprofen) was achieved by spraying the solution into the feed in a cement mixer until a visually even colour was achieved. According to Danbury *et al*. (2000) the dose would provide each bird with therapeutic levels of carprofen (see discussion). The respective position of each feeder (i.e. left or right side of the cage) was chosen at random on the first day, and thereafter this choice was maintained for the entire duration of the experiment. Half of the chickens from each beak trimming method were provided with red analgesic-treated feed and the other half with analgesic-treated blue food, with untreated feed sprayed with the alternative colour.

For the first four days of training with different coloured feeds, the force of pecks at 5 black pebbles glued to a 10 cm diameter white disc was measured using a force-displacement transducer (GRASS (reg.), Australia) and recorded using Chart 5 software (ADInstruments). No attempt was made to distinguish the pecks of the two birds in each cage, so each cage provided a single measure for the pecking force analysis. The duration from placing of the disc through the front of the cage to the first peck of the disc was measured, along with the force of the first 10 pecks on one day when analgesic-treated feed was provided, and one day when untreated feed was provided. Measurements of pecking force began two hours after feeding, and the order of recording on days when treated and untreated feed was balanced for order effect.

At the end of the fourth day, one bird from each cage was removed and placed in a cage alone for two further days so that all 80 birds were in individual cages, randomly assigned in blocks of 10 pullets from each treatment along two rows of cages. Analgesic-treated feed was given one day and untreated feed the other day, and the relative position of the side of the cage that each feeder was placed was retained from the first four days. All coloured feed was then removed and birds were returned to uncoloured grower crumbles for 12 hours. After this period, both analgesic-treated and untreated coloured feed were simultaneously given to the pullets in two feeders/cage. The feeders were weighed daily to measure the amount of each coloured food consumed. After weighing, the feeders were replenished with enough fresh feed (about 150g) to ensure that both colours were available *ad lib*.

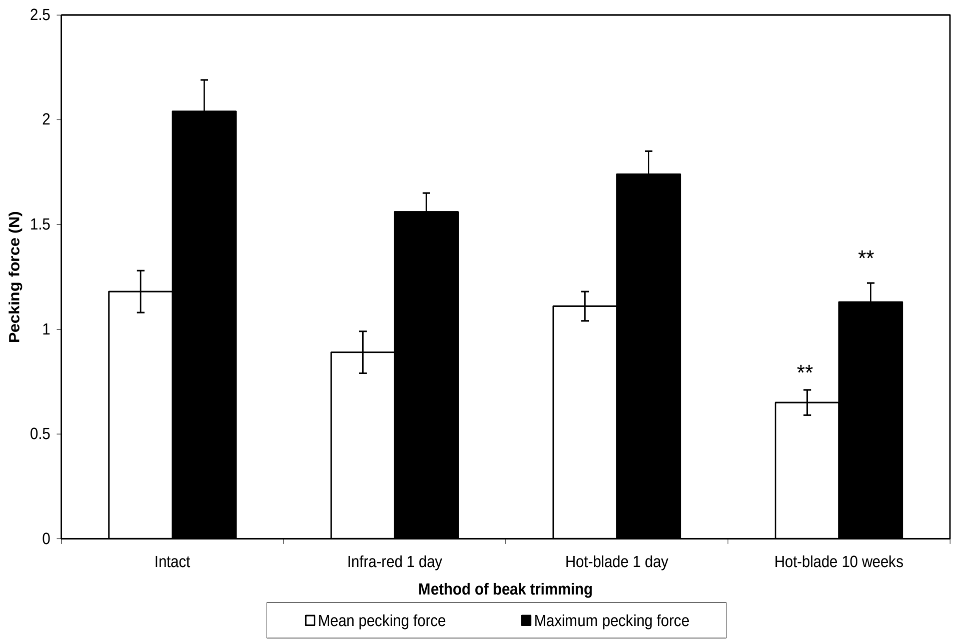
Beak length was measured in all birds and the difference between the upper and lower beak measured in beak trimmed birds using a vernier calliper. Pecking force was analysed in a General Linear Mixed Model (SPSS 14.0, SPSS Inc., USA), with cage as a replicate and four beak methods and two feed treatments (analgesic-treated or untreated) as the repeated measure. The amount of analgesic-treated feed consumed was analysed in a General Linear Model with 4 beak conditions.

III. RESULTS

Pecking force: Birds without beak trimming had strongest pecking force compared to birds trimmed with HB at day 1, trimmed with IR at day 1 and trimmed with HB at 10 weeks of age (Figure 7). However, the mean pecking force was similar for the birds without trimming and trimmed with HB at day 1. Maximum and mean pecking force was weak for IR trimming compared to HB trimming at day 1, but stronger than the birds trimmed with HB at 10 weeks of age.

Figure 7. The mean pecking force (white bars) and maximum pecking force (black bars) in Newtons of 20 pecks (i.e. analgesic-treated and untreated feed data combined) from birds from four beak trimming methods. Birds trimmed at 10 weeks of age pecked more gently (**P<0.001) than other birds (see text).

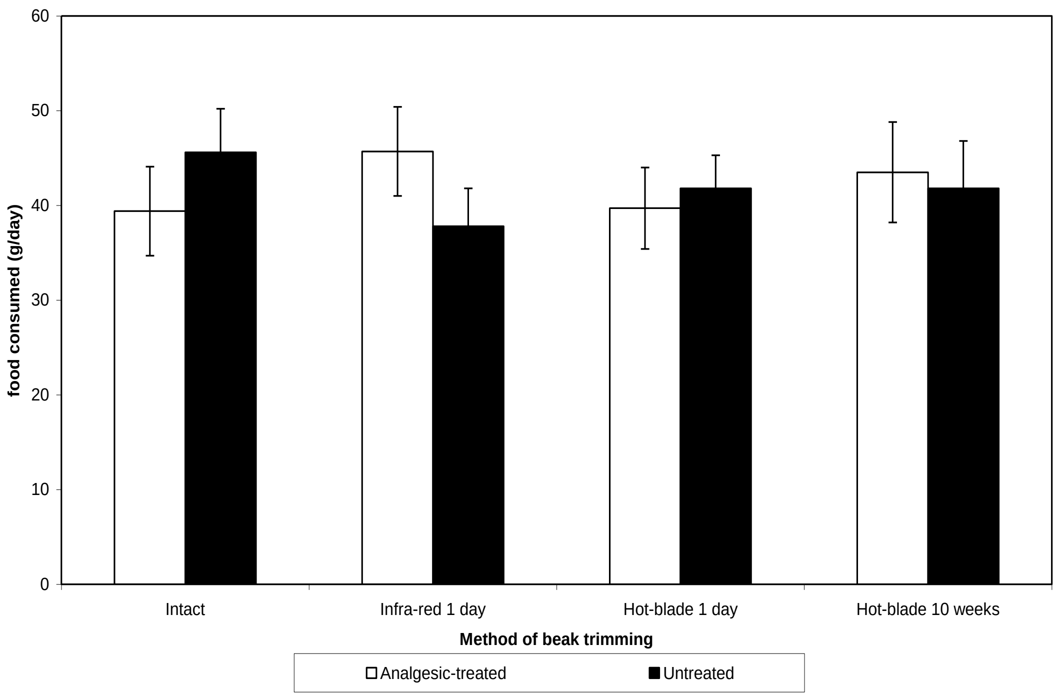
Figure 1



Analgesic treatment: Without analgesic treatment, birds with IR trimming had the lowest feed intake compared to birds without trimming, or trimmed with HB at day 1 and at 10 weeks of age. However, birds trimmed by IR had the highest feed intake compared to the other treatments after analgesic treatment (Figure 8). Feed intake also increased for birds trimmed by HB at 10 weeks of age, but decreases for the birds without trimming and trimmed by HB at day 1. This may indicate that birds were in pain after IR trimming at day 1 and HB trimming at 10 weeks of age.

Figure 8: Birds from four beak trimming methods showed similar daily food consumption and consumed similar amount of analgesic-treated and untreated feed.

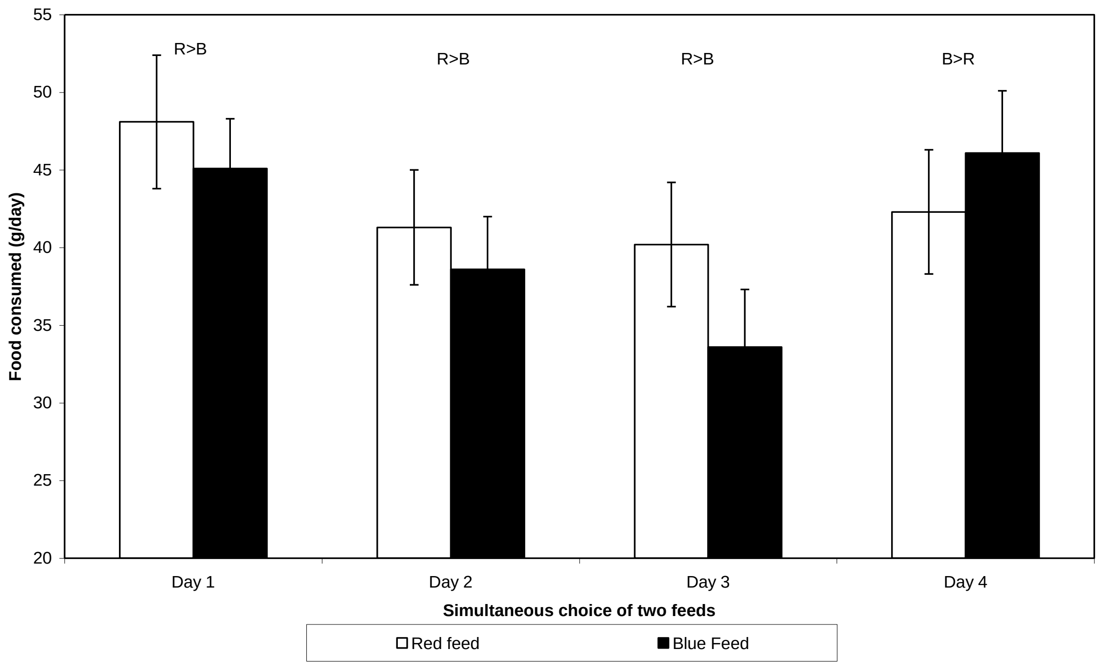
Figure 2



Feed stimulation: using different colour of feed had effect on feed intake at day 1, red feed had better effect compared to blue feed (Figure 9). However, feed intake was reduced at day 2 and day 3 for both colours. At day 4, bird intake was increased compared to day 2 and 3. However, birds on red colour feed did not recover to the day 1 feed intake level, birds on blue colour feed had higher feed intake compared to day 1 at the same colour treatment.

Figure 9: Choice of red and blue feeds, irrespective of presence or absence of carprofen, by all chickens during the simultaneous choice period. Chickens appeared to prefer red feed to blue feed for the first three days but on day four this preference was reversed (P<0.05).

Figure 3



Beak length and pecking force

Beak length did not differ between the three beak trimming methods (ANOVA, $F_{2,57}$=2.2, P=0.13; Table 1), with trimming resulting in an average 34% reduction in beak length. The difference between the upper and lower beaks was lowest in birds trimmed with the HB at 1 day of age (ANOVA, $F_{2,57}$=9.9, P<0.001; Table 8). Birds trimmed at 1 day of age with the HB appeared to peck at the disc sooner after exposure than birds from the other beak conditions (ANOVA, $F_{1,36}$=2.8, P=0.05; Table 1). The latency to peck the disc was not influenced by feeding of analgesic-treated or untreated feed (ANOVA, $F_{1,36}$=0, P=0.96 or the feed type/beak condition interaction, ANOVA, $F_{3,36}$=0.47, P=0.70).

Table 8: Mean (±sem) beak length, gap between the upper and lower beaks and the latency to peck the round disc in the pecking force tests for pullets from the four beak methods, and results from the ANOVA tests.

Beak Treatment	**Beak measurements**		**Latency to peck disc (s)**	
	Beak length	Gap	Untreated	Analgesic
Intact	17.7±0.3	N/A	161±74	264±95
Infra-red 1 day	11.1±0.3	2.6±0.2	177±68	137±78
Hot-blade 1 day	12.0±0.4	1.6±0.3	73±27	95.4±45
HB 10 weeks	12.1±0.4	3.0±0.2	299±97	201±90
ANOVA	$F_{2,57}$=2.2, p=0.13	$F_{2,57}$=9.9, p<0.001	Beak effect, $F_{3,36}$=2.8, p=0.05. Feed type effect, $F_{1,36}$=0, p=0.96.	

There was a difference between the four beak methods in both the mean force of pecks (ANOVA, $F_{1,36}$=7.5, P<0.001) and the maximum force of peck (ANOVA, $F_{1,36}$=9.5, P<0.001; see Figure 1). Birds beak trimmed at 10 weeks of age using a hot-blade had a lower mean force of peck than birds with intact beaks (Tukey's post-hoc test, MD=0.53, P=0.001) and birds beak trimmed with the hot-blade at 1 day of age (Tukey's post-hoc test, MD=0.0.46, P=0.004). The maximum force of peck was similarly lower in birds trimmed at 10 weeks of age with the HB than intact birds (Tukey's post-hoc test, MD=0.92, P<0.001) and birds trimmed at 1 day of age with the HB (Tukey's post-hoc test, MD=0.0.61, P=0.007). The maximum force of peck tended to be lower in birds trimmed at 10 weeks of age with the HB than those trimmed at 1 day of age with the IR method (Tukey's post-hoc test, MD=0.43, P=0.085).

Feeding of analgesic-treated or untreated feed had no effect on either the mean force of ten pecks (ANOVA, $F_{1,36}$=1.68, P=0.20) or the maximum force (ANOVA, $F_{1,36}$=2.83, P=0.10). However, the maximum pecking force of birds trimmed at 10 weeks of age with the HB was positively correlated with the amount of analgesic-treated feed eaten (Pearson Correlation = 0.66, N=10, P=0.032), though the average pecking force was not correlated to the amount of analgesic-treated feed eaten (Pearson Correlation = 0.51, N=10, P=0.13). No other significant differences were found either from the interaction of terms in the ANOVA tests or other post-hoc tests.

Simultaneous choice of analgesic-treated and untreated feeds

No evidence was found that birds from the four beak trimming methods consumed different amounts of analgesic-treated feed when both feeds were presented simultaneously (Figure 2, ANOVA, $F_{3,70}$=0.41, P=0.74). Birds appeared to prefer red analgesic-treated feed over blue analgesic-treated feed for the first 3 days of the simultaneous feeding period, but this preference appeared to reverse on the fourth day (Figure 3; day/colour of feed interaction, ANOVA, $F_{3,210}$=2.8, P=0.039). No evidence was found that food consumption of the treated and untreated feeds varied throughout the four days when both feeds were presented simultaneously (day/beak condition interaction, ANOVA, $F_{3,210}$=1.16, P=0.32). No other significant third order or second order interactions were found (day/beak condition/colour interaction, ANOVA, $F_{3,210}$=0.91, P=0.52; day/ colour interaction, ANOVA, $F_{3,210}$=1.44, P=0.24).

Daily food consumption was 83.5±1.03g of feed, irrespective of colour or drug. Over the four simultaneous choice days similar amounts of analgesic-treated and untreated feed were consumed (Figure 2; Paired t-test, t=0.08, N=80, P=0.94). Similar amounts of red feed (42.3±2.3g/day) and blue feed (41.4±1.9g/day) was eaten irrespective of whether it was treated or not (Paired t-test, t=2.0, N=80, P=0.84).

IV. DISCUSSION

The pullets beak trimmed at 10 weeks of age pecked more gently than intact pullets, consistent with the hypothesis that these recently beak trimmed pullets were guarding a painful beak from further contact. Pullets trimmed at one day of age with the HB or IR method did not show a reduced pecking force compared to intact pullets. No general effect of carprofen was found on the force of pecks, though there was a positive correlation between the amount of analgesic-treated feed eaten and maximum pecking force in birds trimmed at 10 weeks, suggesting that birds that ate large amounts of the analgesic-treated feed may have experienced an analgesic effect. Following a period of training to distinguish between carprofen-treated feed and untreated feed as used by Danbury *et al*. (2000), beak trimmed pullets did not consume more treated feed than intact pullets when both feeds were presented simultaneously. We found no evidence of pain in birds at 11 weeks of age that were trimmed at one day of age by either the HB or the infra-red method.

Neurological studies on beak trimmed hens have shown neuromas form in trimmed beaks some time after trimming (Breward and Gentle, 1985; Gentle, 1986), and neuromas are linked to chronic pain in humans, as occurs in amputated limbs (Wall, 1981). Trimming at day-old appears to reduce the incidence of neuromas as compared to trimming at older ages (Megret *et al*., 1996), and it may be that neuromas are resorbed sometimes between 10 weeks and 70 weeks following trimming (Lunam and Glatz, 1996). In the present study beak trimming resulted in a 34% reduction in beak length with no difference in beak length between the three trimmed methods, which would be considered a light trim compared to the more usual industry practice of removing about 50% of the beak. The amount of beak removed is likely to have a strong effect on the potential pain experienced (Glatz, 2000), so our current results should be considered relevant to a light trim and perhaps not representative of what birds may experience following removal of a larger portion of the beak. Trimming with a HB at 1 day of age resulted in the least difference in the length of the upper and lower beaks, which may be expected to facilitate these birds' ability to pick up and manipulate food. It should be noted though that different hatcheries may achieve different results with respect to the gap between the upper and lower beaks.

Laying hens reduce pecking-related behaviour in the first 2 weeks after trimming (Gentle *et al*., 1997) which has been considered to indicate protection of a painful area from further contact and stimulation (guarding behaviour). Furthermore, the observed decline in feeding rate after beak trimming can be prevented by the application of topical analgesics to the recently trimmed beak (Glatz *et al*., 1992). The lower pecking force of pullets trimmed at 10 weeks of age compared to intact pullets and those trimmed at 1 day of age in the present study supplements the above studies by indicating that even a light trim at this age appears painful to the hen for at least the first week after trimming. VanLiere (1995) found that beak trimmed birds are slower to peck a novel object than intact hens at 42 weeks after trimming, possibly indicating long-term guarding behaviour, though in the present study we found no evidence that the trimmed birds took longer to peck the novel round disc. It is unclear why our results did not replicate those of vanLiere (1995), though one possibility is that responsiveness in beak trimmed birds declines some time between 10 and 42 weeks of age.

Chickens in this study consumed on average 83±1g of feed per day, which would have provided them with 6.6mg of carprofen/day on training days when only analgesic-treated feed was provided. This dose of carprofen compares well with the dose provided by Danbury *et al*. (2000) in their second experiment, in which they found that lame birds provided with a simultaneous choice of analgesic-treated and untreated feed ate 6.7mg of carprofen/day, a significantly greater amount than sound birds. This dose in lame broilers resulted in a plasma concentration of carprofen of 0.28μg/ml and improved their gait. In the present study, the maximum pecking force in birds trimmed at 10 weeks of age was positively correlated with the amount of analgesic-treated feed consumed, suggesting that very high doses of carprofen may have had an analgesic effect in these birds.

In light of the above evidence that indicates that birds in the present experiment received sufficient carprofen for an analgesic effect, it was surprising to find that birds trimmed at 10 weeks of age did not peck with more force when provided with treated feed. One possibility is that the reduced pecking force in birds trimmed at 10 weeks of age was not an expression of guarding behaviour, but instead arose from a bio-mechanical effect linked to the relatively recent shortening of the beak. Aside from the abovementioned correlation between pecking force and amount of analgesic-treated feed consumed by birds trimmed at 10 weeks, no effect of the treated feed was found on pecking force and no selection of treated feed by trimmed birds was found when treated and untreated feeds were provided simultaneous, raising the possibility that carprofen had no analgesic effect on the type of pain arising from beak trimming. Alternatively the birds may not be suffering from pain.

Support for this latter explanation is provided by Kupers and Gybels (1995). They found that rats with neuropathic pain, induced by partial sciatic nerve injury, did not consume more fentanyl (an opioid analgesic) than control rats. In contrast, rats with nociceptive pain, adjuvant induced monoarthritis, consumed significantly more fentanyl than control rats. They concluded that fentanyl has a good analgesic effect on neuromuscular pain but a poor analgesic effect on neuropathic pain. It may be that carprofen has a similar selective analgesic effect in chickens, in being effective for neuromuscular pain in lameness as reported by Danbury *et al*. (2000) but having no effect on neuropathic pain following beak trimming in the present study. Unfortunately, the mode of action of carprofen in birds is unknown.

Additionally, it is possible that the effects of carprofen observed by Danbury *et al*. (2000) may have arisen from the known (in mammals) anti-inflammatory action of carprofen, rather than from its analgesic action. The possibility that neuropathic pain is not affected by some analgesics raises two recommendations for future research on using self-administration of analgesics as a means to examine pain in beak trimmed birds. Firstly, future investigation of pain following beak trimming should consider using analgesics known to alleviate neuropathic pain in chickens, or at least a combination of different analgesics. Second, the possibility that some analgesics may alleviate pain associated with beak trimming, and that some analgesics may not, provides a methodological tool for investigating the neural pathways involved in processing any possible neuropathic pain following beak trimming.

In conclusion, neither pecking force analysis nor a previously used self-administration of analgesic technique provided any evidence of pain at 11 weeks of age in laying pullets receiving a light beak trim at 1 day of age by a HB or IR method. Although we found evidence that birds trimmed at 10 weeks of age may have been in pain one week after the procedure, this pain was unaffected by carprofen. In contrast to the effect of carprofen in alleviating neuromuscular pain associated with lameness in broiler chickens as previously shown by Danbury *et al*. (2000), carprofen administered in a similar manner is not effective in alleviating neuropathic pain following beak trimming in laying pullets.

3.2 The performance and behaviour of birds beak trimmed by different methods

I. INTRODUCTION

Since the introduction of the new Marek Disease vaccine, cannibalism has become the major cause of mortality in Australian layer industry, especially for the imported strains. Mortality from cannibalism in some strains ranges between 10-20 % depending on the production system and management strategies. The Australian egg industry has a flock size of approximately 10 million layers and 10% mortality during lay means a loss of 10 million dollars annually. Currently, the majority of the Australian egg farmers have adopted either 5-bird cages which exacerbate cannibalism problems and there is a considerable cost associated with lost productivity, disposal of birds and flock morbidity.

One of the few ways to prevent cannibalism is the use of beak trimming which is a widely used practice in industry although there maybe some welfare problems associated with imprecise trimming practices. The trial reported below was designed to assess the production, behavioural and welfare impact of different beak-trimming practices including the relatively new IR technique. The techniques used were all accepted as normal commercial practice but there appears to have been no studies reported where long term production outcomes of the different techniques have been assessed under identical conditions.

Irrespective of production outcomes there is also a need to assess the welfare of birds in the different treatments. Clearly a major consideration is the pressure to cease beak trimming practices as there is a perception that beak trim compromises welfare while at the same time improving welfare compared to no-treatment. The methodology of welfare assessment of poultry is not clearly defined in the literature but there is general consensus that measures of stress hormones, immune system function and behaviours are all valid measures of components of welfare. In addition, the possibility that the beak trim treatments may have differences in welfare associated with levels of pain is also worthy of consideration. Direct pain measurement is relatively difficult however a recent study has done this indirectly by measurement of the peak force that birds apply when pecking. This test can possibly be further refined by testing with and without analgesic treatment.

II. MATERIALS AND METHODS

The experiments reported here were approved by the University of New England Animal Ethics committee under approvals AEC 06/069 and AEC 07/126.

Birds and Husbandry: The birds used in this trial came from a hatchery (Kean's Poultry, Huntley, Victoria) as day-old Hyline Brown birds. One thousand birds were purchased with 300 beaked trimmed using HB at the hatchery and 300 trimmed using IR trimming. The remainder of the birds were left untrimmed. Originally it was intended that two strains of bird would be compared but it was found that IR trimming was only available for one strain.

The chicks were reared in their trim treatment groups until 10 weeks of age. At this time half of the IR and HB birds were re-trimmed using the HB technique to remove at least one third of the upper and lower beak. At 11 weeks of age 80 birds representing four groups of twenty from: 1) HB trimming at 1 day of age, 2) IR beak trimming at 1 day of age, 3) HB beak trimming at 10 weeks of age and 4) intact beaks were used in a specific pecking trial. They were housed individually in cages 50x 55 x50 cm and the experiment completed over a few weeks (see appendix 1). During rearing, mortalities were recorded in each of the rearing groups.

At 12 weeks of age, 800 birds were transferred to the layer cage shed and housed at a density of 4 birds per cage in a 50 x 55 x50 cm - 5 bird cage. The cage shed held a single layer of cages and was exposed to natural light through exterior blinds traditional of many poultry sheds. When hens reached around 80% HDEP this was defined as week one of the production trial.

Therefore there were 5 treatment groups of birds: Control (untrimmed), IR-Control (IR not re-trimmed), HB-Control (HB not re-trimmed), HB-HB (HB and re-trimmed) and IR-HB (IR and re-trimmed).These groups were placed in the shed with two replicates of each treatment. Additionally a non- replicated group of 50 Control-HB birds used in the initial pecking trail was maintained although not included in most of the analyses.

Throughout the trial, birds were fed *ad-libitum* with crumbles formulated as appropriate for stage of development, (Ridley Agriproducts). Water was available from nipple drinkers and lighting commenced with a fluorescent lights maintaining a 14h light: 10h dark cycle. Temperature in the layer shed varied considerably throughout the 44 weeks of the study with minimums as low as 4^{o}C and maximums as high as 28^{o}C.

a) *Production Measurements*: From commencement of lay – birds were monitored for feather score, weight (all birds), egg quality (subgroup) and feed intake (replicate) at approximately 7-8 week intervals. Hen day egg production (HDEP), hen housed egg production (HHEP) and mortality was recorded daily throughout the study (replicate level). The study was terminated at week 44 of lay. Throughout dead birds were autopsied to identify cause of death and a monitoring system meant that birds that were identified as having been damaged (skin/tissue damage and blood apparent) by pecking were removed from group cages, treated to prevent infection and housed individually. Mortality figures include all birds removed in such a manner. A threshold of 40% mean cumulative mortality for a treatment group was designated as the point at which birds were transferred to individual cages.

As well as the routine production measures a number of other trails were conducted on subgroups of these hens, including behavioural measures, immunological measurements and hormone levels.

b) *Behavioural Measures*: The behavioural responses of birds from the various beak-trim treatments and birds per cage were tested to monitor aggression and fearfulness. The birds were in week 32 of lay at the time of testing.
Tests were repeated on three occasions, every second day, and 16 birds per treatment group were used with equal numbers coming from 4 and 2 bird cages, the 2 bird cages representing cages where 2 birds had died during the period of the experiment.

Behavioural tests included four "test" procedures designed to allow assessment of fear (freeze behaviours) and aggression (pecking). These tests were:

a) A foreign object test - pecks directed at a foreign object above the cage within a set time and the time to first peak ,
b) A food object test : pecks directed toward a food object and the time to first peak,
c) A freeze response associated with the presence of another bird in an arena, the time to move within a set time period
d) A freeze response associated with placement of the bird alone in the arena, the time taken to move within a set time period

c) *Immunological and stress responsiveness*: In parallel with behavioural assessments of differences between beak trim treatments an assessment of immune function was made on 12 birds from each replicate of each treatment group. The birds were chosen at random from a random cage number until the total required per treatment was reached. The testing was completed in week 38 of lay and consisted of a wattle test to determine if swelling of the wattle in response to a foreign antigen differed between the treatments (Hinch *et al*. 1997). Wattle thickness was measured on (day 1) and then an intra-dermal injection of 20ug of phA (phythemaggutinin mitogen) was made into the wattle. On day two a second measurement of wattle thickness was made and the difference determined.

Antibody response was also assessed by randomly chosing 10 birds from each treatment and injecting intra-peritoneally with 0.2 ml of 12.5% (v/v) Sheep red blood cells (SRBC) in PBS. Wing vein blood samples were then collected from these birds at 4, 8 and 12 weeks post-injection and frozen for later measurement of total antibody titres against SRBC by a haemagglutination assay (van der Zijpp and Leenstra, 1980).

Wing vein blood samples were taken from 10 birds for each beak-trim treatment, one bird per cage, in the week prior to immune testing (week 37 of lay). An initial blood sample was taken on the capture of each bird and its removal from the layer cage. The bird was returned to the cage and then recaptured and a second blood sample was taken from the other wing between 27-32 mins after the initial sample. At each sampling 2 ml blood samples were taken from the wing vein using 2 ml heparinised syringes. The samples were spun and plasma frozen for later assay of corticosterone.

*Statistics***:** All data was analysed using analysis of variance after appropriate transformations to normalise the data. Values are expressed as non-transformed means

III. RESULTS

a) Production Data

i) **Mortality**

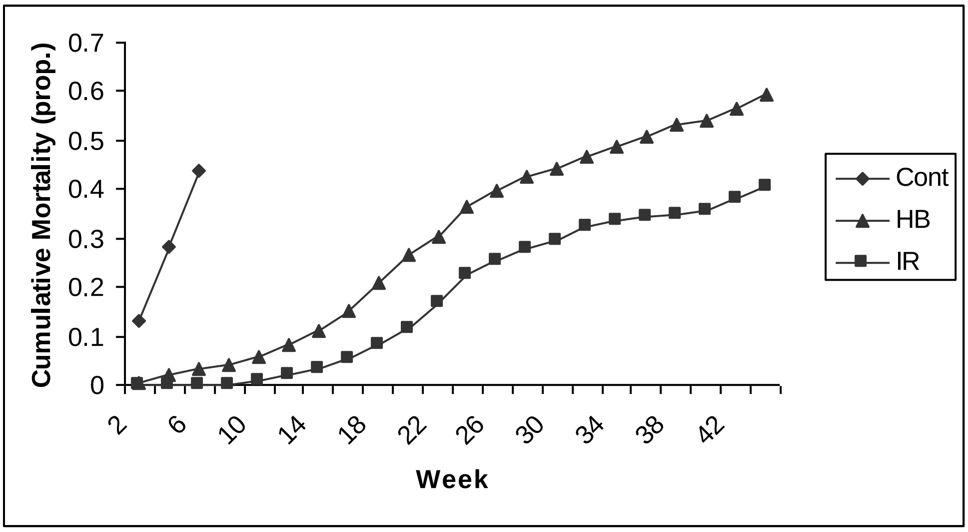


Figure 10. Mean cumulative mortality for each of the 1 day beak trim treatments

The mortality levels prior to entry to the layer shed were low with an average of <2% across treatments. The cumulative mortality in the layer shed for the treatments groups differed significantly between the initial beak trim treatments (Figure 10). Mortality in the first few weeks of lay was high for the control birds and this group were beak trimmed once mortality had reached 40%. Differences between HB and IR treatments became significant after week 20 ($P<0.05$) with IR birds having consistently lower mortality. It is likely the lower levels of trimming practiced for the HB birds in this trial resulted in neuromas being re adsorbed, allowing beak regrowth and increase in pecking. However the IR treated birds have neuromas present irrespective of beak length (see previous study) which may have reduced their pecking activities and reduced mortality.

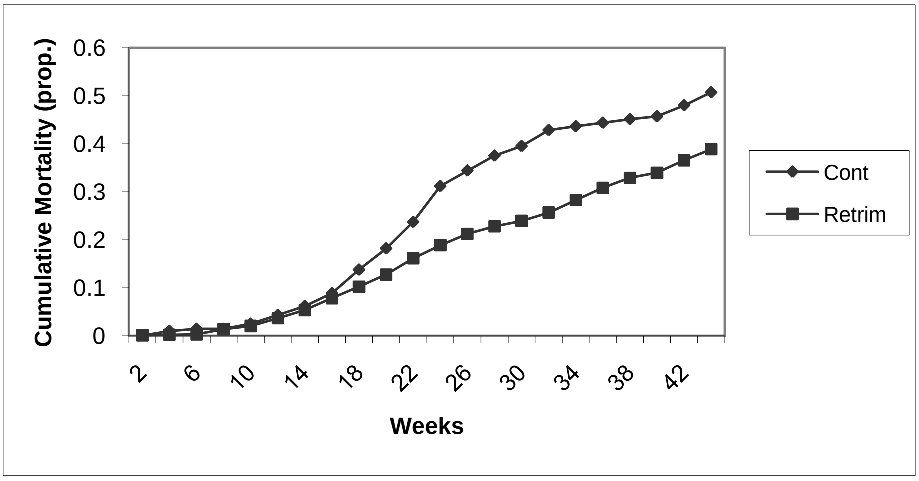


Figure 11. Mean cumulative mortality for re-trimmed vs. no re-trimmed treatment groups

The difference in mean cumulative mortality between the re-trimmed and non-re-trimmed treatments (Figure 11) became significant ($P<0.01$) from week 26 with the higher mortality in the group not re-trimmed.

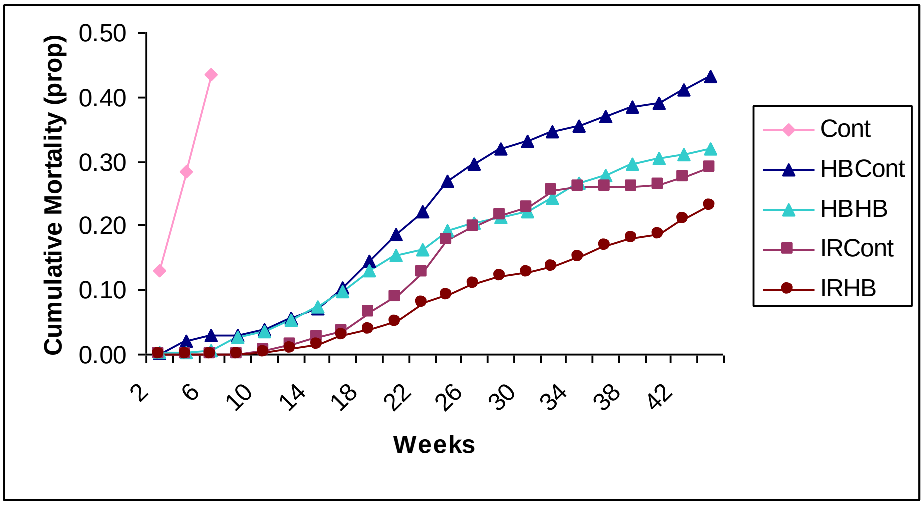


Figure 12. Mean cumulative mortality for each of all beak trim treatments

When a comparison of the cumulative mortality for all treatment groups is made (Figure 12) it is apparent that there were no interactions between initial treatments and later retrimming with IR treatments having lowest losses irrespective of re-trim treatment. However, from week 24 the losses in IR birds not re-trimmed became significantly higher than those that were re-trimmed (P<0.01)

ii) **Egg Production**

There were no significant interactions between treatment and time with a relatively consistent HDEP with time for the various treatment groups (Figure 13).

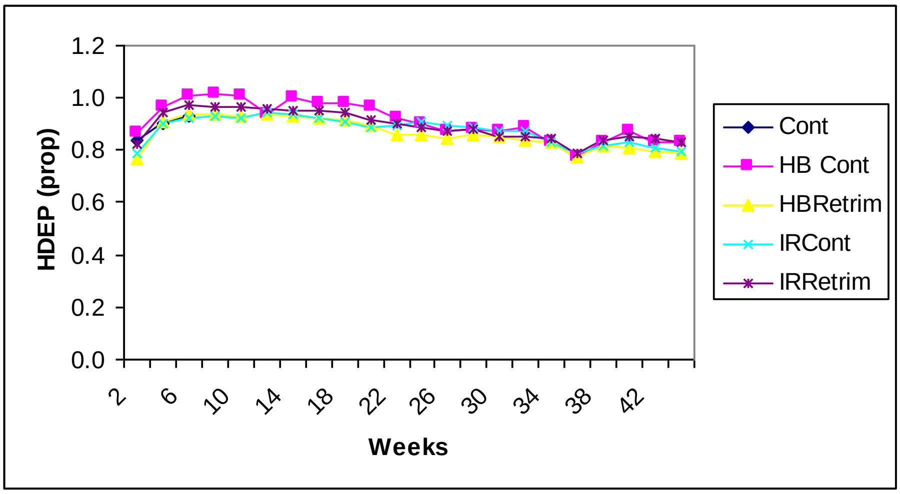


Figure 13. Mean hen day egg production for the weeks of lay for birds from all beak trimmed treatments

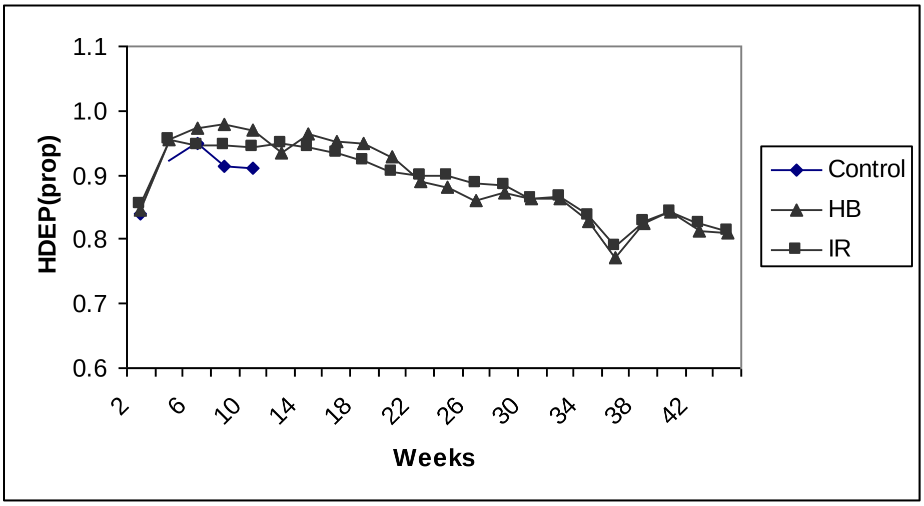


Figure 14. Mean hen day egg production for the weeks of lay for birds from the initial beak trimmed treatments

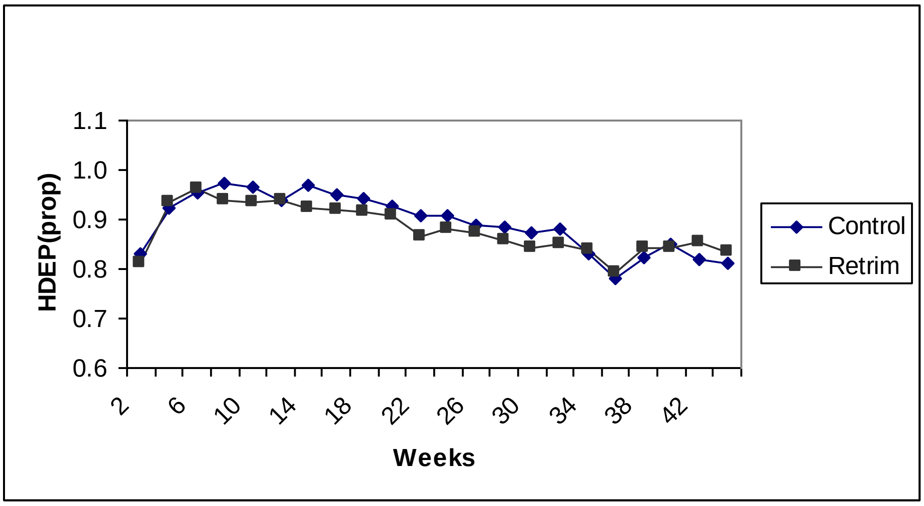


Figure 15. Mean hen day egg production for the weeks of lay for birds from the re-trimmed treatments

Hen day egg production was significantly lower ($P<0.01$) for the Control birds for the short period they were in 4 bird cages (Figure 14) and there were no significant differences between HB and IR treated birds. There re-trimmed birds had a sightly lower HDEP ($P<0.05$) for most of laying period (Figure 15).

This latter difference is reversed when mortality is taken into account in HHEP with a significant ($P<0.01$) and consistently higher production for the re-trimmed birds (Figure 16).

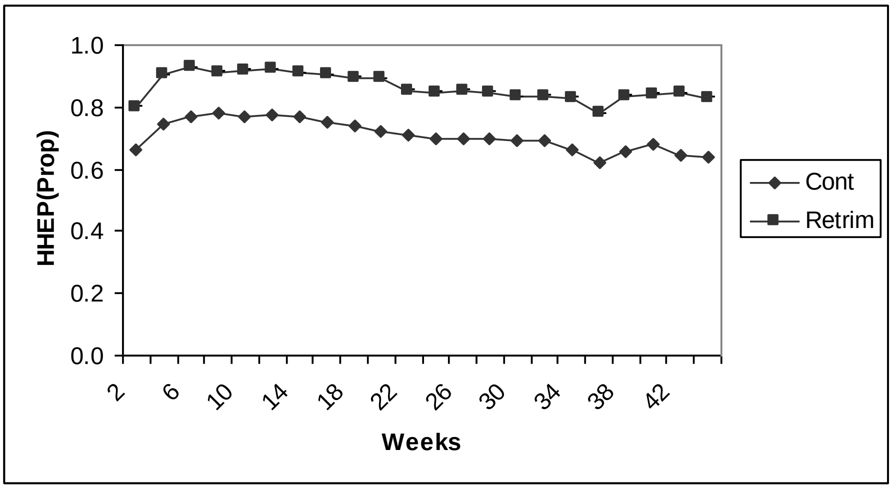


Figure 16. Mean hen housed egg production for the weeks of lay for birds from the re-trimmed treatments

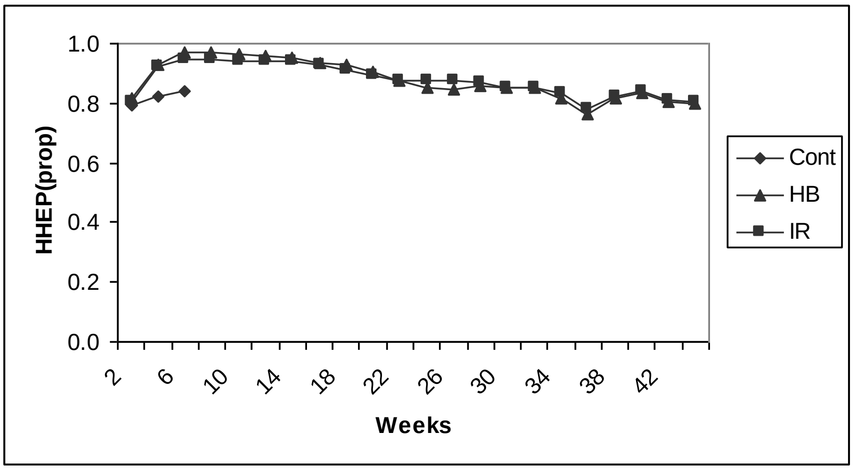


Figure 17. Mean hen housed egg production for the weeks of lay for birds from the initial beak trim treatments

Differences in HHEP of the initial beak trim treatments were not significant except for the lower production of control birds (Figure 17) associated with higher mortality until the birds were moved to individual cages by week 8. Thereafter control birds maintained HHEP levels similar to the other treatments (not shown).

iii) **Egg Quality**

There were no significant differences in egg quality measures between groups re-trimmed or not re-trimmed at 10 weeks (Figure 18). The were also no significant differences in mean egg quality parameters between the 3 initial treatment groups with the exception of a greater at albumien height in the HB trimmed birds (Figure 19). There were no consistent significant differences in egg weights between treatments.

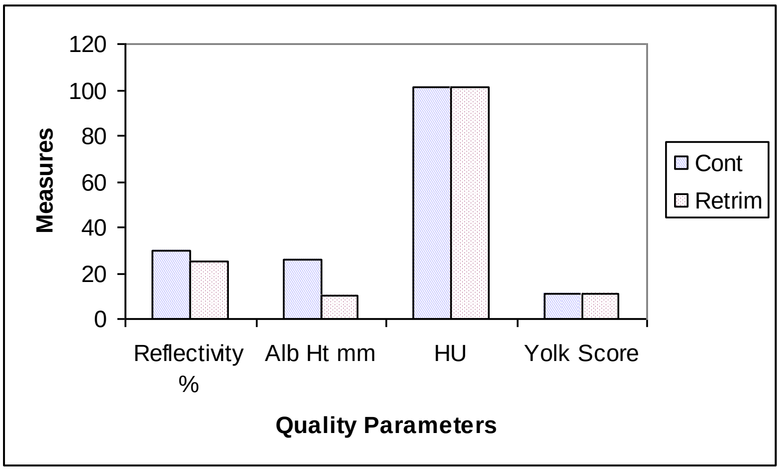


Figure 18. Means for egg quality parameters for re-trimmed and no re-trim treatment groups

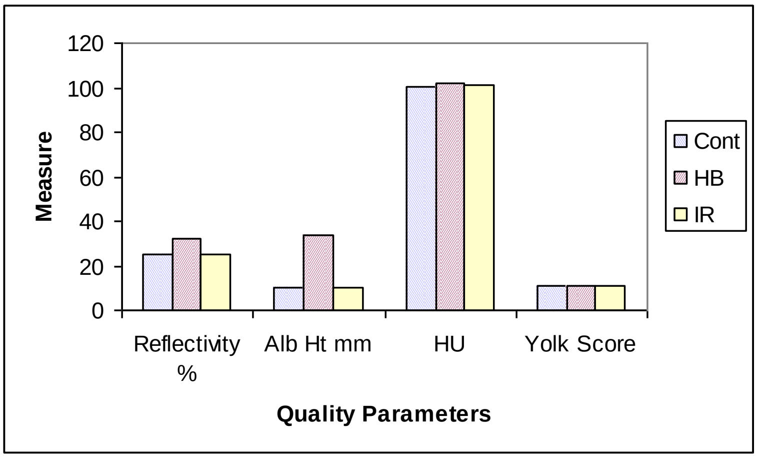


Figure 19. Means for egg quality parameters for initial beak trim treatment groups

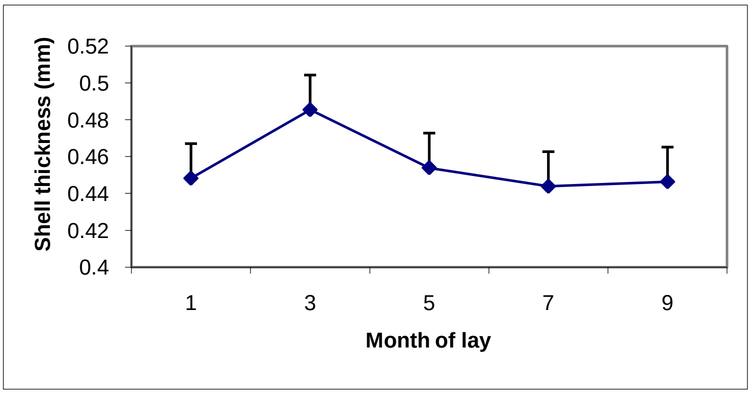


Figure 20. Mean Shell Thickness (mm) throughout the experiment.

Shell thickness did not differ significantly between treatments or over time with considerable variability within treatments. There was an apparent maximum shell thickness early in lay (Figure 20).

iv) **Feather score and hen weight**

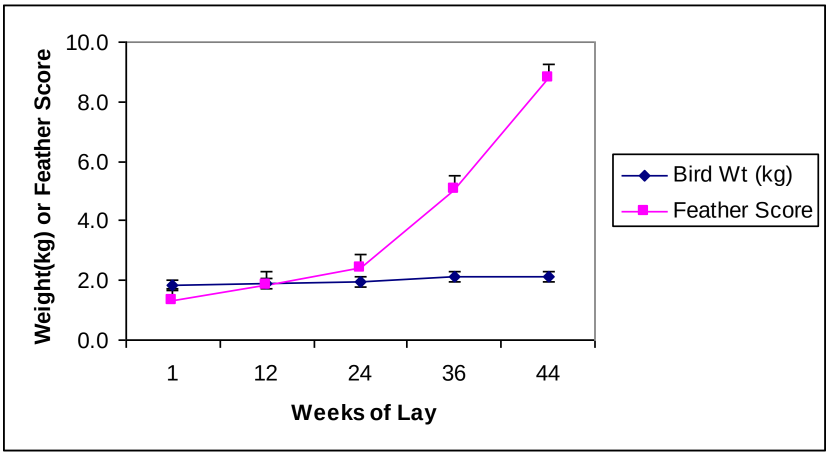


Figure 21. Mean bird weights and feather scores at various stages of lay.

There were minimal changes in bird weights over the laying period with weights maintained at just less than 2 kg (Figure 21). Feather scores significantly ($P<0.01$) increased (poorer covering) over time, particularly from mid lay. There were no significant interactions between time and treatments.

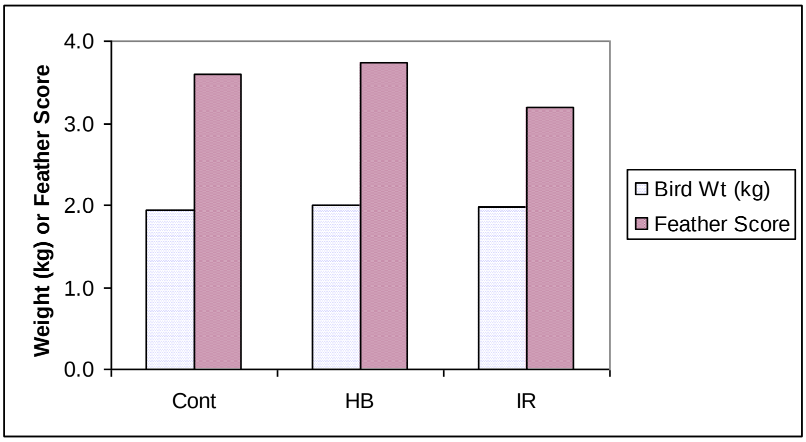


Figure 22. Mean Weights and feather scores for initial trim treatment groups

There were no significant treatment differences in mean bird weights for the three initial treatments (Figure 22) but mean feather score for IR birds was lower (better) approaching significance (P<0.07) compared to HB or Control birds. The re-trim vs. control treatment groups did not differ significantly in mean weights or feather scores (Figure 23).

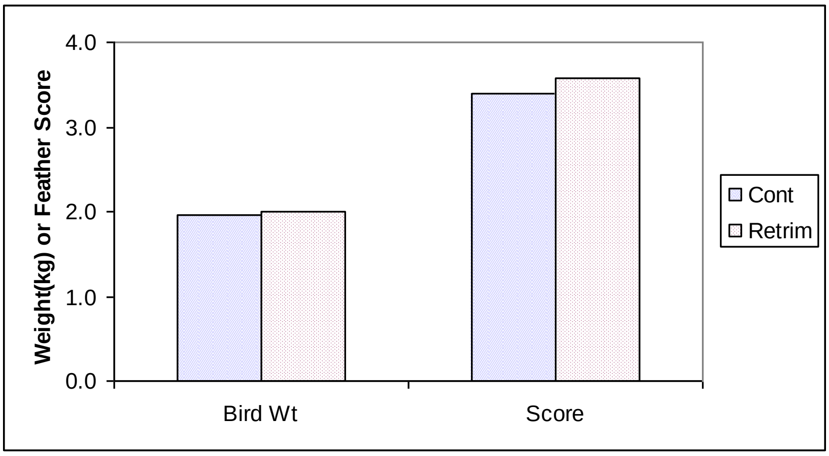


Figure 23. Mean Weights and feather scores for re-trim treatments

v) **Feed intake**

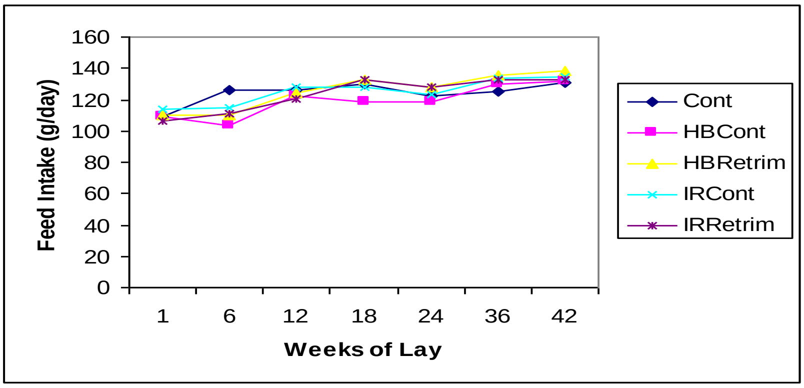


Figure 24. Mean daily feed intake (g/d) of birds from all treatment groups

Feed intake increased significantly (Figure 24, P<0.01) over the period of lay for all treatment groups. There were no significant differences in mean feed intake between re-trimmed and non re-trimmed (125.1 vs. 126.2 +/- 0.31) birds. On average non-trimmed birds (Control) ate around 7 g less per day (P<0.001) than the birds from the two initially trimmed groups (120.9 vs. 127.2)

b) **Immune function**

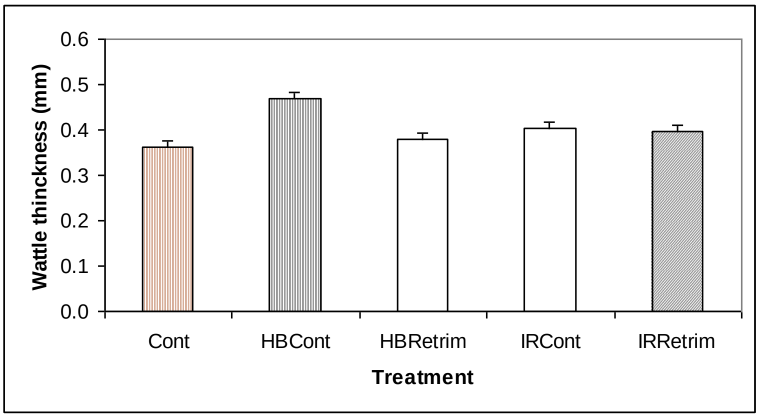


Figure 25. Mean wattle thickness after phA challenge for each of beak trim treatment groups.

There was no significant difference in thickness of wattle (Figure 25) nor in change in wattle thickness for the initial 1 day trimmed groups, but the difference between no re-trim and re-trim at 10 weeks was significant ($P<0.05$) with the re-trimmed birds having a smaller response than the control group. This was largely due to a greater response in the non re-trimmed HB group. Samples taken for cortisterone assay have as yet to be assayed so no stress responses are reported here.

c) **Peck Force**

The differences between initial treatments in peak peck force were significant ($P<0.01$) with the IR group exhibiting significantly lower force than the control or HB birds. This may be due to a greater incidence of neuromas in IR trimmed birds compared to the lightly trimmed HB birds. HB birds also had a peck force greater than the controls (Figure 26). There were no significant differences between re-trim and control treatments applied at 10 weeks with mean force values of 1.59 vs1.64 newtons.

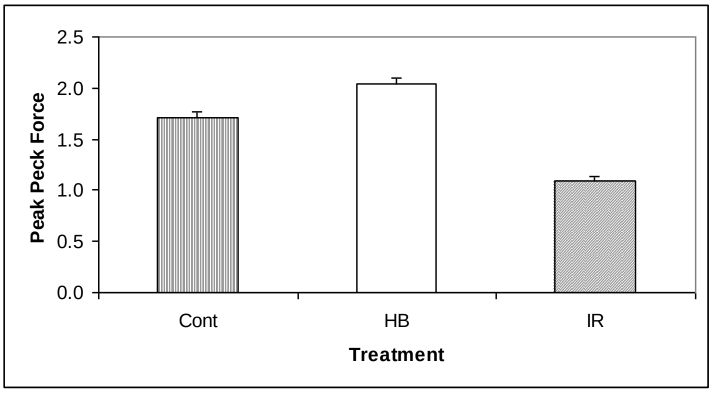


Figure 26. Mean peak force (N) of pecking for initial beak trim treatment groups

d**) Behavioural Data**

Figure 27 shows significant changes over test days in the number of pecks and time to first peck ($P<0.01$). Both parameters indicate a reduction in time to first peck and an increase in the number of pecks toward a foreign object. This habituation to the unfamiliar object occurred over days of testing and was paralleled by an increase in the incidence of pecks and decrease time to first peck ($P<0.01$). This was consistent for all beak treatment groups.

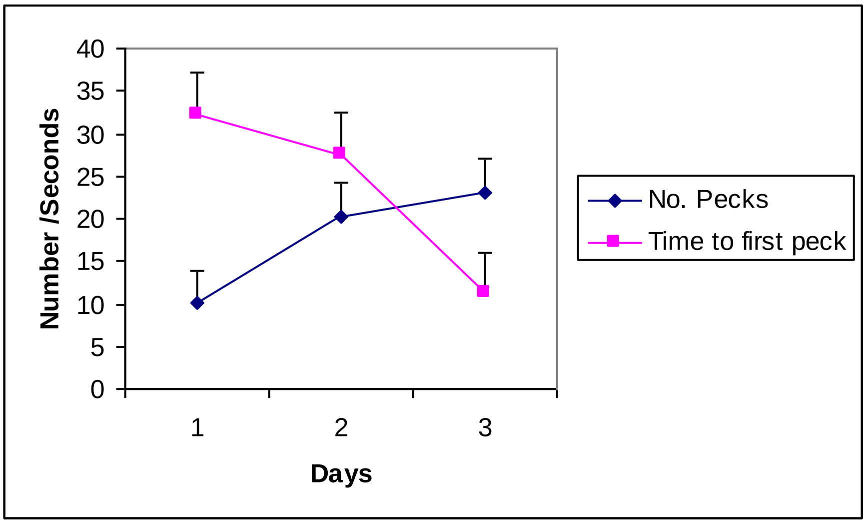


Figure 27. Mean number of pecks and time to first peck for all treatments over three days of testing

Figure 28 shows a significant difference (P<0.001) between beak treatments in the number of pecks directed at a foreign object. The one day trimmed bird (IR and HB) directed significantly more pecks than the control birds (P<0.01) at the foreign object and birds re-trimmed at 10 weeks used significant fewer pecks than the birds only trimmed at day 1 (P<0.05). There was a significant interaction (P<0.05) with the non re-trimmed birds having much lower levels of pecks than those re-trimmed at 10 weeks (Figure 29). The trend was reversed in the birds trimmed at 1 day and again at 10 weeks. Pecks directed at a foreign object were significantly lower in the control birds vs other treatments conducted at day old (Figure 30)

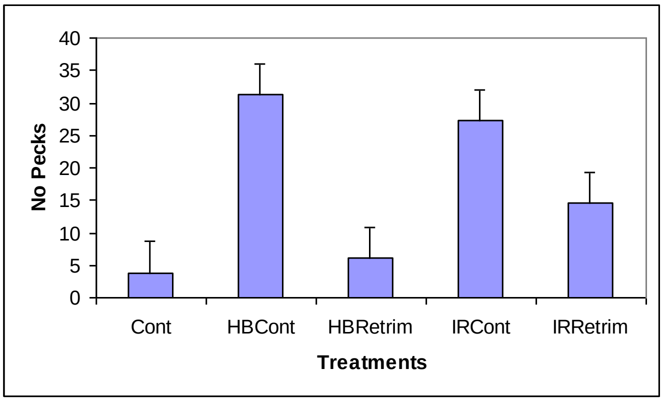


Figure 28. Number of pecks directed at a foreign object for the beak treatments.

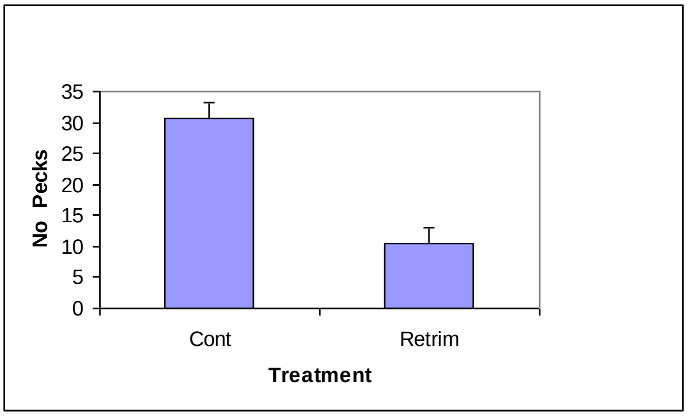


Figure 29. Number of pecks directed at a foreign object for control versus retrim treatments

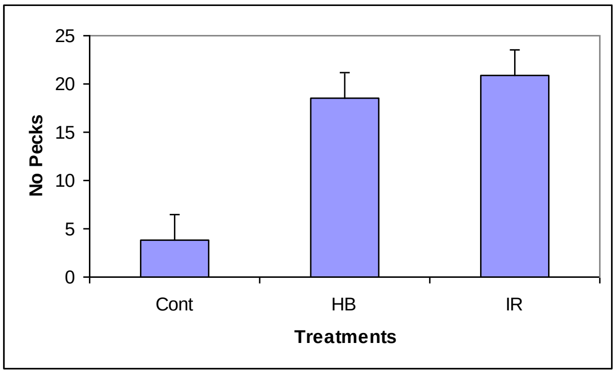


Figure 30. Mean number of pecks directed at a foreign object for birds trimmed at day old.

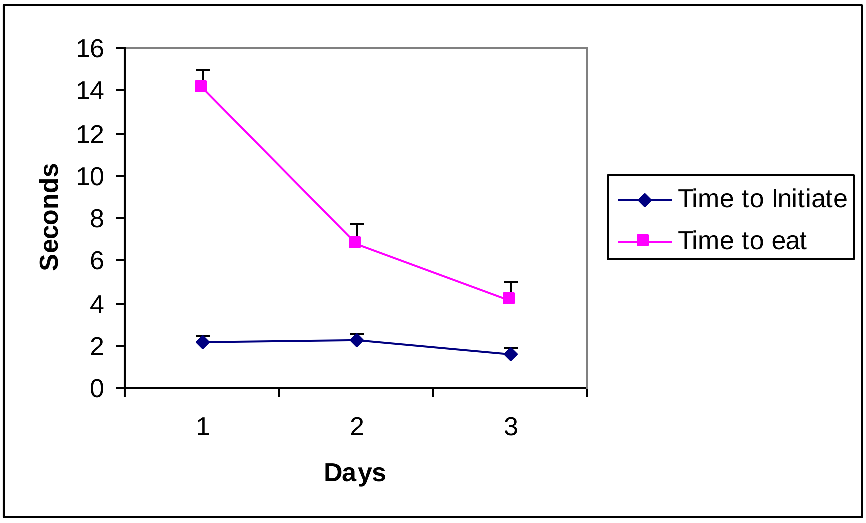


Figure 31. Mean peck number and time to first peck toward an unfamiliar food over the three days of testing.

Figure 31 shows the response of birds to an unfamiliar food item (meal worm) with no significant change in time to first peck across days but a decline in number of pecks over days ($P<0.001$). There were no significant effects of beak treatment or interactions for this measure. These trends suggest that birds have little hesitation in initiating the peck toward a new food item but they may take time to learn how to consume worms.

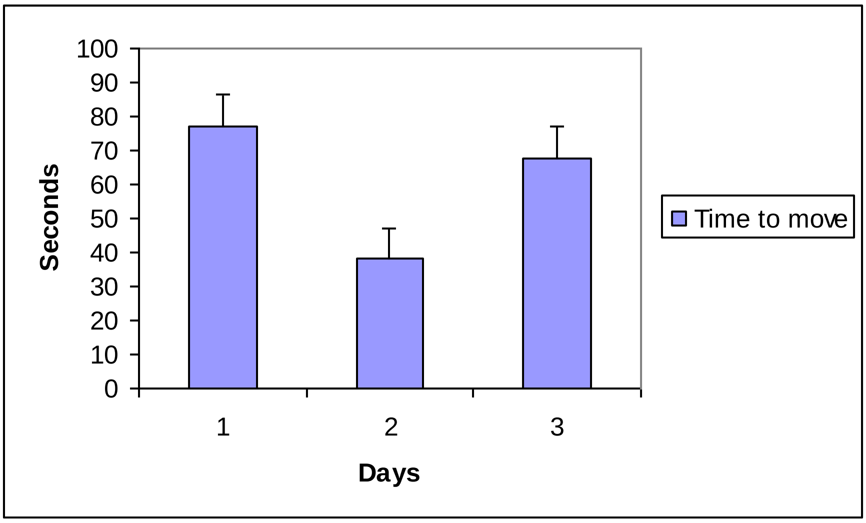


Figure 32. Mean time (sec) to first movement after placement of a strange bird into the arena over the three days of testing.

Figure 32 shows that the mean time of freezing (time to move) of birds varied between the days of testing ($P<0.05$) with day 2 lower than other days. There were no significant interactions with treatments. This difference between days cannot be attributed to a learning/adaptation process as there is no consistent trend and therefore it must be assumed that changes in environmental conditions may have contributed in some way.

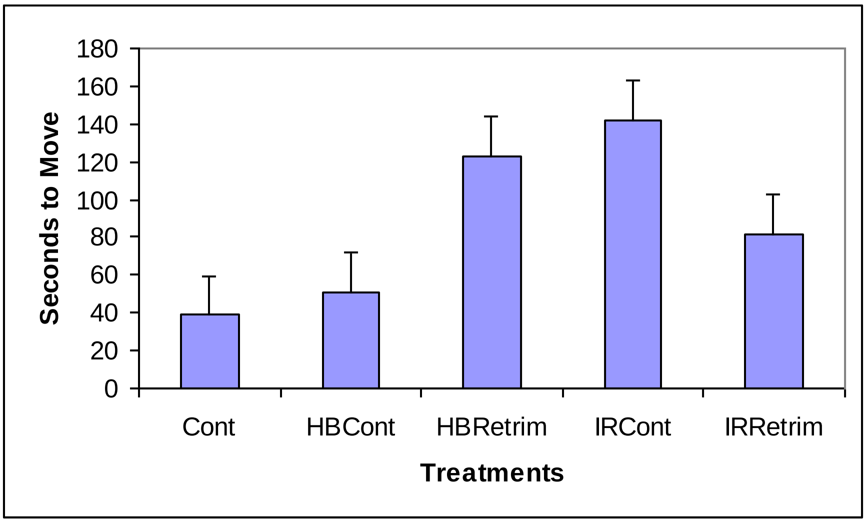


Figure 33. Mean time (sec) for first movement after placement of a strange bird into the arena for beak trim treatments, trimming at day 1 or 10 weeks.

Figure 33 shows large variation between birds within treatments for the time to move (fear) response to another bird and a significantly greater fearfulness of bird trimmed with IR at day 1 compared to HB or control birds ($P<0.05$). The IR trimmed birds may have been subject to greater pain during the beak treatment contributing to the response. The birds HB trimmed at 1 day and re-trimmed at 10 weeks were more fearful than birds trimmed for the first time at 10 weeks (HB10, $P<0.05$). There were no significant differences between treatments in the freeze response of birds when isolated in the arena.

IV. DISCUSSION

Mortality

The large scale trial conducted at UNE showed clearly that when light intensity cannot be controlled in laying sheds cannibalism will occur. It is generally accepted that when light intensity cannot be maintained at 5 lux or less pecking problems will occur (Glatz, 2005). In the current trial mortality levels reached 40% before the birds were relocated to individual cages. It was also clear that the lightly trimmed HB layers had higher mortality suggesting that after beak regrowth birds engaged in damaging pecking. The IR mortality levels were lower than HB and control groups even though the evidence from the PPPI trial indicates IR treated birds do regrow their beaks. It is possible that the presence of neuromas found in the IR treated beaks from the PPPI trial may have reduced the ability of birds to engage in cannibalism. However it is not clear whether the presence of neuromas indicates a higher level of pain in the beaks or poorer proprioception reducing the ability of birds to peck. The retrimming of birds had the desired effect of further limiting the ability of birds to engage in cannibalism, particularly for the IR treated birds.

Production

The non-trimmed birds in the UNE trial had poorer egg production than all the other trimmed groups. The research on production of beak trimmed birds indicates equivocal results on whether production is lower or not in beak trimmed flocks (Hester, 2005). However with the higher levels of pecking that occurred in these facilities both in this trial and previous trials (Hartini 2004) it is apparent that cannibalism and possibly vent pecking caused a significant reduction in production. However moving control birds into individual cages reduced the stocking density and leads to lower feed intake of the control birds. Most other studies have found that control birds have higher feed intake possibly from an increase in feed wastage due to greater ability of non trimmed birds to flick feed out of the trough (Glatz, 2005; Hester, 2005).

Pecking

The UNE trial showed the IR treated birds had better feather cover than other treatments. As mentioned previously it is likely the difference in feather pecking between the IR and other trimmed groups was due the presence of neuromas. This could result in higher levels of pain in the beak reducing pecking activity, or poorer proprioception reducing the ability of birds to peck. The assumption made here is that the light levels of HB trimming practiced at UNE probably lead to recovery of neuromas in the beaks of these birds (Lunam *et al.*, 1996) contributing to the higher peck force of the HB birds. The peck force exhibited by the IR birds, however was lower adding further evidence to the suggestion that IR treatment leads to higher levels of pain in the beak or poorer proprioception compared to the HB trimming. The retrimming of birds had the desired effect of further limiting the ability of birds to engage in cannibalism, particularly for the IR treated birds. The UNE trial also showed that one day old trimmed birds (IR and HB) directed more pecks than the controls at foreign objects. Jongman *et al.* (2008) report that beak trimmed birds may experience phantom sensations in the beak stump which could explain an increase in investigative pecking behaviour. Alternatively beak trimming may only result in a mild irritation (Broom and Johnson, 1993) or the persistent pecking may be used by the bird to mask the pain sensation (Melzack and Wall, 1965).

V. CONCLUSIONS

Overall the behavioural measures suggest that there are differences in behavioural responses resulting from beak trimming treatments. It is apparent that IR and HB treatment at 1 day old increases the level of aggression/pecking activity relative to other treatments and that fearfulness appears significantly higher in the birds treated by IR at day 1 than other trim treatments except the double HB trim. In some ways these results appear counter intuitive, as fearfulness might be would expected to be associated with lower aggression although this may not be the case once birds had overcome the initial freeze. More extended periods of measurement may have assisted in the interpretation of these patterns. The 1-day treatment by IR has had long lasting effects on fear and aggression behaviours and further studies are warranted to determine how these effects might occur.

4. Work conducted at University of Adelaide physics laboratory

4.1 Development of a laser method of beak trimming

Professor Jesper Munch from Adelaide University conducted the laser beak trimming studies

SUMMARY

A series of experiments using different lasers have been conducted to determine the practical viability of laser beak trimming (LBT), following the initial promising trials on live birds. In this series we have used a number of available and scalable continuous wave (cw) lasers ranging from the deep IR to visible laser wavelengths. Experiments have been performed using fresh, but detached chicken beaks. Emphasis has been on quantifying the power levels necessary to cause visible or detectable damage. The lasers used include a CO_2 laser, wavelength 10.6μm, a semiconductor diode laser, wavelength 808nm, and an Nd:YAG laser, wavelength 1.06μm, all in the 5 – 10W power regime. Frozen beaks from day-old male chickens were placed at the focal point of the setup (inside a fume box) and burnt a small distance above the nostrils. All lasers investigated were successful in making a hole in the beak at the zone of ossification in the upper beak. While this work is not complete, initial results indicate that short wavelength, visible lasers may suffer from poor target coupling and general diffuse scattering of the light while long wavelength lasers work well. Tests were made to determine if the beak can transmit significant power through the outer layers to damage the growth point without burning a hole in the outside of the beak. This was found to be limited by excess scatter, but we had insufficient diagnostics capability to determine if this approach is still viable. We could conclude that cw lasers could burn through the beak to the growth point using modest lasers and modest powers. Under these conditions it is reasonable to conclude that the use of a laser as a cutting tool is viable, and this can reduce both the blood loss and pain due to its ability to seal blood vessels and nerve endings during cutting.

I. INTRODUCTION

Lasers are used widely in human medicine and dentistry particularly for minimally invasive surgery. The laser has some additional significant advantages, including self-cauterisation and reduction in long-term pain due to a reduction in the formation of neuromas. This could have significant advantages to the welfare of the chicken and the general public and welfare groups may also perceive that laser trimming of chicken beaks is a milder, more technologically advanced method. The new lasers on the market are smaller, more flexible and easier to transport than earlier models. The costs of lasers are falling dramatically and there is considerable potential for developing a laser machine for mass beak trimming of birds at large hatcheries and for trimming and retrimming older birds. Lasers operate by depositing optical energy to the target tissue, resulting in damage to the target. This damage may be in the form of heating by absorption of the light in the target, or by molecular dissociation or ionisation for short wavelengths. Both cw and pulsed lasers are used, with pulsed systems being favoured since the optical energy is deposited in a very short time, thus minimizing discomfort to the patient. Many lasers are equipped with cooling systems to decrease temperature on the treated area, providing a mild anaesthetic effect. Patients normally feel a burning or stinging sensation. There are many different lasers available for medical and dental procedures, including ophthalmic Nd:YAG lasers, and CO_2 lasers.

In an initial proof of principle experiment, an ophthalmic laser Nd:YAG was used to successfully cut through an upper beak sample from a cull chicken (Glatz, 2004). Two passes of the laser beam were required to complete the cut. There was insufficient power in the laser beam to cut the beak tissue in one action. Live bird studies with 5-day-old chickens established the spot size to enable coagulation of the tissue and prevent bleeding. In live birds the laser was able to cut through the outer layers of keratin, but was not able to cut the inner bone. The lack of success in being able to cut the bony portion of the beak with an ophthalmic laser was considered to be due the lack of power. There was no significant difference in the beak length and body weight of control birds, laser trimmed or trimmed with a HB. There were no apparent problems with healing of the beak stump. The cuts that were made looked cleaner and straighter than the HB cuts. Van Rooijen and van der Haar (1997) reported on a laser method, which cut the beaks of day-old chickens with a laser beam. No details were provided by the authors on the type of laser used, or the severity of beak-trimming. By 16 weeks the beaks of laser trimmed birds resembled the un-trimmed beaks, but without the bill tip. Unfortunately, feather pecking and cannibalism during the laying period were highest among the laser trimmed hens. These results suggest that the severity of beak trimming by this laser was insufficient, enabling regrowth of the beaks.

The aim of the present study was to determine the effectiveness of laser beak trimming using a variety of lasers and power densities. Initial emphasis was placed on obtaining quantitative data using readily available lasers. We have concentrated on the use of longer wavelength lasers, where a focussed laser beam can heat the tissue locally to result in burning a hole and hence in cutting by sweeping the beam. In the initial study we have used cw lasers only.

II. MATERIALS AND METHODS

We chose a series of available cw lasers including a 10W CO_2 at 10.6μm laser, a 20W semiconductor diode, fibre coupled laser at 808mn, and a 5W Nd:YAG laser at 1.06μm. Each of these lasers were characterized in terms of beam quality and power density, and special telescopes were designed to permit focussing the output of each laser onto a beak with a reasonable working distance, consistent with applying the laser to live chickens.

In order for the laser to be suitable, the time taken should probably be minimized to a few seconds or less in order to minimize stress for the chicken and possibly excessive thermal damage to surrounding tissue. Also, the size of the hole produced should be as small as possible while still having a high probability of destroying the growth point of the beak. This prevents excessive burning of the beak and reduces the risk of regrowth if the growth area is not sufficiently eradicated. The required diameter is currently estimated to be of the order of 1mm, but this can be determined only by clinical trials in live chicken. Other factors, such as amount of charring caused, may also be taken into account to a lesser extent.

The target chamber was a vented plexi-glass chamber into which a beak or a live chicken could be placed, and from which the burn fumes could be extracted and disposed of without contaminating the laser or optics. The chamber contained the final focussing optics and typically allowed for a somewhat generous working distance of about 10cm. A HeNe alignment laser to facilitate the setup was used.

Frozen beaks from day-old male chickens were placed at the focal point of the setup and burnt a small distance above the nostrils using different power densities.

III. RESULTS

3.1 CO_2 laser:

This was a commercial RF waveguide laser, emitting quasi-cw power actually consisting of a series of micropulses of constant amplitude, the average power being adjusted by the duty cycle of these pulses The beam quality of the laser was found to be near diffraction limited, and in the particular setup used, the final beam size was ~0.8mm in diameter With this setup, chicken beaks were placed at the focal point and burnt at different power outputs. The holes produced by the CO_2 laser were approximately one millimetre in diameter and had very little charring around the edges. The time taken to burn through the beak at different power densities are tabulated in Table 9. At the highest power density of ~2260W/cm^2 (laser running at 10W), the average time taken to burn from one side of the beak to the other was ~2.5 seconds, or a total energy of 25J.

Table 9: Time taken to burn through beaks at different power densities with the CO_2 laser.

Power Density (W/cm^2)	Time taken to burn through beak (sec)
162	56
272	11.4
381	9.4
490	10.7
742	5
1256	4
1758	4
1758	2.4
1758	2.9
1758	4.4
1758	4.8
2260	2.4
2260	1.8
2260	3.5
2260	1.9
2260	3
2260	2.6

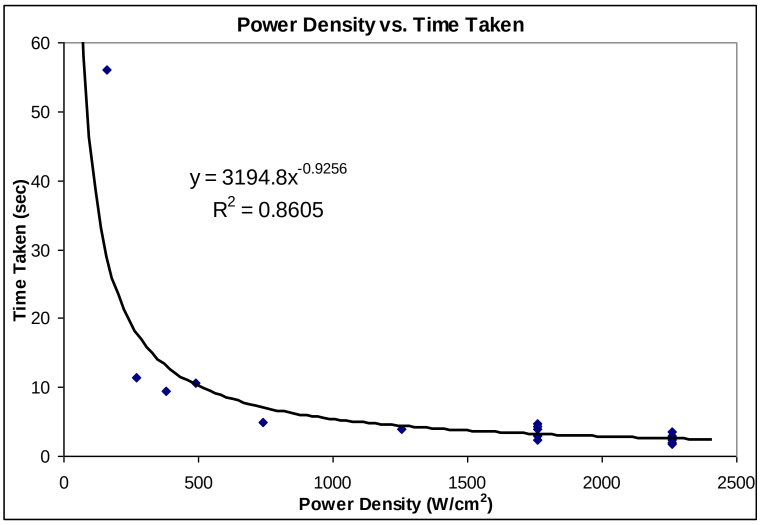


Figure 34. Plot of power density vs time taken

This plot can be used to determine the approximate time required to burn through a chicken beak at certain power densities.

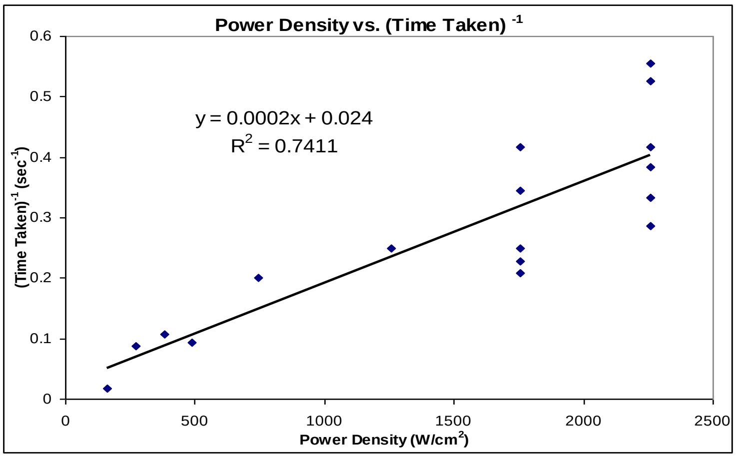


Figure 35. Plot of power density vs. inverse of time taken

From the plots, the dependence of time taken on power density was determined to be approximately an inverse power relationship. Due to the natural variations in thickness between each beak and error in placement of the beak in the setup (i.e. where the beam incidents on the beak), the time taken for each beak varied, and thus produced a mediocre R-squared value for the plots. On average, the energy density required for a burn was thus about 6kJ/ cm^2.

3.2 Semiconductor Diode Laser.

We had available a 20W cw fiber coupled semiconductor laser operating as a multimode pump laser, and delivering the output power through a 0.8mm diameter optical fiber. The advantage of this type of laser is that it is comparatively inexpensive, has a short wavelength, and has a convenient fiber delivery system. The disadvantage is that the laser is multimode, and has a very inferior beam quality. The smallest possible spot size achievable is thus approximately an image of the output fiber, or about 0.8mm. In our setup we did not have optimised lenses available and the smallest spot size achievable was of the order of 1.4mm diameter.

Using this laser was somewhat disappointing since quite high power levels were required before and noticeable effect was achieved. Thus no effect was observed for powers less than 10W, and at 10W it took 10s to burn most of the way through a beak. Due to the large beam size, the holes were large (~3mm diameter). For repeated success in burning holes, 15W were required, producing a power density of 1kW/cm^2. At this power levels the time taken was 5s, thus requiring a total energy of 75J per cut. This equates to an energy density of about 5kJ/ cm^2, which is comparable to that found for the CO_2 laser.

When irradiated at the 10W setting using the diode laser some peculiarities occurred during the burning process of some of the beaks. For these beaks, no damage was observed on the surface of these beaks for a short period, followed by a loud “pop”. The appearance of these beaks resembled a small outward “explosion” from the inside. When observed under the microscope, no charring occurred in the hole, implying the damage was caused not by the beam burning through the beak, but rather the beam heating up the inside of beak. When the beam was carefully focused at the surface of the beak, this peculiarity no longer occurred. This is most likely due to a competition between bulk and surface heating. If the laser is focussed at the surface, burning of the surface can occur, absorbing power there, and not transmitting much power to the underlying tissue. If surface damage does not occur, the laser light is absorbed by the volume of the underlying tissue, leading to bulk heating. Both these mechanisms may be effective for beak trimming.

3.3 Nd:YAG laser:

The Nd:YAG laser used was a high quality cw laser with excellent, near diffraction limited beam quality, and a maximum power of 8W. Using 5W cw and a spot size of 0.7mm diameter, it took a considerable time (20s) to burn through the beak. This translates into a power density of 4kW/cm^2, and a total energy density of 80kJ/cm^2

We found this to be a strong function of the surface cleanliness of the beak, with a clean beak requiring very high power. If for example a black ink mark was made on the target area, the time taken to burn through was reduced from 20s to 1-2s, and thus resulting in an energy density of about 10J/cm^2, or comparable to the energy density required for the other lasers. The results from this laser should be regarded as preliminary in nature.

IV. DISCUSSION

Working distance: We found that we had two constraints on the working distance. One is the minimum distance between an optical surface and the chicken beak. This distance should ideally be of the order of at least 5cm in order to provide reasonable evacuation flow for smoke released. With better engineering of an air-flow system, the optic could probably be protected down to working distances of 2-3cm. The other constraint is the Rayleigh range of the beam, which defines the depth of focus, or the distance along the beam over which the power density changes by less than a factor of 2. This distance should be at least 5mm in order to accommodate a reasonable depth in the beak. It is well known from the laws of diffraction that the minimum spot size achievable scales in proportion to the wavelength, and for a given spot size, the Rayleigh range scales inversely proportional to the wavelength. Thus, to get a small spot with high power density and a long Rayleigh range a shorter wavelength is preferable.

Wavelength choice: A more important factor in the choice of wavelength is the wavelength dependent absorption of the target. For long wavelengths (CO_2 laser) the absorption of the laser is nearly entirely on the surface, resulting in excellent absorption of power. For shorter wavelengths, the beak became somewhat transmissive, and laser power could interact with deeper lying areas. This was especially noted using the 808nm laser, where we observed subsurface heating without burning. This could be a distinct advantage, in that it would allow damage to the growth point of the beak without making a hole in the beak. However this method suffered from excessive scatter and efficient coupling of a small laser beam did not seem possible. Once the laser has ignited the surface for a burn, for example using black ink, the absorption of the laser beam on the black surface increases rapidly, the laser behaves more like the CO_2 laser, but deep volume damage is ruled out.

IV. CONCLUSION

The work on laser beak trimming is still on-going at a low level, limited by the availability of students and staff. Preliminary conclusions can be drawn:

1. A short wavelength is preferable for high power density, small spots.
2. A long wavelength laser such as CO_2 is preferable for coupling to the surface of the target.
3. In terms of reliability and cost in terms of Watts/$, the CO_2 laser is also an excellent choice.

The CO_2 laser reliably burned through all beaks. The disadvantage of this laser is the available choice of optics, requiring either an all mirror system or relatively expensive lenses made from materials such as ZnSe. But on the whole the CO_2 laser is a viable and practical approach for beak trimming chickens.

The near IR laser can work in two modes:

1. By painting a small black spot on each chicken this laser works much the same as the CO_2 laser. If such a procedure is acceptable in a large scale operation, this would be a viable alternative.
2. The laser can deposit heat in deeper regions of the beak, thus allowing for destruction of the underlying growth point without surface damage. This requires significantly higher power densities, and due to scatter may ultimately be similar to the conventional method using an IR heat lamp for beak trimming.

We found that while the shorter wavelength may couple to the beak better and are likely to heat the underlying tissue well, our only diagnostic at this time was beak burning and this limited the study to fairly high powers because the minimum laser spot possible was not very small. The beam quality of the semiconductor lasers themselves is not very good, and this limits the minimum area achievable.

Under the above condition, we tested if the beak can actually transmit significant power through the outer layers to damage the growth point without burning a hole in the outside of the beak. This does not appear to be possible as there was too much scatter. From this we conclude that it may require burning through the beak in order to stunt growth.

Additional Remarks:

1. We have obtained slightly conflicting data, and the best way to resolve this is to proceed to trials in live birds to determine if a laser burn is necessary, or if subsurface burning is viable and/or preferable.
2. If we were to build a system based on current data, we would pick a CO_2 laser.
3. We have not performed a complete study of various wavelengths, but wish to emphasize that future trials should include Er lasers at 2.8 microns, similar to lasers used by dentists, due to the high absorption in bone and enamel tissues.
4. We have worked only with cw systems, and the exposure durations have been unacceptably long in some cases. We should consider extending this study to include pulsed lasers. Using a short pulse, high energy laser has some advantages. Much energy can be deposited in a very short time, thus leading to a much more humane approach. A pulsed laser also couples energy to the target more efficiently, because it creates absorbing debris, or absorbing gases or plasmas.

Implications

- There is a need to improve the consistency of beak trimming for both the IR and HB method in Australia
- Mortality of layers trimmed with the IR method is relatively low indicating this method is acceptable for use in Australia to control cannibalism
- Birds trimmed with a HB at 10 days of age and those IR trimmed at day old formed traumatic neuromas which persisted to adulthood. There is a need to practice HB trimming at day old according to the Code of Practice to overcome neuroma formation and chronic pain
- IR and HB trimmed pullets do not consume more analgesic treated feed than pullets with an intact beak suggesting pain from IR and HB beak trimming either is not excessive or is an ineffective analgesic for neuropathic pain.
- There is a need to continue with the development of high technology laser methods of beak trimming as an alternative to current methods of beak trimming.

Recommendations

The IR method of trimming is suitable for use as a method to control cannibalism in layers but further development is required with this method to reduce the incidence of neuromas.

HB trimming at day old should be done according to the Code of Practice to allow neuromas to resolve and reduce chronic pain.

Further Research Required

IR trimming
Each hatchery must determine the level of IR treatment that best suits their customer's needs. The level of beak treatment is controlled by making settings to the lamp power on the IR control panel. Work is required to examine the impact of different levels of lamp power on neuromas, pain, pecking and feeding behaviour, particle selection, production, beak regrowth and fear in birds at different ages compared to HB trimming. This will require collaboration with the equipment manufacturer and a commercial hatchery using an IR trimming machine. Meat breeders are also being trimmed using the IR system and evaluation of welfare issues associated with IR vs. HB trimming is also needed.

Laser Trimming
Further studies are required to determine if a laser burn is necessary, or if subsurface burning is viable and/or preferable. Efforts should be made to encourage Nova Tech Company to communicate with the laser specialists to incorporate laser design features in the IR machine

Phyto Agglutination is another laser technique which could be used to agglutinate blood vessels in the tip of the beak. The hypothesis is agglutination of blood vessels causes beak die back and blunting of the beak.

Analgesics
This study found that IR and HB trimmed pullets do not consume more analgesic treated feed than pullets with an intact beak suggesting that either pain from IR and HB beak trimming is not excessive or the analgesic is ineffective for neuropathic pain. Further research is required with other analgesics to determine if beak trimmed birds will select feed containing analgesics to overcome pain.

Lighting
The trial at UNE showed that when light intensity cannot be controlled in sheds cannibalism will occur. Some layer houses in Europe are using blue lighting systems to calm birds. It is known that day old chicks have a preference for coloured lights with older birds preferring the colour that they have

been reared in and also blue light (which reduces activity). The role of light colour in reducing cannibalism needs to be evaluated on commercial egg farms in Australia.

Acknowledgements

Acknowledgment is given to the following colleagues and organisations that provided support, assistance, encouragement and advice during the project.

- The Poultry CRC for providing funds to undertake this work and the program management support from Assoc Professor John Barnett.

- Dr Christine Lunam from Flinders University for histopathology of beaks

- Professor Jesper Munch from University of Adelaide for the laser beak trimming studies

- Mrs Belinda. Rodda, Mrs Sandy Wyatt and Dr Zhihong Miao from the poultry productions systems team at the PPPI who provided valuable on farm and technical support.

- Thanks to Ms M Choice and Mr M Raue from UNE for their considerable inputs into data collection and collation.

References

Aerni, V., M.W.G. Brinkhof, B. Wechsler, H. Oester and E. Fröhlich. (2005). Productivity and mortality of laying hens in aviaries: a systematic review. *World's Poult. Sci. J.* 61:130-142.

Appleby, M.C. and B. O. Hughes (1991). Welfare of laying hens in cages and alternative systems: environmental, physical and behavioural aspects. *World's Poult. Sci. J.* 47:109-128.

Appleby, M.C., G.S. Hogarth, J.A. Anderson, B.O. Hughes and C.T. Whittemore. (1988). Performance of a deep litter system for egg production. *Bri. Poult. Sci.* 29:735-751.

Anderson K.E. and G.S. Davis. (1997). Performance and fearfulness during the production phase of Leghorn hens reared utilizing alternative beak trimming methods. *Poult. Sci.* 76 (Suppl. 1):2.

Angrill, A. and U. Koster. (2000). Psychophysiological stress responses in amputees with and without phantom limb pain. *Physiol. Behav.* 68:699-706.

Bell, D.D. (1996). Can egg producers afford too not beak-trim their flocks? 45th Western Poultry Disease Conference. Cancun, Mexico.

Bennett, G.J. (1993). An animal model of neuropathic pain: a review. *Mus. Nerve* 16:1040-8.

Bilcik, B. and L.J. Keeling. (2002). Relationship between feather pecking and group pecking in laying hens and the effect of group size. *Appl. Anim. Behav. Sci.* 68:55-66.

Blokhuis, H.J. and J.H.M. Metz. (1996). An evaluation on aviary housing for laying hens. Proceedings XVth World's Poultry Congress, New Delhi, 2-5 Sept, Vol. 2. pp. 821-830.

Blokhuis, H.J. and P.R. Wiepkema (1998). Studies of feather pecking in poultry. *Vet. Quarterly* 20:6-9.

Bloomquist, T. (2001). Amputation and phantom limb pain: a pain-prevention model. *AANA J.* 69:211-217.

Bourke, M., Glatz, P.C., Barnett, J.L. and K.L. Critchley (2002). Beak trimming training manual. Edition 1, Publication no. 02/092. Rural Industries Research and Development Corporation.

Breward, J. and M.J. Gentle. (1985). Neuroma formation and abnormal afferent nerve discharges after partial beak amputation (beak-trimming) in poultry. *Experientia* 41:1132-1135.

Broom, D.M. and K.G. Johnson (1993). In "Stress and Welfare" (Ed. D.M. Broom). Chapman and Hall Animal Behaviour Series. Chapman and Hall, London. pp.143-144.

Carey, J.B. and B.W. Lassiter. (1995). Influences of age at final beak trim on the productive performance of commercial layers. *Poult. Sci.* 74:615-619.

Cheng, H.W. (2006). Morphopathological changes and pain in beak trimmed laying hens. *World's Poult. Sci. J.* 62:41-52.

Choct, M. and S. Hartini. (2005). Interaction between nutrition and cannibalism in laying hens. In: Poultry Welfare Issues-Beak Trimming. Ed. Glatz, P. C. Nottingham University Press. pp.111-116.

Colburn, R.W., A.J. Rickman and J.A. DeLeo. (1999). The effect of site and type of nerve injury on spinal glial activation and neuropathic pain behavior. *Exp. Neurol.* 157:289-304.

Colpaert, F.C., J.P. Tarayre, M. Alliaga, L.A.B Slot, N. Attal and W. Koek. (2001). Opiate self-administration as a measure of chronic nociceptive pain in arthritic rats. *Pain* 91:33-45.

Danbury, T.C., C.A. Weeks, J.P. Chambers, A.E. Waterman-Pearson and S.C. Kestin. (2000). Self-selection of the analgesic drug carprofen by lame broiler chickens. *Vet. Rec.* 14:307-311.

Davis, G.S., K.E. Anderson and D.R. Jones. (2004). The effects of different beak trimming techniques on plasma corticosterone and performance criteria in single comb white leghorn hens. *Poult. Sci.* 83:1624-1628.

Devor, M. and Z.H. Rappaport (1990). In "Pain syndromes in Neurology" (Ed. H.L. Fields) Butterworths, London. pp.47-76.

Elson, H.A. (1990). Design and management of different production systems. In: Proceedings of the 8th European Poultry Conference, Barcelona. pp.186-195.

Engstrom, B. and G. Schaller. (1993). Experimental studies of the health of laying hens in relation to housing system. In: Proceedings of the 4th European Symposium on Poultry Welfare (Eds. Savory, C.J. and Hughes, B.O.), Potters Bar, University Federation for Animal Welfare, pp.87-96.

Foster, W.H. and Z.T. Taha. (1978). Whole grain diets for pullets. *Bri. Poult. Sci.* 19:233-242.

Gentle, M.J. (1986). Neuroma formation following partial beak amputation (beak trimming) in the chicken. *Res. Vet. Sci.* 41:383-385.

Gentle, M.J., B.O. Hughes, A. Fox and D. Waddington. (1997). Behavioural and anatomical consequences of two beak trimming methods in 1- and 10-d-old domestic chicks. *Br. Poult. Sci.* 38:453-463.

Gentle, M.J. and D.E.F. McKeegan. (2007). Evaluation of the effects of infrared beak trimming in broiler breeder chicks. *Vet. Rec.* 160:145-148.

Glatz, P.C. (1990). Effect of age of beak trimming on the production performance of hens. *Aust. J. Exp. Agr*., 30:349-355.

Glatz, P.C. (1998). Productivity and profitability of caged layers with poor feather cover. Tech. Report No. SAR-6A, RIRDC, Barton, Australia. www.rirdc.gov.au

Glatz P.C. (2000). Beak trimming methods. Review. *Asian-Aust. J. Anim. Sci.* 13:1619-1637.

Glatz, P.C. (2004). Laser beak trimming. Final Report to the Australian Egg Corporation Limited.

Glatz, P.C. (2005). What is beak-trimming and why are birds trimmed? In: Poultry Welfare Issues-Beak Trimming. (Ed. Glatz, P.C.) Nottingham University Press. pp.1-17.

Glatz, P.C. and M. Bourke. (2005). Beak Trimming Handbook-Best Practice for Minimising Cannibalism. Poultry CRC, Australia.

Glatz, P.C., L.B. Murphy and A.P. Preston. (1992). Analgesic therapy of beak-trimmed chickens. *Aust. Vet. J.* 69:18-18.

Gleaves, J.W. (1999). Cannibalism. Cause and prevention in poultry. University of Nebraska-Lincoln.

Gibson, S.W.; P. Dun and B.O. Hughes (1988). The performance and behaviour of laying fowls in a covered strawyard system. *Res. Dev. in Agric.* 5:153-163.

Gibson, S.W.; P. Dun and D.G.B. Riddell. (1985). The covered strawyard system for egg-laying fowls. *Farm Build. Prog.* 79:21-28.

Grigor, P.N., B.O. Hughes and M.J. Gentle. (1995). An experimental investigation of the costs and benefits of beak-trimming in turkeys. *Vet. Rec.* March 18, pp.257-265.

Guesdon, V., A.M.H. Ahmed, S. Mallet, J.M. Faure and Y. Nys. (2006). Effects of beak trimming and cage design on laying hen performance and egg quality. *Bri. Poult. Sci.* 47:1-12.

Hartini, S. (2004). Dietary Amelioration of Cannibalism in Laying Hens. Ph D. thesis. Department of Sciences. The University of New England, Armidale, New South Wales, Australia.

Hester, P.Y. (2005). Production responses of beak-trimmed birds. In: Poultry Welfare Issues-Beak Trimming. (Ed. Glatz, P.C.) Nottingham University Press. pp.79-86.

Hester, P.Y. and M. Shea-Moore. (2003). Beak trimming egg-laying stains of chickens. *World's Poult. Sci. J.* 59:458-474.

Hill, J.A. (1986). Egg production in alternative systems- a review of recent research in the UK. *Res. Dev. Agric.* 3:13-18.

Hinch, G.N., J.V. Nolan, S. Walkden-Brown and E. Thomson. (1997). Interactions between the immune system and food choice in cockerels. Recent Advances in Animal Nutrition in Australia 12:249.

Jongman, E.C. and J.L. Barnett. (2005). Physiological and behavioural aspects of beak trimming in poultry. In: Poultry Welfare Issues-Beak Trimming. (Ed. Glatz, P.C.) Nottingham University Press. pp.69-78.

Jongman, E.C., P.C. Glatz and J.L. Barnett. (2008). Changes in behaviour of laying hens following beak trimming at hatch and re-trimming at 14 weeks. *Asian-Aust. J. Anim. Sci.* 21(2):291-298.

Konig, H.J., H. Themann, U. Hiller and F. Gullotta. (1987). Prevention of neuroma formation by Neodym Yag laser – Experimental observations. *Acta Neurochir (Wien)* 87:63-69.

Kawai, M.; N. Kawaguchi and I. Umeda (1990). Histological changes in the chick beak caused by debeaking. *J. Poult. Sci.* 27:363-372.

Keeling, L.J., B.O. Hughes and P. Dun. (1988). Performance of free range laying hens in a polythene house and their behaviour on range. *Farm Build. Prog.* 94:21-28.

Kuenzel, W.J. (2007). Neurobiological basis of sensory perception: welfare implications of beak trimming. *Poult. Sci.* 86:1273-1282.

Kull, K.-E. (1948). The prevention and treatment of cannibalism and feather eating in fowls. Eighth World's Poultry congress, Vol 1. pp.124-125. Copenhagen, Denmark.

Kathle, J. and N. Kolstad (1996). Non debeaked laying hens in aviaries. I Production performance in cages and three types of aviaries. *Nor. J. Agric. Sci.* 10:413-424.

Kupers, R. and J. Gybels. (1995). The consumption of fentanyl is increased in rats with nociceptive but not neuropathic pain. *Pain* 60:137-141.

Lee, H. Y. and J. V. Craig. (1990). Beak-trimming effects on behavior patterns, fearfulness, feathering, and mortality among three stocks of White Leghorn pullets in cages or floor pens. *Poult Sci.* 70:211-21.

Luo, Z.D., N.A. Calcutt, E.S. Higuera, C.R. Valder, Y.H. Song, C.I. Svensson and R.R. Myers. (2002). Injury type-specific calcium channel alpha 2 delta-1 subunit up-regulation in rat neuropathic pain models correlates with antiallodynic effects of gabapentin. *J Pharmacol Exp Ther.* 303:1199-205.

Lunam, C.A., P.C. Glatz and Y.–J. Hsu. (1996). The absence of neuromas in beaks of adult hens after conservative trimming at hatch. *Aust. Vet. J.* 74:46-49.

Lunam C.A. (2005). The anatomy and innervation of the chicken beak: effects of trimming and re-trimming. In: Poultry Welfare Issues-Beak Trimming. (Ed. Glatz, P.C.) Nottingham University Press. pp.73-85

Marchant-Forde, R. and H.W. Cheng. (2006a). Infrared beak treatment: part I, comparative effects of infrared and 1/3 hot-blade trimming on beak topography and growth. *Poultry Science Association* Meeting Abstract. 85(1):104.

Marchant-Forde, R. and H.W. Cheng. (2006b). Infrared beak treatment: part iii, comparative effects of infrared and 1/2 hot-blade trimming on beak topography and growth. *Poult. Sci. Assoc. Meeting Abstr.* 85(1):105.

Marchant-Forde, R. and H.W. Cheng. (2006c). Comparative effects of infrared and hot-blade trimming on feeding behavior and productivity. *Inter. Soc. App. Ethol*. pp.49.

McGeown, D., T.C. Danbury, A.E. Waterman-Pearson and S.C. Kestin. (1999). Effect of carprofen on lameness in broiler chickens. *Vet. Rec.* 144:668-671.

McAdie, T.M. and L.J. Keeling. (2000). Effect of manipulating feathers of laying hens on the incidence of feather pecking and cannibalism. *Appl. Anim. Behav. Sci.* 68:215-229.

Megret, S., F. Rudeaux, J-M. Faure and M. Picard. 1996. The role of the beak in poultry. Effects of debeaking. *INRA Prod. Anim.* 9:113-119.

Melzack, R and P.D. Wall (1965). Pain Mecanisms: *New Theory. Sci.* 150:171-179.

Menovsky T, J.F. Beek, M. van der Bergh Weerman and J.J. van Overbeeke. (1999). Effect of a modified Nd:YAG laser technique on neuroma formation: An experimental study in rat sciatic nerve. *Lasers Surg. Medi.* 25:213-218.

Michie, W. and C.W. Wilson (1985). The perchery system for housing layers. The Scottish Agricultural Colleges Research and Development Note (March). ISSN 0261 3719.

Neal, W.M. (1956). Cannibalism, pick-outs and methionine. *Poult. Sci.* 35:10-13.

Norgaard-Nielsen, J.; G. Kjaer and H.B. Simonsen. (1993). Afprovning af to alternative aegproduktions-systemer-Hans Kier Systemet og Boleg II systemet. Statens Husdyrbrugsforsog Forskningsrapport 9/1993.

Petersen, J. (1994). Evaluation of alternative housing systems for laying hens. *Archives Geflugelkunde* 58(5):197-206.

Ries, W.R. and M.T. Speyer. (1996). Cutaneous applications of Lasers. *Otolaryngol. Clin. North Am.* 29(6):915-929.

Shaver Focus (1982). Minimising the blow out problem in caged layers. April, pp.1-4.

Sheen, K. and J.M. Chung. (1993). Signs of neuropathic pain depend on signals from injured nerve fibers in a rat model. *Brain Res.* 610:62-68.

Tablante, N.L., J.P. Vaillancourt, S.W. Martin, M. Shoukri and I. Estevez. (2000). Spatial distribution of cannibalism mortality in commercial laying hens. *Poult. Sci.* 79:705-708.

Takac. S, Stojanovic, S. and B. Muhi. (1998). Types of medical lasers. *Med Pregl.* 51(3-4):146-150.

van Krimpen, M.M., R.P. Kwakkel, B.F.J. Reuvekamp, C.M.C. van der Peet-Schwering, L.A . den Hartog and M.W.A. Verstegen. (2005). Impact of feeding management on feather pecking in laying hens. *World's Poult. Sci. J.* 61(4):663-686.

van Rooijen, J. and J. W.van der Haar. (1997). Comparison of laser trimming with traditional beak trimming at day 1 and week 6. 5th European Symposium on Poultry Welfare. pp.141-142

van Liere, D.W. (1995). Responsiveness to a novel preening stimulus long after partial beak amputation (beak trimming) in laying hens. *Behav. Proc.* 34:169-174.

van der Zijpp and F.R. Leenstra, (1980). Genetic analysis of the humoral immune response of White Leghorn chicks. *Poult Sci.* 59(7):1363-9

Tauson, R. and P. Abrahamson (1992). Keeping systems for laying hens-effects on production, health, behaviour and working environment. Proceedings XIX World's Poultry Congress, Amsterdam, 20-24 Sept. Vol 2:327-332.

Wells, R. (1983). Beak-trimming. Is it really necessary? *World Poultry*, June, pp.28-31.

Wall, P.D. (1981). On the origin of pain associated with amputation. In: Phantom and stump pain, Edited by Siegfried, J. and Zimmermann, M., Springer Verlag. Berlin. pp.2-14.

Weinstein, S.M. (1998). Phantom limb pain and related disorders. *Neurol Clin.* 16:919-36.

Wilkinson, L. (1996). Systat 6.0 for Windows-Statistics. S P S S Inc., USA.

Yang, K.C. and Y.T. Li. (2002). Treatment of recurrent ingrown great toenail associated with granulation tissue by partial nail avulsion followed by matricectomy with sharpulse Carbon Dioxide laser. *Dermatol Surg* 28:419-421.

Yngvesson, J. and L.J. Keeling. (2001). Body size and fluctuating asymmetry in relation to cannibalistic behaviour in laying hens. *Anim. Behav.* 60:211-216.

Zeitouni, N. C., Shieh. S. and A. R. Oseroff. (2001). Laser and photodynamic therapy in the malignancies. *Clinics in Dermatol.* 19:328-339.

Zeltser, R., B. Beilin, R. Zaslansky and Z. Seltzer. (2000). Comparison of autonomy behaviour induced in rats by various clinically-used neurectomy methods. *Pain* 89:19-24.

Zuberbueher, C.A, R.E. Messikommer and C. Wenk. (2002). Choice feeding of selenium-deficient laying hens affects diet selection, selenium intake and body weight. *J. Nutr.* 132:3411-3417.

Plain English Compendium Summary

Project Title:	Minimise cannibalism using innovative beak trimming methods
Project No.:	04-20
Researchers:	Phil Glatz and Geoff Hinch
Organisation:	South Australia Research and Development Institute
Phone:	(08) 83037786
Fax:	(08) 83037689
Email:	Glatz.phil@saugov.sa.gov.au; ghinch@une.edu.au
Objectives	• Establish if IR beak trimming minimises cannibalism and reduces development of neuromas and pain compared to HB trimming. • Determine the beak length, beak step, beak condition, production, feather pecking and physiological status of poultry beak-trimmed using the IR and HB methods. • Develop a laser method of beak trimming.
Background	Layer mortality (about 10%) is considered to be a major cost to the egg industry in Australia. Currently, cannibalism is the main contributor to mortality during the rearing and laying period in cage, barn and free-range systems. Associated with the cannibalism is a reduction in farm income from lost productivity, disposal of birds, and flock morbidity. Mortality from cannibalism in some strains can be greater than 20% when beak trimming is not used and efforts are required to minimise cannibalism to ensure that the egg industry remains sustainable. The increasing public knowledge of poultry welfare issues means that any improvements in the control of cannibalism are perceived by the community as being welfare friendly. Public perception can be influenced by the knowledge of the welfare of birds subjected to existing practices and new practices that might be introduced to control cannibalism. Currently the most effective method for controlling cannibalism is HB beak-trimming, but the negative long-term effects of the procedure are a welfare concern. Many European Union countries have banned trimming or intend to ban it. Attempts have been made to develop better methods of beak-trimming. The IR method of trimming developed by Nova-Tech in the USA is an innovative procedure and is gaining popularity. The method uses an IR energy source to treat the beak. Immediately following treatment, the beak looks physically the same as it did before and the bird is able to continue to use its beak. Welfare and production aspects of the IR process were examined to determine if the method was sustainable compared to HB beak trimming. Previous work conducted by SARDI indicates potential for using lasers to beak trim poultry. Research focused on determining the best method of beak trimming in Australia, which minimises welfare concerns for poultry. One of the concerns associated with the conventional HB method is the inability of operators to achieve a consistent level of trimming.
Research	i) *Work conducted at the PPPI* (*Measurement of beak length, beak step, beak condition and production of IR and HB trimmed layers*): Fifty IR trimmed Hyline Brown chicks were treated at day old in the hatchery

	using an IR beak treatment machine developed by Nova-Tech engineering. Another 50 chicks were trimmed at 10 days of age by an experienced beak trimmer using a Lyon beak trimming machine to remove one half of the upper beak and one third of the lower beak from chickens. Beak length, beak step, beak condition, body weight, egg production and egg weight were determined monthly throughout the growing and laying period. Beak length and beak step were measured using a digital electronic vernier calliper and beak condition was assessed using a grading system; Grade 1 (no imperfections and beak not too short) to Grade 3 (major imperfections and beak very short). ii) *Work conducted on 3 egg farms in South Australia (Measurement of beak length, beak step and beak condition)***:** Beak length, beak step and beak condition were measured on Hyline Brown layers on 3 commercial layer farms in South Australia. For the 3 industry farms data was assessed on 100 birds at 45 and 60 weeks of age. Farm 1 and 2 used only one of the trimming methods while farm 3 used both methods of trimming. iii) *Mortality of layers trimmed with the IR method for birds housed in cage and free range barn systems across Australia*: Mortality was measured for 32 flocks of hens housed in cages (Hi-rise, multi-tier and conventional) with natural ventilation or controlled environment and compared with 14 free range barn systems (slats or slats/litter) with natural ventilation. Total number of birds housed in the 46 sheds was approximately 1m birds with an age range from 20-80 weeks of age. Mortality of birds from each production system was corrected to 50 weeks of age. iv) *Work conducted at the University of Adelaide Physics laboratory* **(***Testing of laser devices for their potential as a beak trimming machine):* Experiments were performed on fresh, but detached chicken beaks with a CO_2 laser, wavelength 10.6μm, a semiconductor diode laser, wavelength 808nm, and an Nd:YAG laser, wavelength 1.06μm, all in the 5–10W power regime. The lasers were set up to focus on a small point after a certain propagating distance by the use of lenses or focusing mirrors. The beaks from day-old male chickens were placed at the focal point of the setup (inside a fume box) and burnt a small distance below the nostrils. The time taken for the laser beam to pass through the beak was measured at different power densities. v) *Work conducted at UNE:* An experiment aimed to identify if the IR and HB beak trimming methods cause pain by examining self-administration of an analgesic (carprofen) and pecking behaviour. In addition a large layer trial was conducted at UNE to examine pecking behaviour, cannibalism, productivity and egg characteristics at 4-6 weekly intervals during lay of birds trimmed with the IR and HB method. Interactions between rearing and laying environment and the beak trimming methods were also evaluated. The housing treatments imposed in this trial created the variable housing conditions that can often initiate feather pecking and cannibalism. vi) *Work conducted at Flinders University*: Upper beak samples were obtained from 5 birds for each of the IR and HB treatments from the PPPI trial at 32, 144 and 420 days of age. The histopathology of the beaks including incidence of neuromas was assessed.

<table>
<tr><td></td><td></td></tr>
<tr><td>Outcomes</td><td>i) Work conducted at the PPPI and on South Australian egg farms

Beak condition (a measure of its appearance and shape) was superior for IR treated birds in the rearing period but by mid lay was similar for birds whether trimmed with the HB method or the IR method.
The upper beak length of IR trimmed birds was consistently longer (4mm) than HB trimmed birds throughout the laying period. No difference in egg production was observed throughout the production period between the beak-trimming treatments. Body weight of IR treated birds was higher throughout lay while egg weight was lower.
There was a significant variation in beak condition and beak length of HB and IR trimmed birds monitored on South Australian egg farms. There is a need for further consistency in the application of both trimming methods.

ii) Mortality of layers trimmed with the IR method for 46 farms across Australia

Barn/free range production systems had higher mortality (2.5%) compared to cage systems (1.8%) when mortality was corrected to 50 weeks of age.
Conventional and Hi-rise cage systems had similar mortality (1.85 vs 1.79%) as did Controlled environment and naturally ventilated cage systems (1.79 vs 1.83%).
Lilewise there was similar mortality (2.78%) for the flooring systems whether it was slats only or slats/litter in free range/barn production systems.

iii) Pain, performance and behaviour studies undertaken at UNE

Birds monitored 1 week after being HB trimmed at 10 weeks of age pecked more ($P<0.001$) gently (0.6 ± 0.06N) at a disc attached to a force-displacement transducer compared to day old IR trimmed birds (0.9 ± 0.1N), day old HB trimmed (1.1 ± 0.07N) and intact birds (1.2 ± 0.1N).
Maximum force of pecks recorded was also lower ($P<0.001$) in birds trimmed at 10 weeks of age compared to intact birds or birds IR and HB birds trimmed at 1 day of age..
Carprofen, reported to have an analgesic effect on neuromuscular pain in chickens, had no effect on the pecking force in birds trimmed at 10 weeks of age; however, when more carprofen-treated feed was eaten by birds there was a higher maximum force of peck ($P=0.03$).
No evidence was found that beak trimmed pullets consumed more carprofen-treated feed than pullets with an intact beak.
The three beak trimming methods resulted in an average 34% reduction in beak length, considered a light trim, and is perhaps not representative of commercial birds where greater portions of the beak are removed.
It appears Carprofen has no analgesic effect on potential neuropathic pain arising from the nerves severed by a light beak trim.
</td></tr>
</table>

	• A large layer trial showed that IR trimmed birds had lower mortality after 20 weeks ($p<0.05$) compared to HB trimming. The difference in average cumulative mortality between a re-trimmed and non-re-trimmed treatments became significant ($p<0.01$) from week 26 with higher mortality in the non re-trimmed group. • HDEP was significantly lower ($p<0.01$) for the control birds but there were no significant differences between HB and IR treated birds. Re-trimmed birds had a slightly lower HDEP for most of the laying period. • There was no significant difference in egg quality and egg shell thickness between treatments. There were minimal differences in body weight over the laying period. • It is apparent that IR and HB treatment at 1 day old increases the level of aggression/pecking activity relative to other treatments and that fearfulness appears significantly higher in the birds treated by IR at day 1 than other trim treatments except the double HB trim. The 1 day treatment using IR has had long lasting effects on fear and aggression behaviours. *iv) Development of a laser method of beak trimming at Adelaide University:* All lasers investigated were successful in making a hole in the beak at the zone of ossification in the upper beak. Tests were made to determine if the beak can transmit significant power through the outer layers to damage the growth point without burning a hole in the outside of the beak. This was found to be limited by excess scatter. However the use of a laser as a cutting tool is viable, and this can reduce both the blood loss and pain due to its ability to seal blood vessels and nerve endings during cutting. *v) Histology work conducted in Flinders University:* Similar histopathology of the upper beaks was found for IR and HB trimming methods at 32, 144 and 420 days of age. Sensory receptors were not found in the upper beak for both trimming methods at any ages. The histopathology suggests that excessive tissue was removed for the age at which the birds were trimmed. This results in the formation of traumatic neuromas which persisted to adulthood.
Implications	• There is a need to improve the consistency of beak trimming for both the IR and HB method in Australia • Mortality of layers trimmed with the IR method is relatively low indicating this method is acceptable for use in Australia to control cannibalism but further development is required with this method to reduce the incidence of neuromas. • There is a need to practice HB trimming at day old to overcome neuroma formation and chronic pain • IR and HB trimmed pullets do not consume more analgesic treated feed than pullets with an intact beak suggesting pain from IR and HB beak trimming is not excessive or the analgesic is ineffective for neuropathic pain. • There is a need to continue with the development of high technology laser methods of beak trimming as an alternative to current methods of beak trimming.

Publications	Freire, R. P. C Glatz and G. Hinch (2008). Self-administration of an analgesic does not alleviate pain in beak trimmed chickens. Asian Australasian Journal of Animal Science, 21 (3) 443. Glatz, P.C., Z.H. Miao, B.K. Rodda and S.J. Wyatt. (2008). Comparison of HB beak trimming and IR treatment in laying hens. In *Proceedings of XXIII World's Poultry Congress.* Brisbane, Australia. 29th June-4th July, p 268

Appendix

Paper was published in *Proceedings of XXIII World's Poultry Congress.* Brisbane, Australia. 29th June-4th July p268

Appendix 1. Comparison of HB beak trimming and IR treatment in laying hens

P.C. GLATZ, Z.H. MIAO, B.K. RODDA and S.J. WYATT

Summary

The two beak trimming methods used in the Australian egg industry are HB and IR. Beak parameters and production performance of Hyline Brown layers trimmed using both methods were monitored throughout the production cycle. Beak condition was superior for IR treated birds in the rearing period but by mid-lay was similar, irrespective of treatment. The upper beak of IR trimmed birds was longer (4mm) than HB trimmed birds throughout the laying period. While beak trimming method had no effect on egg production, the IR treatment resulted in higher body weight throughout lay and lower egg weight. Industry flocks, monitored for comparison, showed a significant variation in beak condition and length of birds between both methods. Consistency needs to be improved for both methods of trimming.

I. INTRODUCTION

Cannibalism is a significant problem for layers in Australia. It is a source of production loss and reduced welfare of birds with mortality ranging from 25-30% for non beak trimmed birds (Glatz, 2000). There are a number of strategies to reduce cannibalism, but the most effective method to prevent cannibalism in layers is beak trimming (Glatz and Bourke, 2005; Kuenzel, 2007). HB beak trimming involves the partial removal of the upper and lower beak by using an electrically heated blade that cuts and cauterises the beak (Glatz, 2005). The HB method has been the most popular method of beak trimming since the 1940s. However, the IR method was recently introduced and involves the use of an IR beam to treat the bird's beak (Glatz, 2005; Gentle and McKeegan, 2007). The procedure involves exposing part of the beak to an intense IR beam, which kills the underlying beak tissue. The treated tissue erodes after a few weeks resulting in a partially trimmed beak (Glatz, 2004; Gentle and McKeegan, 2007). The aim of the study was to compare the production performance and beak condition of birds beak trimmed using the HB and IR method.

II. MATERIALS AND METHODS

A total of 100 Hyline Brown chicks were used in the study; 50 were trimmed at day old using the IR beak treatment machine developed by Nova-Tech engineering and 50 by an experienced HB beak trimmer using a Lyon beak trimming machine. Birds were housed in growing cages until 16 weeks and then at 4 per cage ($550cm^2$/bird) in a controlled environment cage layer shed at the poultry unit at Roseworthy Campus, University of Adelaide. A standard starter, grower, and layer diet was fed and water was available *ad libitum* throughout the trial. Birds were monitored from 0-60 weeks from March 2006 to April 2007.

Beak length, beak step, beak growth and beak condition and body weight were determined at regular intervals from 0-60 weeks. Egg production variables were measured from 22-60 weeks. Beak length was measured using a digital vernier calliper. The measurement was made from the edge of the external nare to the tip of the beak. Beak condition was assessed using a scoring system (1= no beak imperfections; 2 = beak shows minor imperfections; 3 = beak shows major imperfections). Hyline layers housed in cages were monitored for the same beak variables at 45 and 60 weeks on 3 commercial egg farms in South Australia.

III. STATISTICAL ANALYSIS

The birds were selected at random for each treatment in the Roseworthy trial and for birds monitored on farm. Comparisons were analysed over the period 0-60 weeks for the Roseworthy trial. For the 3 industry farms data was assessed on 100 birds at 45 and 60 weeks of age. Farm 1 and 2 used only one of the trimming methods while farm 3 used both methods of trimming. Trimming method and age were the main factors in the analyses. Treatment effects were analysed using the ANOVA in the Systat software (Wilkinson, 1996).

IV. RESULTS

a. Roseworthy trial

Beak length, beak step, beak growth and beak condition: Beak length was significantly (P<0.01) longer for IR trimmed birds than HB trimmed birds over the whole experimental period (Figure 1). However, the beak step (gap between top and bottom beak) was significantly (P<0.01) larger for HB trimmed birds compared to the IR trimmed birds except for the first week. IR trimmed beaks regrew more (P<0.01) than HB trimmed birds in weeks 1, 6, 8, 12, 36 except in weeks 4, 14, 24. Beak regrowth declined as the birds aged. Birds trimmed with the HB had significantly (P<0.01) poorer beak condition than IR trimmed birds up to 40 weeks age but thereafter there was no significant difference in beak condition with a score of 2.01 for IR trimmed birds and 2.11 for HB trimmed birds (Figure 2).

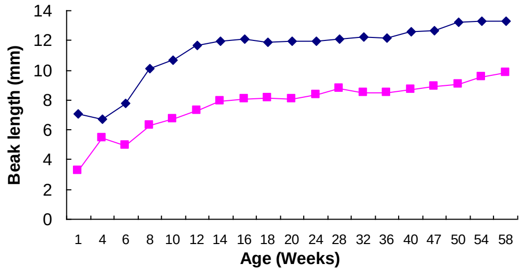


Figure 1. Beak length at different ages for IR (ω) and HB (♣) treatments.

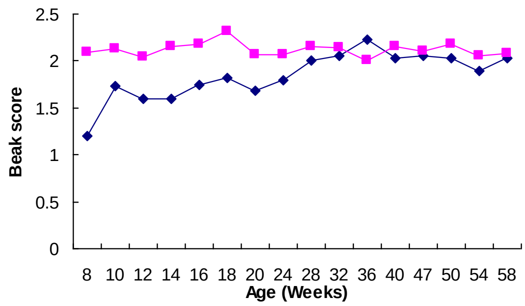


Figure 2. Beak score at different ages for IR (ω) and HB (♣) treatments.

b. Industry egg farms

Beak length of layers at 45 and 60 weeks was longer (P<0.001) for IR trimmed birds compared to HB trimmed birds (Table 1) except for farm 3 at 60 weeks. However, the beak step was significantly (P<0.001) larger for HB trimmed birds than IR trimmed birds at week 45 (4.01 vs. 1.46mm) and 60 (4.17 vs. 1.60mm) for birds on farms 1 and 2 but no differences were observed for farm 3. Beak condition was better (P>0.05) for IR trimmed birds compared to HB trimmed birds at week 45 and 60 for birds on farms 1 and 2. This difference was significant on farm 3. There was no difference in beak regrowth for both trimming treatments at week 60.

Table 1. Beak characteristics at week 45 and 60 weeks on 3 industry egg farms

Farm	Age (weeks)	Beak length (mm)	Beak step (mm)	Beak condition
Farm 1 (IR)	45	11.526[a]	1.462[a]	1.955
Farm 2 (HB)	45	9.602[b]	4.012[b]	1.840
	P	0.000	0.000	0.245
	SEM	0.177	0.225	0.049
Farm 1 (IR)	60	11.172[a]	1.602[a]	2.119
Farm 2 (HB)	60	9.402[b]	4.166[b]	2.091
	P	0.000	0.000	0.814
	SEM	0.175	0.236	0.059
Farm 3 (IR)	45	9.859 [a]	1.739	2.000[a]
Farm 3 (HB)	45	10.561[b]	1.474	1.280[b]
	P	0.001	0.339	0.000
	SEM	0.107	0.138	0.059
Farm 3 (IR)	60	9.640	1.241[a]	2.024
Farm 3 (HB)	60	9.508	1.872[b]	1.684
	P	0.810	0.035	0.016
	SEM	0.272	0.150	0.071

[a, b] Indicates significant difference for paired comparisons between farm 1 and 2 at 45 or 60 weeks and for farm 3 at 60 weeks.

V. DISCUSSION

Beak length from 0-60 weeks ranged from 3.26-9.82mm for HB trimmed birds and from 6.75-13.29mm for IR trimmed. However, for the first 6 weeks after trimming there was less variation in beak length for both trimming methods. This was also noted by Gentle and McKeegan (2007) in their 6 week experiment comparing IR and HB trimming methods. In our trial there was continual regrowth of the beak from week 1-60 after trimming for both methods. At the end of the trial the HB trimmed birds had a shorter beak (9.82mm) compared to IR trimmed beaks (13.29mm).

Beak step of birds that were HB trimmed ranged from 0.20mm at one week of age to 5.10mm at 47 weeks of age. A smaller beak step was found for birds IR trimmed, ranging from 0.15mm at 4 weeks of age to 0.90mm at 50 weeks of age. Glatz and Bourke (2005) reported that most producers aim to have a blunt beak with a beak step of 3mm at 30 weeks of age to prevent feather pecking and cannibalism. Beak step for birds on HB trimming at 28 and 32 weeks of age was 3.48 and 3.87mm respectively and for birds on IR trimming was 0.46 and 0.76mm respectively. These results may indicate that IR trimmed birds have a greater capacity to engage in feather pecking and cannibalism by having a longer beak and a shorter beak step. In Australia field reports have indicated that flocks trimmed using the IR technology have resulted in variable beak length within the flock, which may predispose some birds to increased levels of feather pecking.

IR trimmed birds had a heavier body weight and a superior weight gain than the birds trimmed with the HB when compared at the same age. This result was similar to Gentle and McKeegan's (2007), who found body weight of HB trimmed birds was lower than IR trimmed birds over a 6 week experiment. Egg production for both trimming methods was similar, but HB trimmed birds laid heavier eggs (63.7g) compared to the IR trimmed birds (62.0g). This could be due to a greater ability of HB trimmed birds to consume smaller particles of feed. No significant effects on bird behaviour for the two trimming methods were found after trimming up to 6 weeks of age (Gentle and McKeegan, 2007). In terms of beak condition it was clear (particularly early in the production phase) that birds trimmed with the HB method had a poorer beak appearance than the IR trimming method. However the potential for of IR trimmed birds to engage in more feather pecking and cannibalism due to a longer beak and better beak condition needs to be evaluated. The results indicate there is variation in beak length and regrowth on farms for birds trimmed with both methods. This suggests that further work is required to ensure beak trim methods are practiced consistently.

REFERENCES

Gentle, M.J. and McKeegan, D.E.F. (2007). *Veterinary Record*, **160**:145-148.
Glatz, P.C. (2000). *Asian-Australasian Journal of Animal Science*, **13**:1619-1637.
Glatz, P.C (2004). Laser beak trimming. Final Report to the Australian Egg Corporation Limited.
Glatz, P.C. (2005). What is beak-trimming and why are birds trimmed? In: Poultry Welfare Issues-Beak Trimming. Ed. Glatz, P. C. Nottingham University Press. pp.1-17.
Glatz, P.C. and Bourke, M. (2005). Beak Trimming Handbook-Best Practice for Minimising Cannibalism. Poultry CRC, Australia.
Kuenzel, W.J. (2007). *Poultry Science*, **86**:1273-1282.
Wilkinson, L. (1996). Systat 6.0 for Windows-Statistics. S P S S Inc., USA.

ACKNOWLEDGEMENT

The authors are grateful to the Poultry CRC for providing funds for this study.

Appendix 2 Self-administration of an analgesic does not alleviate pain in beak trimmed chickens

Paper published in Asian Australasian Journal of Animal Science in 2008 V 21 (3) 443

Freire, R. P. C. Glatz and G. Hinch. (2008). Self-administration of an analgesic does not alleviate pain in beak trimmed chickens. Asian Australasian Journal of Animal Science 21(3):443-448.

Rafael Freire, Philip C Glatz[1] and Geoff Hinch

ABSTRACT: Beak trimming in laying hens is a routine practice in which about ⅓ – ½ of the upper and lower beak is removed with the aim of reducing cannibalism. This experiment aimed to identify if this procedure causes pain by examining self-administration of an analgesic (carprofen) and pecking behaviour in 80 laying pullets beak-trimmed by two different methods; at one day of age using hot-blade cauterisation or infra-red cauterisation. We also tested a control treatment, pullets with intact beaks, and a positive control treatment of pullets beak trimmed at 10 weeks of age which were expected to experience some pain due to recent severing of the underlying nerves in the beak. At 11 weeks of age birds trimmed at 10 weeks of age pecked more ($P<0.001$) gently (0.6 ± 0.06N) at a disc attached to a force-displacement transducer than birds trimmed at 1 day of age with an infra-red machine (0.9 ± 0.1N) or a HB (1.1 ± 0.07N) and intact birds (1.2 ± 0.1N). Maximum force of pecks recorded was also lower ($P<0.001$) in birds trimmed at 10 weeks of age than birds trimmed at 1 day of age with an infra-red method or a HB and intact birds. However, the pecking force in birds trimmed at 10 weeks of age was not increased by providing them with analgesic-treated feed, though birds that ate more carprofen had a higher maximum force of peck ($P=0.03$). Pecking force in birds beak trimmed at 1 day of age was the same as the pecking force of intact birds, and was unaffected by feeding pullets carprofen. A method of self-administration of an analgesic had previously revealed that chickens in neuromuscular pain arising from lameness consumed more of a feed containing carprofen than healthy chickens. However, we found no evidence that beak trimmed pullets consumed more carprofen-treated feed than pullets with an intact beak. It should be noted that the three beak trimming methods resulted in an average 34% reduction in beak length, considered a light trim, and is perhaps not representative of commercial birds where greater portions of the beak are removed. We conclude that although carprofen has been reported to have an analgesic effect on neuromuscular pain in chickens, it appears to have no analgesic effect on potential neuropathic pain arising from the nerves severed by a light beak trim.
Key Words: Beak trimming, Analgesic, Hens, Neuropathic pain, Carprofen

INTRODUCTION

There is a pressing need to develop reliable and unequivocal indicators of pain in farm animals to identify the welfare implications of various routine industry procedures. Beak trimming in laying hens is the removal of about ⅓ – ½ of the upper and lower beak of the young chicken, commonly using a hot-blade which simultaneously amputates and cauterizes. This routine industry practice is undertaken because it reduces the extent of cannibalism and vent pecking during rearing and in adulthood (Glatz, 1990). Within the industry, beak trimming is also often considered to improve feed efficiency and this has been supported by some studies (e.g. Glatz, 2000; Davis *et al*., 2004), though others have failed to find any improvement in feed conversion following beak trimming (e.g. Carey and Lassiter, 1995). The beak of the chicken is a complex functional organ with an extensive nerve supply that is used for food manipulation, exploration of the environment, preening and social interaction. Objections to beak trimming have centred on the possibilities that this practice causes acute and/or chronic pain and that trimming deprives the chicken of sensory feedback and impairs the function of the beak (Glatz, 2000).

To date, animal welfare research has provided some behavioural and neurological evidence to inform the debate on the acceptability of routine beak trimming within the industry (see Cheng, 2006 for a recent review). However, there are limitations to both these lines of evidence: first, it is unclear whether the reported reduction in pecking following beak trimming, termed guarding behaviour, indicates pain or arises from the loss of sensory perception in the beak. Since the nerves have been severed, pecking with a trimmed beak will not provide the sensory feedback that an intact beak may provide, and may thus reduce the sensory stimulation achieved through exploration with the beak resulting in less pecking. Additionally, the regrown tips of the beak do not always contain afferent nerves or sensory corpuscles (Gentle *et al*., 1997); therefore the loss of sensory feedback may be long-term and may explain long-term evidence of guarding behaviour. It appears that the amount of beak removed appears critical, with some evidence that sensory receptors are still present in moderately trimmed birds (Lunam *et al*., 1996). It should also be noted that the main objective of beak trimming, a reduction in cannibalism, could arise both from a resultant reduction in the tendency of birds to peck or by reducing the amount of damage that birds can cause each other. Second, it is also unclear whether nerves that form neuromas project to the brain, and if they do whether they transmit action potentials to brain areas that may interpret these as pain. Animal welfare research therefore urgently needs reliable and unequivocal indicators of pain in beak trimmed birds that will aid the moral debate as to the suitability of this routine procedure.

When given a choice of feeds, rats with clinical symptoms of pain will consume more of an analgesic-containing feed than animals not in pain (e.g. Colpaert *et al*., 2001). It has been known for some time that chickens are able to select some feeds over others, even when both feeds are visually similar but differ only in nutrients, such as by consuming more feed high in selenium than feed lacking in selenium (Zuberbueher *et al*., 2002). Similarly, Danbury *et al*. (2000) found that when given a choice of feeds with and without an analgesic (carprofen), lame broiler chickens consumed more of the analgesic-treated feed than sound birds. Additionally, the consumption of carprofen in chickens was positively correlated to the severity of lameness, and consumption resulted in an improved gait (Danbury *et al*., 2000). The authors conclude that lame birds are able to select feeds with analgesics, thereby indicating that they are in pain and that they will actively seek relief from this pain. Carprofen is a non-steroidal analgesic which has previously been shown to have an effect on chickens, by improving the gait of lame broilers (McGeown *et al*, 1999). In the present experiment we used a method based on the approach described by Danbury *et al*. (2000) to investigate the potential impact of pain in beak trimmed birds. If trimmed birds are in pain and attempt to guard the beak from further pain stimulation, then we predicted that trimmed birds should peck more gently than intact birds. This difference in pecking force should however be removed by administering an analgesic. We also trained chickens using colour cues to distinguish between carprofen-treated feed and untreated feed as undertaken by Danbury *et al*. (2000). We predicted that beak trimmed birds should consume more analgesic-treated feed than intact beak birds when both feeds were presented simultaneously.

Chickens were beak trimmed at one day of age by either a hot-blade or an infra-red method by a commercial hatchery as is common commercial practice. We also tested intact beak birds as a control condition and birds that had been beak trimmed at 10 weeks of age using a hot-blade as a positive control; behavioural and neurological evidence (Megret *et al*., 1996; Gentle *et al*., 1997) indicates that birds trimmed at 10 weeks of age are likely to experience pain in the two weeks following trimming.

MATERIALS AND METHODS

Eighty Hyline Brown laying pullets were housed in pairs in cages measuring 50 x 55cm (wxd) x 50cm high at the front of the cage at 10 weeks of age in an open sided layer shed. Pullets were *ad lib* fed with pullet grower crumbles (Ridley Agriproducts, Victoria), and water was available from nipple drinkers. Fluorescent lights were on a 14h light: 10h dark cycle and temperature was 21 ± 5^0C. Four groups of twenty chickens had been subjected to one of 4 beak trimming methods as follows: 1) hot-blade trimming at 1 day of age, 2) infra-red beak trimming at 1 day of age, 3) hot-blade beak trimming at 10 weeks of age and 4) intact beaks. Trimming at one day of age was undertaken by staff at a commercial hatchery (Kean’s Poultry, Huntley, Victoria), and trimming at 10 weeks by an experienced technician, and in both cases about ⅓rd of the upper and lower beak was removed.

At 11 weeks of age chickens were given experience of two different feeds on alternate days for 6 days. The feeds consisted of grower crumbles which were coloured either red or blue using food dye (Queen’s blue and red food colouring, Queen fine foods, Queensland, Australia) at a concentration of 125ml/20kg crumbles. Feed was provided in individual metal feeders 20 x 14 x 10cm at front (20 cm at the back and sides) and sprayed with the food dye colour. One of these coloured feeds was treated with an analgesic, carprofen (Pfizer animal health, rimadyl injection) at a dose of 80mg/kg of feed. Mixing of the feed with the colouring (and carprofen) was achieved by spraying the solution into the feed in a cement mixer until a visually even colour was achieved. According to Danbury *et al*. (2000) the dose would provide each bird with therapeutic levels of carprofen (see discussion). The respective position of each feeder (i.e. left or right side of the cage) was chosen at random on the first day, and thereafter this choice was maintained for the entire duration of the experiment. Half of the chickens from each beak trimming method were provided with red analgesic-treated feed and the other half with analgesic-treated blue food, with untreated feed sprayed with the alternative colour.

For the first four days of training with different coloured feeds, the force of pecks at 5 black pebbles glued to a 10 cm diameter white disc was measured using a force-displacement transducer (GRASS (reg.), Australia) and recorded using Chart 5 software (ADInstruments). No attempt was made to distinguish the pecks of the two birds in each cage, so each cage provided a single measure for the pecking force analysis. The duration from placing of the disc through the front of the cage to the first peck of the disc was measured, along with the force of the first 10 pecks on one day when analgesic-treated feed was provided, and one day when untreated feed was provided. Measurements of pecking force began two hours after feeding, and the order of recording on days when treated and untreated feed was balanced for order effect.

At the end of the fourth day, one bird from each cage was removed and placed in a cage alone for two further days so that all 80 birds were in individual cages, randomly assigned in blocks of 10 pullets from each treatment along two rows of cages. Analgesic-treated feed was given one day and untreated feed the other day, and the relative position of the side of the cage that each feeder was placed was retained from the first four days. All coloured feed was then removed and birds were returned to uncoloured grower crumbles for 12 hours. After this period, both analgesic-treated and untreated coloured feed were simultaneously given to the pullets in two feeders/cage. The feeders were weighed daily to measure the amount of each coloured food consumed. After weighing, the feeders were replenished with enough fresh feed (about 150g) to ensure that both colours were available *ad lib*.

Beak length was measured in all birds and the difference between the upper and lower beak measured in beak trimmed birds using a vernier calliper. Pecking force was analysed in a General Linear Mixed Model (SPSS 14.0, SPSS Inc., USA), with cage as a replicate and four beak methods and two feed treatments (analgesic-treated or untreated) as the repeated measure. The amount of analgesic-treated feed consumed was analysed in a General Linear Model with 4 beak conditions.

RESULTS

Beak length and pecking force

Beak length did not differ between the three beak trimming methods (ANOVA, $F_{2,57}$=2.2, P=0.13; Table 1), with trimming resulting in an average 34% reduction in beak length. The difference between the upper and lower beaks was lowest in birds trimmed with the HB at 1 day of age (ANOVA, $F_{2,57}$=9.9, P<0.001; Table 1). Birds trimmed at 1 day of age with the HB appeared to peck at the disc sooner after exposure than birds from the other beak conditions (ANOVA, $F_{1,36}$=2.8, P=0.05; Table 1). The latency to peck the disc was not influenced by feeding of analgesic-treated or untreated feed (ANOVA, $F_{1,36}$=0, P=0.96 or the feed type/beak condition interaction, ANOVA, $F_{3,36}$=0.47, P=0.70).

There was a difference between the four beak methods in both the mean force of pecks (ANOVA, $F_{1,36}$=7.5, P<0.001) and the maximum force of peck (ANOVA, $F_{1,36}$=9.5, P<0.001; see Figure 1). Birds beak trimmed at 10 weeks of age using a hot-blade had a lower mean force of peck

Table 1: Mean (±sem) beak length, gap between the upper and lower beaks and the latency to peck the round disc in the pecking force tests for pullets from the four beak methods, and results from the ANOVA tests.

Beak Treatment	Beak measurements		Latency to peck disc (s)	
	Beak length	Gap	Analgesic	Untreated
Intact	17.7±0.3	N/A	161±74	264±95
Infra-red 1 day	11.1±0.3	2.6±0.2	177±68	137±78
Hot-blade 1 day	12.0±0.4	1.6±0.3	73±27	95.4±45
HB 10 weeks	12.1±0.4	3.0±0.2	299±97	201±90
ANOVA	$F_{2,57}$=2.2, p=0.13	$F_{2,57}$=9.9, p<0.001	Beak effect, $F_{3,36}$=2.8, p=0.05. Feed type effect, $F_{1,36}$=0, p=0.96.	

than birds with intact beaks (Tukey's post-hoc test, MD=0.53, P=0.001) and birds beak trimmed with the hot-blade at 1 day of age (Tukey's post-hoc test, MD=0.0.46, P=0.004). The maximum force of peck was similarly lower in birds trimmed at 10 weeks of age with the hot-blade than intact birds (Tukey's post-hoc test, MD=0.92, P<0.001) and birds trimmed at 1 day of age with the hot-blade (Tukey's post-hoc test, MD=0.0.61, P=0.007). The maximum force of peck tended to be lower in birds trimmed at 10 weeks of age with the hot-blade than those trimmed at 1 day of age with the infra-red method (Tukey's post-hoc test, MD=0.43, P=0.085). Feeding of analgesic-treated or untreated feed had no effect on either the mean force of ten pecks (ANOVA, $F_{1,36}$=1.68, P=0.20) or the maximum force (ANOVA, $F_{1,36}$=2.83, P=0.10). However, the maximum pecking force of birds trimmed at 10 weeks of age with the HB was positively correlated with the amount of analgesic-treated feed eaten (Pearson Correlation = 0.66, N=10, P=0.032), though the average pecking force was not correlated to the amount of analgesic-treated feed eaten (Pearson Correlation = 0.51, N=10, P=0.13). No other significant differences were found either from the interaction of terms in the ANOVA tests or other post-hoc tests.

Simultaneous choice of analgesic-treated and untreated feeds

No evidence was found that birds from the four beak trimming methods consumed different amounts of analgesic-treated feed when both feeds were presented simultaneously (Figure 2, ANOVA, $F_{3,70}$=0.41, P=0.74). Birds appeared to prefer red analgesic-treated feed over blue analgesic-treated feed for the first 3 days of the simultaneous feeding period, but this preference appeared to reverse on the fourth day (Figure 3; day/colour of feed interaction, ANOVA, $F_{3,210}$=2.8, P=0.039). No evidence was found that food consumption of the treated and untreated feeds varied throughout the four days when both feeds were presented simultaneously (day/beak condition interaction, ANOVA, $F_{3,210}$=1.16, P=0.32). No other significant third order or second order interactions were found (day/beak condition/colour interaction, ANOVA, $F_{3,210}$=0.91, P=0.52; day/ colour interaction, ANOVA, $F_{3,210}$=1.44, P=0.24).

Daily food consumption was 83.5±1.03g of feed, irrespective of colour or drug. Over the four simultaneous choice days similar amounts of analgesic-treated and untreated feed were consumed (Figure 2; Paired t-test, t=0.08, N=80, P=0.94). Similar amounts of red feed (42.3±2.3g/day) and blue feed (41.4±1.9g/day) was eaten irrespective of whether it was treated or not (Paired t-test, t=2.0, N=80, P=0.84).

DISCUSSION

The pullets beak trimmed at 10 weeks of age pecked more gently than intact pullets, consistent with the hypothesis that these recently beak trimmed pullets were guarding a painful beak from further contact. Pullets trimmed at one day of age with the HB or infra-red method did not show a reduced pecking force compared to intact pullets. No general effect of carprofen was found on the force of pecks, though there was a positive correlation between the amount of analgesic-treated feed eaten and maximum pecking force in birds trimmed at 10 weeks, suggesting that birds that ate large amounts of the analgesic-treated feed may have experienced an analgesic effect. Following a period of training to distinguish between carprofen-treated feed and untreated feed as used by Danbury *et al*. (2000), beak trimmed pullets did not consume more treated feed than intact pullets when both feeds were presented simultaneously. We found no evidence of pain in birds at 11 weeks of age that were trimmed at one day of age by either the HB or the infra-red method.

Neurological studies on beak trimmed hens have shown neuromas in trimmed beaks some time after trimming (Breward and Gentle, 1985; Gentle, 1986), and neuromas are linked to chronic pain in humans, as occurs in amputated limbs (Wall, 1981). Trimming at day-old appears to reduce the incidence of neuromas as compared to trimming at older ages (Megret *et al*., 1996), and it may be that neuromas are resorbed sometimes between 10 weeks and 70 weeks following trimming (Lunam *et al*., 1996). In the present study beak trimming resulted in a 34% reduction in beak length with no difference in beak length between the three trimmed methods, which would be considered a light trim compared to the more usual industry practice of removing about 50% of the beak. The amount of beak removed is likely to have a strong effect on the potential pain experienced (Glatz, 2000), so our current results should be considered relevant to a light trim and perhaps not representative of what birds may experience following removal of a larger portion of the beak. Trimming with a HB at 1 day of age resulted in the least difference in the length of the upper and lower beaks, which may be expected to facilitate these birds' ability to pick up and manipulate food. It should be noted though that different hatcheries may achieve different results with respect to the gap between the upper and lower beaks.

Laying hens reduce pecking-related behaviour in the first 2 weeks after trimming (Gentle *et al*., 1997) which has been considered to indicate protection of a painful area from further contact and stimulation (guarding behaviour). Furthermore, the observed decline in feeding rate after beak trimming can be prevented by the application of topical analgesics to the recently trimmed beak (Glatz *et al*., 1992). The lower pecking force of pullets trimmed at 10 weeks of age compared to intact pullets and those trimmed at 1 day of age in the present study supplements the above studies by indicating that even a light trim at this age appears painful to the hen for at least the first week after trimming. VanLiere (1995) found that beak trimmed birds are slower to peck a novel object than intact hens at 42 weeks after trimming, possibly indicating long-term guarding behaviour, though in the present study we found no evidence that the trimmed birds took longer to peck the novel round disc. It is unclear why our results did not replicate those of vanLiere (1995), though one possibility is that responsiveness in beak trimmed birds declines some time between 10 and 42 weeks of age.

Chickens in this study consumed on average 83±1g of feed per day, which would have provided them with 6.6mg of carprofen/day on training days when only analgesic-treated feed was provided. This dose of carprofen compares well with the dose provided by Danbury *et al*. (2000) in their second experiment, in which they found that lame birds provided with a simultaneous choice of analgesic-treated and untreated feed ate 6.7mg of carprofen/day, a significantly greater amount than sound birds. This dose in lame broilers resulted in a plasma concentration of carprofen of 0.28μg/ml and improved their gait. In the present study, the maximum pecking force in birds trimmed at 10 weeks of age was positively correlated with the amount of analgesic-treated feed consumed, suggesting that very high doses of carprofen may have had an analgesic effect in these birds.

In light of the above evidence that indicates that birds in the present experiment received sufficient carprofen for an analgesic effect, it was surprising to find that birds trimmed at 10 weeks of age did not peck with more force when provided with treated feed. One possibility is that the reduced pecking force in birds trimmed at 10 weeks of age was not an expression of guarding behaviour, but instead arose from a bio-mechanical effect linked to the relatively recent shortening of the beak. Aside from the abovementioned correlation between pecking force and amount of analgesic-treated feed consumed by birds trimmed at 10 weeks, no effect of the treated feed was found on pecking force and no selection of treated feed by trimmed birds was found when treated and untreated feeds were provided simultaneous, raising the possibility that carprofen had no analgesic effect on the type of pain arising from beak trimming.

Support for this latter explanation is provided by Kupers and Gybels (1995). They found that rats with neuropathic pain, induced by partial sciatic nerve injury, did not consume more fentanyl (an opioid analgesic) than control rats. In contrast, rats with nociceptive pain, adjuvant induced monoarthritis, consumed significantly more fentanyl than control rats. They concluded that fentanyl has a good analgesic effect on neuromuscular pain but a poor analgesic effect on neuropathic pain. It may be that carprofen has a similar selective analgesic effect in chickens, in being effective for neuromuscular pain in lameness as reported by Danbury *et al*. (2000) but having no effect on neuropathic pain following beak trimming in the present study. Unfortunately, the mode of action of carprofen in birds is unknown.

Additionally, it is possible that the effects of carprofen observed by Danbury *et al*. (2000) may have arisen from the known (in mammals) anti-inflammatory action of carprofen, rather than from its analgesic action. The possibility that neuropathic pain is not affected by some analgesics raises two recommendations for future research on using self-administration of analgesics as a means to examine pain in beak trimmed birds. Firstly, future investigation of pain following beak trimming should consider using analgesics known to alleviate neuropathic pain in chickens, or at least a combination of different analgesics. Second, the possibility that some analgesics may alleviate pain associated with beak trimming, and that some analgesics may not, provides a methodological tool for investigating the neural pathways involved in processing any possible neuropathic pain following beak trimming.

In conclusion, neither pecking force analysis or a previously used self-administration of analgesic technique provided any evidence of pain at 11 weeks of age in laying pullets receiving a light beak trim at 1 day of age by a hot-blade or IR method. Although we found evidence that birds trimmed at 10 weeks of age may have been in pain one week after the procedure, this pain was unaffected by carprofen. In contrast to the effect of carprofen in alleviating neuromuscular pain associated with lameness in broiler chickens as previously shown by Danbury *et al*. (2000), carprofen administered in a similar manner is not effective in alleviating neuropathic pain following beak trimming in laying pullets.

Acknowledgements
The authors thank the Poultry Cooperative Research Centre for funding this project.

REFERENCES

Breward, J. and M.J. Gentle. 1985. Neuroma formation and abnormal afferent nerve discharges after partial beak amputation (beak-trimming) in poultry. Experientia, 41:1132-1135.

Cheng, H.W. 2006. Morphopathological changes and pain in beak trimmed laying hens. World's Poult. Sci. J., 62:41-52.

Carey, J.B. and B.W. Lassiter. 1995. Influences of age at final beak trim on the productive performance of commercial layers. Poult. Sci., 74:615-619.

Colpaert, F.C., J.P. Tarayre, M. Alliaga, L.A.B Slot, N. Attal and W. Koek. 2001. Opiate self-administration as a measure of chronic nociceptive pain in arthritic rats. Pain, 91, 33-45.

Danbury, T.C., C.A. Weeks, J.P. Chambers, A.E. Waterman-Pearson and S.C. Kestin. 2000. Self-selection of the analgesic drug carprofen by lame broiler chickens. Vet. Rec., 14:307-311.

Davis, G.S., K.E. Anderson and D.R. Jones. 2004. The effects of different beak trimming techniques on plasma corticosterone and performance criteria in single comb white leghorn hens. Poult. Sci., 83:1624-1628.

Gentle, M.J. 1986. Neuroma formation following partial beak amputation (beak-trimming) in the chicken. Res. Vet. Sci., 41:383-385.

Gentle, M.J., B.O. Hughes, A. Fox and D. Waddington. 1997. Behavioural and anatomical consequences of two beak trimming methods in 1- and 10-d-old domestic chicks. Br. Poult. Sci., 38:453-463.

Glatz, P.C. 1990. Effect of age of beak trimming on the production performance of hens. Aust. J. Exp. Agr., 30:349-355.

Glatz, P.C. 2000. Beak trimming methods. Asian-Aust. J. Anim. Sci., 13:1619-1637.

Glatz, P.C., L.B. Murphy and A.P. Preston. 1992. Analgesic therapy of beak-trimmed chickens. Aust. Vet. J., 69:18-18.

Kupers, R. and J. Gybels. 1995. The consumption of fentanyl is increased in rats with nociceptive but not neuropathic pain. Pain, 60:137-141.

Lunam, C.A., P.C. Glatz and Y. –J. Hsu. 1996. The absence of neuromas in beaks of adult hens after conservative trimming at hatch. Aust. Vet. J., 74:46-49.

McGeown, D., T.C. Danbury, A.E. Waterman-Pearson and S.C. Kestin. 1999. Effect of carprofen on lameness in broiler chickens. Vet. Rec., 144:668-671.

Megret, S., F. Rudeaux, J-M. Faure and M. Picard. 1996. The role of the beak in poultry. Effects of debeaking. INRA Prod. Anim., 9:113-119.

vanLiere, D.W. 1995. Responsiveness to a novel preening stimulus long after partial beak amputation (beak trimming) in laying hens. Behav. Processes, 34:169-174.

Wall, P.D. 1981. On the origin of pain associated with amputation. In: Phantom and stump pain (Ed. J. Siegfried and M. Zimmerman). Springer Verlag, Berlin. Pp. 2-14.

Zuberbueher, C.A, R.E. Messikommer and C. Wenk. 2002. Choice feeding of selenium-deficient laying hens affects diet selection, selenium intake and body weight. J. Nutr., 132:3411-3417.

Figure 1: The mean pecking force (white bars) and maximum pecking force (black bars) in Newtons of 20 pecks (i.e. analgesic-treated and untreated feed data combined) from birds from four beak trimming methods. Birds trimmed at 10 weeks of age pecked more gently (**P<0.001) than other birds.

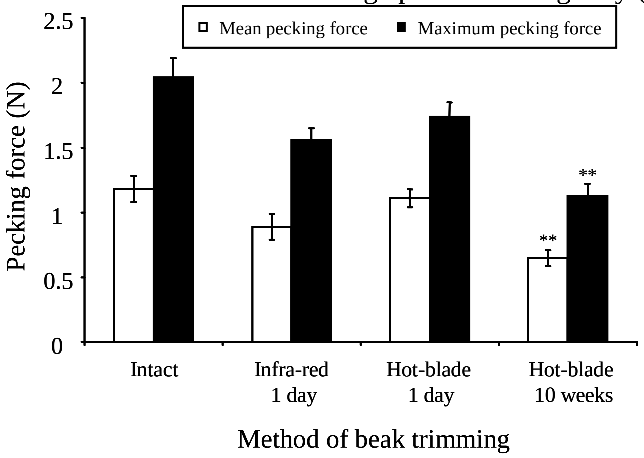


Figure 2: Birds from four beak trimming methods showed similar daily food consumption and consumed similar amount of analgesic-treated and untreated feed.

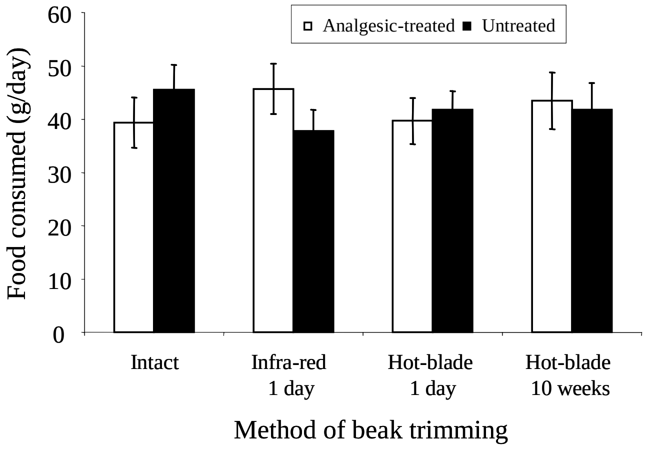


Figure 3: Choice of red and blue feeds, irrespective of presence or absence of carprofen, by all chickens during the simultaneous choice period. Chickens appeared to prefer red feed to blue feed for the first three days but on day four this preference was reversed (P<0.05).