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Rachel Nichole Cook
Iowa State University

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Effects of stocking density and beak trimming method on feeding behaviors of poultry

by

Rachel Nichole Cook

A thesis submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE

Major: Agricultural Engineering
(Agricultural Structures and Environmental Systems Engineering)

Program of Study Committee:
Hongwei Xin, Major Professor
Jay Harmon
Dan Nettleton

Iowa State University
Ames, Iowa
2005
This is to certify that the master’s thesis of

Rachel Nichole Cook

has met the thesis requirements of Iowa State University

Signatures have been redacted for privacy
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Finally thanks to all the support staff and other faculty in the ABE Department. My experience at ISU has been great as a result of being surrounded by many great people.
Concern over animal welfare has had a substantial and growing impact on the livestock industry both in the US and abroad. Quantification of animal welfare has been a challenging area for both the production and the research communities. Feeding behaviors have been shown to be an indicator of animal well-being, thus one method to evaluate and quantify animal welfare is through continuous and automated monitoring of feeding behaviors.

Two studies were designed and conducted to evaluate the effects of controversial management practices on the feeding behaviors of poultry. The first study investigated the effects of four cage stocking densities on the feeding characteristics of mature laying hens. The second study investigated the effects of three different beak trimming methods performed at one day of age and two feed forms on the feeding activities of turkey poults from 8 to 21 days of age.

As a result of the first study, no significant differences in feeding characteristics could be detected among the four stocking densities studied (348, 387, 426, and 465 cm² cage floor space per hen; 54, 60, 66, and 72 in² cage floor space per hen). The second study detected no significant differences in feeding characteristics measured or body weight gains for the four beak trimming methods (non-trimmed control, hot blade, electric arc, or infrared) and the two feed forms (mash or crumble) studied.

Quantification of specific responses such as feeding behavior to potential stressors (i.e. stocking density, beak trimming method, and feed form) through studies such as these may yield better livestock housing design and management decisions based upon scientific data to improve animal welfare.
CHAPTER 1. GENERAL INTRODUCTION

Introduction

The intent of this thesis is to utilize measurements of feeding behaviors as a method to determine the welfare implications of certain poultry management practices, namely stocking density of group-housed caged laying hens and beak trimming method and feed form used for turkey poults. These two studies were conducted with the particular management practice and species pairings due to current issues facing the poultry industry. Actions concerning animal welfare being carried out by governmental bodies, private companies, and activist groups are currently having a substantial impact on the animal agriculture industry. As a result, there is significant interest in animal welfare research both in the scientific and industry communities. Stocking density of caged layers in particular is one major topic of controversy, as animal welfare activists are presently focused on the egg industry for questions of space. The practice of beak trimming is another hotly debated area. Substantial work has been completed concerning beak trimming of chickens, but beak trimming in turkeys has not been as thoroughly researched. However, turkeys are regularly beak trimmed and the industry is at risk for criticism by utilizing this practice without scientific justification. The research that has been conducted with turkeys has had limitations relative to type of beak trim and/or age conducted, and no studies have focused specifically on feeding behavior or evaluation of the infrared method of trimming.

The measurement system and analysis methods used in these projects represent an effort toward developing methods of measuring animal welfare in an objective, quantitative, and non-invasive manner. The information gained through such studies may result in improvements to housing design and management practices in the poultry industry.
Thesis Organization

This thesis has been prepared in journal paper format, consisting of two papers prepared for submission to *Transactions of ASAE*. The thesis includes four chapters including a general introduction, paper one entitled “Evaluating Effects of Cage Stocking Density on Feeding Behaviors of Group-Housed Laying Hens”, paper two entitled “Evaluating Effects of Beak Trimming Methods and Feed Forms on Feeding Behaviors of Turkey Poults”, and a general conclusion. The general introduction includes an overall literature review, and the general conclusion includes recommendations for future research that can be drawn from the work completed. Figures and tables relevant to each paper are included at the end of each chapter, and an appendix is included for each paper presenting Visual Basic code samples and additional data for reference.

Literature Review

The issue of farm animal welfare or well-being has become a tremendous and growing controversy both in the United States and abroad. The debate has spawned governmental action in Europe, and in the US the issue has been brought to the fore by recent minimum welfare standards imposed by private companies such as McDonald’s in response to animal rights extremists. International pressures have also increased US interest in these issues, such as the European Union’s request that animal welfare be included in future international trade talks (Estevez, 2003). The dispute over animal welfare is well documented in the literature, including many articles addressing methods for the scientific community to address these concerns, and reports on significant ongoing research in the area.
Issues in modern farm animal welfare

Fraser claims that the growing popular literature by groups opposing intensive livestock production has created a perception of animal agriculture as an industry that is detrimental to animal welfare, controlled by corporate interests, and motivated by profit rather than traditional animal care values, among other claims. He also asserts that agricultural organizations have responded by producing public relations materials that deny all of these accusations and paint a positive picture of animal agriculture. Therefore, the public is forced to form opinions based only on these two completely conflicting viewpoints. These two portrayals of animal agriculture offer no options except either completely eliminating animal agriculture, or accepting it the way it is now. In this highly emotional and oversimplified argument between the two sides, there are obviously disagreements on the basic facts of modern animal agriculture, pointing out the need for scientific investigation (Fraser, 2001).

Several authors have pointed out the need for sound, unbiased scientific study on issues of farm animal welfare. Armstrong and Pajor indicate that the major challenge to the industry is the lack of research on key questions concerning the impact of production practices on animal welfare (Armstrong and Pajor, 2001). Fraser argues that scientists and ethicists can provide real, scientifically based information for the public to base opinions upon, but have historically fallen short by referencing unreliable information from advocacy sources rather than seeking out their own answers. He indicates that genuine investigations and analyses are needed to clarify the issues, rather than entrenching the information found in advocacy literature by repeating it in the scientific forum (Fraser, 2001). Koerkamp et al. indicate that as public concern about present livestock farming systems increases, it is of
importance to work towards changing livestock farming systems from socially tolerated to socially desirable (Koerkamp et al., 2001).

**The issue of stocking density in the egg industry**

Opposition to intensive livestock production systems has become a serious issue for the industry, with the housing of hens in cages being one of the “hottest” subjects of criticism (Estevez, 2003). Estevez indicates that much of the dissidence over farm animal welfare issues is related the apparent conflict of interest that some management practices, such as stocking density, increase farm profitability but may negatively impact animal welfare.

Although the livestock, broiler, and turkey industries are dealing with the same issues, the egg industry has come under the greatest fire from animal welfare and animal rights groups (Estevez, 2003). Hens housed in battery cages comprise a significant amount of the global egg production industry. The United Egg Producers estimate that 98% or more of commercial egg production in the United States and 70-80% of the world’s egg production is derived from caged layers. Although the trend in Europe is moving away from cage production, the increased use of cages in developing countries is causing an overall increase in these numbers (UEP, 2000). The UEP represents 80% of all producers in the US. Animal welfare is not a new concern to the egg industry, as the UEP first established guidelines for laying flocks in the 1980’s (Armstrong and Pajor, 2001).

Estevez points out that since most animals are kept under spatial restriction in production settings, there is great interest in the investigation of how animals use the available space and the consequences of spatial restriction (Estevez, 2003). The 1997 "Report on the Welfare of Laying Hens" by the UK’s Farm Animal Welfare Council stated that “scientific literature provides relatively little information on the use of space by hens”,

and that “further research, under a range of conditions which reflect practice, is required to clarify understanding of the space requirements of hens which can be translated into more precise and practical recommendations” (FAWC, 1997).

**Current management recommendations for improved welfare of caged layers**

Companies and organizations such as McDonald's, The American Humane Association, and the National Chicken Council have recently developed voluntary recommendations for practices involving animal welfare (Estevez, 2003). In response to rising welfare concerns, UEP commissioned the Scientific Advisory Committee in 1999 to develop recommendations based upon existing science for presentation to the UEP Producer Committee for Animal Welfare and ultimately, to the egg industry as a whole (UEP, 2000). In the UEP guidelines, the Scientific Advisory Committee did not find compelling evidence to support the abandonment of cages although cage housing is a target of such strong criticism. The committee instead recognized that cage and non-cage systems have costs and benefits associated with them, and that other considerations such as specific housing designs and the care given by farm workers can have a much stronger impact on animal welfare (Estevez, 2003). The guidelines established in 2000 by UEP and McDonald’s made a significant impact on the housing and husbandry of laying hens (Armstrong and Pajor, 2001). UEP guidelines call for cage space per hen to increase from the US industry standard of 54 in$^2$ (348 cm$^2$) per bird to a range from 67 to 86 in$^2$ (432 to 555 cm$^2$) (UEP, 2000). McDonald's Recommended Welfare Practices call for 72 in$^2$ (465 cm$^2$) floor space per bird (McDonald’s, 2000). These new recommendations are similar to those of the EU, which require 70 in$^2$ (452 cm$^2$) per hen (Hy-Line, 2000).
Previous research on stocking density of laying hens

Bell and Weaver describe cage floor space requirements for layers as “the basis of more research than any other cage management factor” (Bell and Weaver, 2002). So how do we measure animal welfare as it relates to the stocking density of caged layers? Dawkins asserts that there are no universal indicators of poultry welfare because the birds do not have universal ways of responding to different threats to their health and well-being. She proposes that researchers investigate specific responses of poultry to particular situations rather than searching for general indicators of welfare (Dawkins, 1999).

Previous studies on this subject have focused on many possible indicators of animal welfare. Carmichael et al. studied the effects of stocking density on the behavior patterns of laying hens in a multi-level perchery system. They focused on the way the birds distributed themselves in the space and the use of resources within the pen at different density levels. They found that time in locomotion decreased from 10% at 9.9 birds per square meter to 7% at 19 birds per square meter, and did not find an effect of density on the number of birds feeding at any given time (Carmichael, et al. 1998).

Dawkins and Hardie studied the space needs of laying hens by videotaping hens under various conditions to measure the amount of space hens used to perform common behaviors. They determined the space required for turning, stretching wings, wing flapping, feather ruffling, preening, and ground scratching. They concluded that the European Commission Directive on space allowances for laying hens of minimum (69.8 in²) 450 cm² (at that time) was insufficient for hens to perform basic behavior patterns that were regarded as essential by the Codes issued by the Ministry of Agriculture (Dawkins and Hardie, 1989). Dawkins also studied priorities in cage size and flooring preference for hens comparing large
to small cages and wire versus littered floors. She concluded that hens’ preference for littered floors is stronger than their preference for more space (Dawkins, 1981).

Goodling et al. studied the effects of toe-clipping and stocking density on laying hen performance, and increased stocking density (72 in² or 465 cm² versus 57.6 in² or 372 cm²) resulted in significant reductions in hen-day feed consumption and body weight gain (Goodling et al., 1984). Hann and Harvey studied hens at 64 in² and 96 in² (413 cm² and 619 cm²) per bird, and concluded from their study that a trend for higher egg production at lower stocking density suggests that lower densities are preferable (Hann and Harvey, 1971). Mench et al. studied hens housed in pens and cages at low and high densities. Although they witnessed dissimilarities in behavior between penned and caged birds, physiological and production data they collected did not provide evidence that caged housing was a stressor in itself; however, high-density conditions in the study resulted in increased mortality, decreased production, elevation of nighttime corticosterone levels, and disruption of synchronous behavior. They suggest further studies of behavioral and physiological effects of different group sizes and population densities in order to determine optimal conditions for laying hens (Mench et al., 1986).

Moinard et al. studied the effects of cage area, cage height, and perches on feather condition, bone breakage, and mortality. They found that although walking frequencies were higher in larger cages, the exercise had no measurable physiological impact on tibia breaking strength (Moinard et al., 1998). Nichol studied the effect of cage height and area on the behavior of caged hens. She found that increased area resulted in increased head scratching, body shaking, and feather raising and decreased cage pecking. She concluded that spatial restriction appears to affect the rate of performance of certain behaviors rather than affecting
whether not they are performed at all (Nichol, 1987). Patterson and Siegel measured the effects of cage densities greater than and less than the US standard on pullet live performance and blood indices of stress. Using spaces of 22 and 44 in\(^2\) (142 and 284 cm\(^2\)) per bird, they found that body weight and feed intake were reduced at greater bird densities (Patterson and Siegel, 1998).

Roush and Cravener used fuzzy decision analysis to determine a crossover point between crowded and un-crowded conditions for caged layers based on performance measure of hen-day egg production and cumulative mortality. They found that in both 240 and 480 in\(^2\) (1548 and 3097 cm\(^2\)) cages, the crossover point was 3 birds per cage, yielding 80 and 160 in\(^2\) (516 and 1032 cm\(^2\)) per bird. In 720 in\(^2\) (4645 cm\(^2\)) cages, the crossover point was 3 to 4 birds, yielding 180 to 240 in\(^2\) (1161 to 1548 cm\(^2\)) per bird. All these results are much higher than those recommended in the literature, which they cited as ranging from 54 to 106 in\(^2\) (348 to 684 cm\(^2\)) (Roush and Cravener, 1990).

**The issue of beak trimming in the turkey industry**

Commercial market turkeys undergo beak trimming at the hatchery prior to placement on the farm. Beak trimming is conducted to decrease aggressive activities that result in feather picking and cannibalism leading to late mortality losses especially in tom flocks grown to heavy weights. Just as the laying hen industry has come under fire from animal rights groups and scrutiny by private companies and the public, the practice of beak trimming turkey pouls may eventually deal with these same issues. There is a perception that the beak trimming process results in more than just temporary distress. One concern is that beak trimming may interfere with normal feeding behavior due to a pain response or the inability to pick certain-sized feed particles.
Previous research on turkey beak trimming

There has been limited research to date on beak trimming in turkeys. Some of this research has dealt with hot blade cutting of the upper beak. This method has been associated with blood loss, stress and early poult mortality. Newer methods of beak trimming include electric arc and infrared, which kill tissue and result in loss of the beak tip at about one week of age, with a healing process following the tip loss. However, there has been no work to date focused on determining whether these procedures are less stressful than hot blade trimming, and how much influence the healing process has on feed intake and bird performance.

Turkey performance (weight gain and feed conversion) is greatly affected by the form of feed (mash vs. pellets). Some of the response may be due to an influence of particle size on feed intake. Nixey (1989) has long promoted starting poult s on crumble as opposed to mash feed. Beak trimming in chickens reduced the ability of the bird to grasp the pellet with the trimmed beak (Gentle et al., 1982). Work by Persyn et al. (2004) revealed that feeding behavior was different between laying hens with or without their beaks trimmed. Frequency of eating, meal duration and meal size varied as well as size of feed particles left in the feeder. Similar studies with turkeys may help to better define appropriate feed particle size that will be conducive to the development of beak-trimmed young poults.

Beak trimming and production parameters

The review on beak trimming written by Cunningham (1992) focused on beak trimming of chickens, and came to the following conclusions: beak trimming (correctly done) was effective in reducing mortality in flocks while having little or no effect on other production parameters. In turkeys, only a limited amount of published research is available
studying the effects of beak trimming on production. The most consistent positive effect noted in the research was an improvement in feed conversion when turkeys were beak trimmed (Cunningham et al., 1992; Noble et al., 1994). Noble and Nestor (1997) demonstrated less feed wastage in large-bodied turkeys but not medium sized turkeys with no effect on feed conversion. Noble et al. (1994) noted reduced feed intake in beak-trimmed turkeys less than 8 weeks of age. Cunningham et al. (1992) and Denbow et al. (1984) found reduced mortality with trimmed males. Noble et al. (1994) found that injuries were greater with birds with intact beaks in one of two strains of turkeys, which also correlated with mortality and culling rates. However, Renner et al. (1989) found that severe arc beak trimming resulted in greater poult mortality than hot blade trimming at 11 days of age. A limitation of this study was that a comparison to an untrimmed control was not made. The above results suggest a similar conclusion as arrived at by Cunningham (1992), being that positive benefits have been shown as a result of beak trimming, but these are not consistent from study to study, and improper beak trimming can have devastating effects on poult mortality.

**Beak trimming and animal welfare**

Despite the fact that beak trimming reduces mortality from cannibalistic activity, concerns have been expressed about birds experiencing pain associated with the actual process and/or discomfort that lingers (Cunningham, 1992). Gentle and co-workers have conducted considerable study in behavior and potential pain with beak trimming in chickens (Gentle et al., 1982; Gentle, 1986; Gentle and Breward, 1986; Gentle et al., 1990; Hughes and Gentle, 1995). Based on the anatomy of the beak and changes in behavior after beak trimming, they concluded that beak trimming is painful and results in long lasting effects on
feeding behavior. In chickens, formation of neuromas associated with scar tissue is thought to signal pain. Guarding behavior is also observed. Feeding behavior appears to be altered because of changes in sensory perception in the beak. Neuroma formation is thought to occur with chickens as beak trimming is often done in older birds.

Gentle et al. (1995) has also conducted similar research with turkeys and could find no evidence of neuroma formation perhaps because turkeys are beak trimmed as young birds. In his study, turkeys were beak trimmed at day of age (Bio-beaker); cold blade cutting at 6 and 21 days; and hot blade trim at 6 and 21 days of age. Comparisons were made to untrimmed controls. Behavior was observed to 12 weeks of age. Beak length was shortest with the Bio-beak treatment at 12 wks of age and birds in this group had fewer beak associated injuries. Behavior in general was not affected by beak trimming method. This study indicates that beak trimming in turkeys has fewer negatives associated with the process. A limitation to this study was that the study ended at 12 wks of age. Male turkeys tend to become more aggressive with older ages and treatment differences may have widened if the study had continued past 12 wks of age.

Beak trimming and feeding behavior

As indicated in the review by Cunningham (1992), behavior studies have been incorporated as a method to assess animal well-being. Chickens that have undergone beak trimming typically will have depressed feed intake following beak trimming. Andrade and Carson (1975) found that layer pullets debeaked at day old had reduced feed consumption through 20 weeks and reduced body weight through 35 weeks. In addition, Gentle et al. (1982) found that beak trimmed chickens were less efficient in being able to grasp pellets after trimming, thus requiring more pecking activity to ingest an equivalent amount of feed
as compared to mash. Persyn et al. (2004) also noted beak trimming in laying hens led to particle size separation with feeding. No similar type research with turkeys could be found in the literature.

In one study by Cunningham et al. (1992), behavior was categorized relative to time spent on different behaviors — feeding, drinking, sleeping, and huddling. Beak trimming was found to decrease feeding and drinking activity in hen poults and increase sleeping and huddling activity in both hen and tom poults in comparison to untrimmed controls. Deaton et al. (1987) found that day-old laying pullets with their top beak hot blade trimmed and a full block retrim at 70 days of age fed pellet or mash had significantly different feeding behaviors. The pellet-fed birds ate significantly less food per day than the mash birds, and the pellet birds lost weight while the mash birds gained weight. A second trial used three methods of retrim, being top beak only, full block trim, or no second trim. Feed consumption for pellet vs. mash birds was dependent upon trim type. Weight change for pellet vs. mash was also significantly different, with pellet trimmed being the same, and all others being the same. They concluded that feeding pellets to three-fourths or fully trimmed birds prior to 12 weeks of age can have disastrous effects on the birds’ productivity. However, feeding pellets to pullets after 12 weeks of age that had been trimmed at day old had no adverse effect on feed intake or body weight gain.

**Previous uses of methodology**

The studies presented in this thesis measure the welfare of caged layers at different stocking densities and of turkeys subjected to different beak trimming methods and feed forms using a technique to quantify feeding behavior, validating the information with video imaging. This method has proven to be successful in several past studies.
Xin and Ikeguchi developed a measurement system and analysis protocols to quantify feeding behavior of individual poultry. The system consists of electronic balances for measuring feed weight and accelerometers for quantifying head movement. Analog outputs from the instruments were stored and analyzed to determine feeding parameters including meal size, meal duration, meal interval, feed ingestion rate, daily feeding time, and daily feed intake. These techniques were developed to quantify feeding behavior responses of poultry to biophysical factors such as light, ration, noise, and thermal variables (Xin and Ikeguchi, 2001).

Gates and Xin developed and tested algorithms for determining individual feeding statistics and pecking behavior from time-series recordings of feed weight. Two separate experiments were conducted using broilers and laying hens, and the results were compared with video observations. This experiment was a successful effort to replace video imaging as a means for recording feeding and pecking behavior, which is time-consuming and prone to human error, with an automated system of data acquisition (Gates and Xin, 2001). Puma et al. developed an instrumentation system to study dynamic feeding and drinking behavior of individual birds. They planned for the system to be used in subsequent studies to investigate the effects of environmental and dietary manipulations on ingestion behavior and poultry performance (Puma et al., 2001).

Persyn et al. used the measurement system and computational algorithm developed by Xin and Ikeguchi (2001) to quantify feeding behavior in a study of the effects of beak trimming on laying hens and pullets (Persyn et al., 2003; Persyn et al., 2004).
References


CHAPTER 2. EVALUATING EFFECTS OF CAGE STOCKING DENSITY ON FEEDING BEHAVIORS OF GROUP-HOUSED LAYING HENS

A paper to be submitted to the Transactions of ASAE

R. N. Cook, H. Xin, D. Nettleton

The authors are Rachel N. Cook, EIT, ASAE Member, Graduate Research Assistant, Agricultural and Biosystems Engineering Department, Iowa State University, Ames, IA. Hongwei Xin, Ph.D., ASAE Member Engineer, Professor, Agricultural and Biosystems Engineering Department, Iowa State University, Ames, Iowa. Dan Nettleton, Ph.D., Associate Professor, Department of Statistics and Statistical Laboratory, Iowa State University, Ames, IA. Corresponding author: Hongwei Xin, 3204 NSRIC, Iowa State University, Ames, IA 50011-3310; phone: 515-294-4240; fax: 515-494-4250; e-mail: <hxin@iastate.edu> Mention of vendor or product names is for presentation clarity and does not imply endorsement by the authors or their institutions, or exclusion of other suitable products.

Abstract

Although quantification of animal welfare continues to be a challenging task for both the animal agriculture industry and the scientific community, characterization of feeding behavior has been shown to be a good indicator of animal welfare. This study quantifies the effects of cage stocking density (348, 387, 426, and 465 cm² cage floor space per hen; 54, 60, 66, and 72 in² cage floor space per hen) on the feeding behavior of W-36 White Leghorn laying hens. Feeding behavior was characterized using a specialized instrumentation system and computational algorithm for each cage of six hens during four (24-hen) trials. Statistics showed no significant difference among the stocking densities under thermoneutral conditions with regard to daily feed intake (97-101 g/hen, p=0.37), hen-hours spent feeding per cage (17.8-24.0 hen-hours/day, p=0.32), average daily feeding time per hen (3.0-4.0 h/day, p=0.32), number of meals ingested per day per cage (117-181 meals/day, p=0.18), meal size (1.6-2.6 g/meal-hen, p=0.09), average meal duration (174-258 sec/meal, p=0.40), ingestion rate (0.47-0.77 g/min-hen, p=0.06), and number of hens feeding per meal (1.9-2.0 hens/meal, p=0.72). Other characteristics measured and reported include simultaneous...
feeding behaviors and diurnal group feeding patterns. Quantification of specific responses such as feeding behavior to potential stressors (i.e. cage stocking density) may yield better housing design and management decisions based upon scientific data to improve animal welfare. **Keywords.** animal welfare, ingestion, poultry housing

**Introduction**

The issue of farm animal welfare or well-being continues to be a controversy both in the United States and abroad. Outcry from animal rights groups has focused the public eye on the animal production industry, resulting in the implementation of regulations meant to improve animal welfare with meager scientific evidence. The animal welfare debate has spawned governmental actions in Europe, and the issue has been brought to the fore in the US by recent minimum welfare standards imposed by private companies such as McDonald's. International pressures have also increased US interest in these issues, such as the European Union's request that animal welfare be included in future international trade talks (Estevez, 2003).

Cage floor space requirements for layers have been described as "the basis of more research than any other cage management factor" (Bell and Weaver, 2002). But how do we measure the impacts of stocking density on the welfare of caged layers in a truly scientific manner? One specific indicator of stress or welfare in poultry is feeding behavior. Continuous, automated measurement of feeding behavior has proven to be a useful tool for differentiating and quantifying the impacts of different environments or management practices on poultry. At the same time, this method has proven to be less time consuming, tedious, costly, and error-prone than direct human observation or video analysis (Gates and Xin, 2001; Persyn, et al., 2002, 2003, 2004; Puma et al., 2001; Xin and Ikeguchi, 2001; Xin
et al., 2002). Using this method allows an objective, quantitative, and non-invasive means of measuring an indicator of animal welfare.

The guidelines established in 2000 by the United Egg Producers (UEP) and McDonald’s made a significant impact on the housing and husbandry of laying hens (Armstrong and Pajor, 2001). The UEP guidelines call for cage floor space per hen to increase from the US industry standard of 348 cm\(^2\) (54 in\(^2\)) per bird to a range of 432 to 555 cm\(^2\) (67 to 86 in\(^2\)) (UEP, 2000). McDonald’s Recommended Welfare Practices call for 465 cm\(^2\) (72 in\(^2\)) of floor space per bird (McDonald’s, 2000). These new recommendations are similar to those of the European Union, which require 452 cm\(^2\) (70 in\(^2\)) per hen (Hy-Line, 2000).

As a result of her studies, Dawkins (1999) asserts that there are no universal indicators of poultry welfare, and proposes that researchers investigate specific responses of poultry to particular situations. Previous studies on cage space have focused on many possible indicators of animal welfare and methods of measurement (Carmichael et al., 1998; Dawkins, 1981; Dawkins and Hardie, 1989; Goodling et al., 1984; Hann and Harvey, 1971; Mench et al., 1986; Nichol, 1987; Patterson and Siegel, 1998; Roush and Cravener, 1990).

Xin and Ikeguchi (2001) developed a measurement system and analysis protocols to quantify feeding behavior of individual poultry in order to study effects of biophysical factors such as light, ration, noise, and thermal variables. Gates and Xin (2001) developed and tested algorithms for determining individual feeding statistics and pecking behavior from time-series recordings of feed weight. Puma et al. (2001) developed an instrumentation system to study dynamic feeding and drinking behaviors of individual birds. The system was used to investigate the effects of drinking water temperature on ingestion behavior and
performance of laying hens subjected to heat challenge (Xin et al., 2002). Persyn et al. (2002, 2003, 2004) used the measurement system and computational algorithm developed by Xin and Ikeguchi (2001) to quantify feeding behaviors of pullets and laying hens with or without beak trimming.

The objectives of this research were a) to adapt and expand the feeding behavior measurement system and analytical algorithm used by Persyn et al. (2002, 2003, 2004) from individual bird measurement only to also include measurements for group-housed birds, and b) to investigate the effects of cage stocking density on the feeding behavior of group-housed laying hens.

Materials and Methods

Equipment and Setup

This study was conducted in environmentally controlled testing rooms (4.6L x 2.7W x 2.6H m; 15L x 9W x 8.5H ft) at the Livestock Environment and Animal Physiology (LEAP) Lab II at Iowa State University. Environmental conditions in the rooms were monitored and recorded every one minute using portable data loggers (HOBO H8 Pro Series RH/Temp. Onset Computer Corp., Pocasset, MA, USA). Conditions were maintained at an average temperature of 22.7°C (72.8°F) and relative humidity between 45-60%. Minimum ventilation rate was used in the rooms. Fluorescent illumination at 10 lux (1.0 fc) throughout the rooms was provided for a 16-hour lighting period each day (5:30 AM to 9:30 PM). Room lighting values were checked periodically using a digital light meter (model DLM2, Cole Parmer Instrument Company, Vernon Hills, IL, USA).

The testing room held four cages with a stocking density of 348 cm² (54 in²) per bird (SD54), 387 cm² (60 in²) per bird (SD60), 426 cm² (66 in²) per bird (SD66), or 465 cm² (72
in$^2$) per bird (SD72). All cages were constructed to have the same depth of 46 cm (18 in) and same height of 40.6 cm (16 in). The width determined the difference among the cages, being 46, 51, 56, and 61 cm (18, 20, 22, 24 in), respectively, for the SD54, SD60, SD66, and SD72 cages. This variation in width led to a feeder space of 7.6, 8.4, 9.4, and 10.2 cm (3, 3.3, 3.7, and 4 in) per hen for the SD54, SD60, SD66, SD72 cages, respectively.

Each cage holding six hens was equipped with two nipple drinkers and a feed trough spanning the front width of the cage. Each feed trough rested across two electronic balances (2200 ± 0.1 g, model GX 2000, A&D Company Limited, Tokyo, Japan) with the base secured to the balances with Velcro strips. The balances had automatic response adjustment to compensate for vibration and drafts, with an analog output of 0-2.2 VDC corresponding to the weighing capacity. The eight balances were connected to an electronic data logger (model CR10X, Campbell Scientific Inc., Logan, UT, USA).

Six access openings were available for feeding across the front of each cage, with each opening equipped with an infrared (IR) sensor pair to detect the presence of a hen eating at that particular location. This setup allowed the recording of the number of hens feeding at any given time. These sensor pairs consisted of an IR light emitting diode (LED) (model OP165A, Optek Technology, Inc., Carrollton, TX, USA) below the opening and an IR phototransistor (model OP505A, Optek Technology, Inc., Carrollton, TX, USA) above the opening (See Figure 1 for IR sensor circuit diagram.) The 24 pairs of IR sensors were connected to the CR10X datalogger via a 32-channel multiplexer (model AM416, Campbell Scientific, Inc., Logan, UT, USA) with an output between 0-2.5 VDC. Data from both the balances and from the IR sensor pairs were recorded every two seconds. The data were
automatically downloaded to a computer every ten minutes via the datalogger’s associated PC208W software, and the files were retrieved and saved once every 24 hours.

One video camera (Panasonic wv-CP410) was mounted directly above each cage. The images from the four cameras were recorded during the lighting hours using a time-lapse videocassette recorder (model AG-6730, Panasonic, set to 72 hr/tape recording mode) and were viewable on a color monitor simultaneously using a quad-system (model WJ-420, Panasonic). Real-time viewing allowed undisturbed monitoring of the birds from outside the testing room, and the recorded images were used to validate the data acquisition system and computational algorithm (See Figure 2 for photos of the experimental setup.)

**Experimental Hens**

The experimental hens were Hy-Line W-36 between 32-40 weeks of age and approximately 1.5 kg (3.3 lbs.) body weight at procurement. All experimental hens had been housed at 348 cm² (54 in²) cage floor space per bird at the farm. The hens were acclimated to their new environment in the testing room for at least four days before data collection began on a trial and lasted seven to nine days. Four days of stabilized feeding behavior data were analyzed from each replicate. Eggs were collected once each day during data collection. Feed troughs were refilled every other day with the same commercial diet the hens had been fed at the farm.

**Analysis of Feeding Characteristics**

Feeding behaviors of the laying hens and the effects of stocking density were evaluated by an analysis protocol adapted from that used by Xin and Ikeguchi (2001) and Persyn et al. (2002, 2003, 2004). The characterized feeding behaviors included average daily feed intake per hen, daily time spent feeding in hen-hours per cage and average hours per
hen, number of meals per day, meal size, meal duration, ingestion rate, average number of
hens feeding per meal, distribution of simultaneous feeding activity, and diurnal feeding
patterns. To obtain these values, the start and stop time of each feeding event had to be
determined as well as the recorded feeder weights at these moments. The feeder weight of
each cage was spanned over two balances and the sum of their recorded values yielded the
total feeder weight. A two-minute sample of feeding event signals is shown in Figure 3. The
IR sensor signals were used to determine the presence of a hen feeding at a particular feeder
opening. A high signal indicated the presence of a hen, with a high signal defined as any
reading within 5% of the maximum reading for a particular sensor. Based on review of the
video recordings, a hen fully obstructed the IR sensors to reach the feed trough, giving a full
high reading during feeding. The readings that are in-between a full high or low signal seem
to be a result of partial obstruction of the sensors during other activities, such as a hen
entering or exiting a feeder opening, tail feathers protruding from the opening when a hen
turns around, etc. A sample of IR sensor signals is shown in Figure 4.

Based on trial and error optimization, a threshold change in total feeder weight of 2
grams between two adjacent readings was chosen to signal a feeding event, allowing one
gram of variation in the signal from each balance during a period of no feeding activity. This
resulted in the feed intake values as determined from the algorithm being within 4% of the
values obtained from the feeder weights at the beginning and ending of day. A time span of
at least 16 seconds (8 readings) in which the feeder weight remained stable (<2 g in feeder
weight change) was used to define the breaks between feeding events. Due to the absence of
feeding activity during the dark hours of the day, the data from the dark period were
excluded from the analysis of the feeding characteristics. All of the analyses were conducted
on the pooled data from the four groups of birds with the exception of the SD54 cage. The loss of one bird in the SD54 cage during the first trial caused the change in stocking density and group size; thus, these data points were excluded from the analysis.

**Results and Discussion**

The feeding characteristics of the hens are summarized in Table 1, where the mean and standard errors are shown for each stocking density. The p-value shown corresponds to a mixed linear model analysis using SAS that included factors for the fixed effect of stocking density and the random effects of trial and day of data collection within each trial. A p-value of 0.05 or less would indicate a significant difference between the stocking densities for a parameter. From the data shown, it can be concluded that no significant differences could be detected among the stocking densities for any of the feeding behavior parameters recorded during these four trials.

Data reported by Persyn et al (2003, 2004) for individually housed hens at 77 weeks of age showed a mean daily feed intake value of 87.4 ± 6.3 g/hen for beak trimmed birds and a mean time spent feeding per day of 3.3 ± 0.4 hours per day. The group-housed hens in the current study tended to consume more feed and spend more time at the feeder. The hens in the current study were near their production peak; hence higher feed intake would be expected. Diurnal feeding patterns are shown in Figure 5, where anticipatory feeding before lights off was apparent. These points represent the percent of each hour spent feeding by a particular cage of hens throughout a 24-hour period, and were averaged over all the days of data collection. Simultaneous feeding behavior data are shown in Figure 6 as the percentage of total feeding time that different numbers of birds were present at the feeder for each cage. This information is useful to determine whether more birds tend to eat simultaneously if
space at the feeder is available. Inability to feed with the rest of the group due to lack of space at the feeder could be a stressor for the hens. Although feeder space in particular was not the focus of this study, the results indicate that the variation in feeder space did not have a statistically significant impact on the feeding behaviors studied.

Due to the relatively small number of trials and the missing data with the SD54 cage, some additional data analysis was conducted on the feeding characteristics to determine the precision obtained in the statistical analysis. If indeed there were differences among the stocking densities, the responses would be expected to be progressive in nature. For example, if daily feed intake were affected, intake for the SD54 cage might be 5% lower intake for the SD60 cage, which in turn might be 5% lower than that for the SD66 cage, and so on. Using these progressive differences as a model, a linear contrast was performed in SAS to estimate the slope of a line passing through the mean values for each feeding characteristic. This slope would indicate the effect of one additional square inch of space per hen on the response variable in question. The resulting estimated slopes are shown in Table 2, along with a 95% confidence interval for each estimate. All of these confidence intervals include zero because no overall statistical differences could be detected; thus the possibility of no effect cannot be ruled out. The confidence intervals are useful to see the range of possible values of the stocking density effect. For example, for the daily feed intake per hen in grams, the estimated effect is a 0.08 g/hen-day increase in feed intake for every additional square inch of space per hen. The confidence interval indicates that the effect could actually lie anywhere in the range of a decreased intake of 0.18 g/hen-day to an increased intake of 0.34 g/hen-day for each additional square inch of space per hen. These numbers translate to an estimated increased intake of 1.43 g/hen-day with a 95% CI range of -3.20 to 6.05 g/hen-day for the
maximum difference in stocking density studied, i.e. 18 additional in² per hen or 72 in²/hen versus 54 in²/hen. The magnitude of the effect on each feeding characteristic for 72 in²/hen versus 54 in²/hen is also shown in Table 2. Because no statistical differences could be detected, the confidence intervals allow us to consider whether or not differences of practical significance might exist at the extremes of the confidence interval range.

Conclusions

This study successfully adapted and expanded the previously used instrumentation system and computational algorithm from its single-bird measurements to group-housed birds. This experiment also investigated the effects of cage stocking density on the feeding behavior of group-housed laying hens. The data revealed no statistically significant differences for daily feeding behaviors of hens subjected to stocking density of 54, 60, 66, or 72 in² per hen. Hence, from the standpoint of feeding behavior as an animal welfare indicator, the stocking densities examined in this study did not compromise the hens' welfare under thermoneutral conditions.

Acknowledgements

The authors would like to thank Ham and Eggs, LLC for their cooperation in providing the experimental hens and feed. Funding for this research was provided in part by the multi-state research project NE-127 “Biophysical Models for Poultry Production” and by the Iowa Egg Council.
References


toe-clipping and stocking density on laying hen performance. *Poultry Science.*
63:1722-1731.


Des Moines, IA: Hy-Line International.


McDonald’s Corporation.

Baker. 1986. Effects of cage and floor pen management on behavior, production, and 

Nichol, C. J. 1987. Effect of cage height and area on the behaviour of hens housed in battery 

Patterson, P.H. and H.S. Siegel. 1998. Impact of cage density on pullet performance and 

laying hens with or without beak trimming. Transactions of the ASAE. 47(2): 591- 
596.


Table 1. Statistics of feeding characteristics for the four stocking densities of 348, 387, 426, and 465 cm² (54, 60, 66, 72 in²) per hen.

<table>
<thead>
<tr>
<th>Feeding Characteristic</th>
<th>SD54 Mean</th>
<th>SD54 SE</th>
<th>SD60 Mean</th>
<th>SD60 SE</th>
<th>SD66 Mean</th>
<th>SD66 SE</th>
<th>SD72 Mean</th>
<th>SD72 SE</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily feed intake per hen (g)</td>
<td>100</td>
<td>4</td>
<td>97</td>
<td>4</td>
<td>98</td>
<td>4</td>
<td>101</td>
<td>4</td>
<td>0.37</td>
</tr>
<tr>
<td>Daily hen-hours spent feeding per cage</td>
<td>24.0</td>
<td>2.8</td>
<td>17.8</td>
<td>2.4</td>
<td>22.0</td>
<td>2.4</td>
<td>18.8</td>
<td>2.4</td>
<td>0.32</td>
</tr>
<tr>
<td>Average daily feeding time per hen (hr/hen)</td>
<td>4.0</td>
<td>0.5</td>
<td>3.0</td>
<td>0.4</td>
<td>3.7</td>
<td>0.4</td>
<td>3.1</td>
<td>0.4</td>
<td>0.32</td>
</tr>
<tr>
<td>Number of meals per day per cage</td>
<td>144</td>
<td>22</td>
<td>181</td>
<td>22</td>
<td>170</td>
<td>22</td>
<td>117</td>
<td>22</td>
<td>0.18</td>
</tr>
<tr>
<td>Average meal size (g)</td>
<td>1.9</td>
<td>0.3</td>
<td>1.9</td>
<td>0.3</td>
<td>1.6</td>
<td>0.3</td>
<td>2.6</td>
<td>0.3</td>
<td>0.09</td>
</tr>
<tr>
<td>Average meal duration (sec/meal)</td>
<td>258</td>
<td>39</td>
<td>174</td>
<td>39</td>
<td>198</td>
<td>39</td>
<td>220</td>
<td>39</td>
<td>0.40</td>
</tr>
<tr>
<td>Average ingestion rate (g/min-hen)</td>
<td>0.47</td>
<td>0.0</td>
<td>0.63</td>
<td>0.0</td>
<td>0.50</td>
<td>0.0</td>
<td>0.77</td>
<td>0.0</td>
<td>0.06</td>
</tr>
<tr>
<td>Average number of hens feeding per meal</td>
<td>2.0</td>
<td>0.1</td>
<td>1.9</td>
<td>0.1</td>
<td>1.9</td>
<td>0.1</td>
<td>2.0</td>
<td>0.1</td>
<td>0.72</td>
</tr>
</tbody>
</table>

Table 2. Estimates of stocking density (SD) effect on feeding characteristics per additional square inch of space per hen and for 18 additional square inches per hen (the maximum SD difference studied). 95% confidence intervals indicate the range of possible effects; all confidence intervals include zero indicating the possibility of no effect.

<table>
<thead>
<tr>
<th>Feeding Characteristic</th>
<th>SD effect per in² of additional space per hen</th>
<th>SD effect for 72 vs. 54 in² per hen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimated Effect (95% CI)</td>
<td>Estimated Effect (95% CI)</td>
</tr>
<tr>
<td>Daily feed intake per hen (g)</td>
<td>0.08 (-0.18, 0.34)</td>
<td>1.43 (-3.20, 6.05)</td>
</tr>
<tr>
<td>Daily hen-hours spent feeding per cage</td>
<td>-0.19 (-0.61, 0.23)</td>
<td>-3.38 (-10.93, 4.19)</td>
</tr>
<tr>
<td>Number of meals per day per cage</td>
<td>-1.5 (-5.2, 2.1)</td>
<td>-27.6 (-93.2, 37.9)</td>
</tr>
<tr>
<td>Average meal size (g)</td>
<td>0.029 (-0.017, 0.075)</td>
<td>0.529 (-0.300, 1.357)</td>
</tr>
<tr>
<td>Average meal duration (sec/meal)</td>
<td>-1.5 (-7.3, 4.3)</td>
<td>-27.2 (-131.4, 76.9)</td>
</tr>
<tr>
<td>Average ingestion rate (g/min-hen)</td>
<td>0.013 (-0.0001, 0.026)</td>
<td>0.233 (-0.001, 0.468)</td>
</tr>
<tr>
<td>Average number of hens feeding per meal</td>
<td>-0.004 (-0.021, 0.014)</td>
<td>-0.066 (-0.378, 0.245)</td>
</tr>
</tbody>
</table>
Figure 1. Circuit diagram of infrared emitter detector pairs used to detect bird presence at a feeder opening.
Figure 2. Photo views of the experimental setup: testing room (A); close-up view of feeder access openings with IR sensor pairs above and below each opening (B); hens feeding through instrumented feeder openings (C); video display and recording system (D).
Figure 3. Two-minute time series of raw feeding event signals from the electronic balances of different stocking density (SD) indicating the dynamic feeder weight in grams.

Figure 4. Sample of two raw infrared sensor signals used to determine the presence of a hen at a particular feeder opening.
Figure 5. Diurnal feeding patterns of hens at four stocking densities (348, 387, 426, and 465 cm² per hen; 54, 60, 66, and 72 in² per hen). Chart displays average percent of time spent feeding in each hour. Based on averages from four days' feeding data from each group of 24 hens. Lighting schedule 16h light (5:30AM-9:30PM) and 8h dark (9:30PM-5:30AM). Data for SD54 Group 1 omitted due to mortality.

Figure 6. Distribution of simultaneous feeding behavior of hens under four stocking densities (348, 387, 426, and 465 cm² per hen; 54, 60, 66, and 72 in² per hen), expressed as the percentage of the total feeding time of the cage when a particular number of hens were at the feeder simultaneously. Standard error bars are shown. Based on pooled data from four replications except Group 1 SD54 cage data omitted due to mortality.
CHAPTER 3. EVALUATING EFFECTS OF BEAK TRIMMING METHODS AND FEED FORMS ON FEEDING BEHAVIORS OF TURKEY POULTS

A paper to be submitted to the Transactions of ASAE

R. N. Cook, H. Xin, S. L. Noll, D. Nettleton

The authors are Rachel N. Cook, EIT, ASAE Member, Graduate Research Assistant, Agricultural and Biosystems Engineering Department, Iowa State University, Ames, IA. Hongwei Xin, Ph.D., ASAE Member Engineer, Professor, Agricultural and Biosystems Engineering Department, Iowa State University, Ames, Iowa. Sally L. Noll, Ph.D., Professor, Department of Animal Science, University of Minnesota, St. Paul, Minnesota. Dan Nettleton, Ph.D., Associate Professor, Department of Statistics and Statistical Laboratory, Iowa State University, Ames, IA. Corresponding author: Hongwei Xin, 3204 NSRIC, Iowa State University, Ames, IA 50011-3310; phone: 515-294-4240; fax: 515-494-4250; e-mail: <hxin@iastate.edu> Mention of vendor or product names is for presentation clarity and does not imply endorsement by the authors or their institutions, or exclusion of other suitable products.

Abstract

Although quantification of animal welfare continues to be a challenging task for both the animal agriculture industry and the scientific community, characterization of feeding behavior has been shown to be a good indicator of animal welfare. This study quantifies the effects of beak trimming method (non-trimmed control, hot blade, electric arc, or infrared) and feed form (mash or crumble) on the feeding behaviors of Large White turkey poults to 21 days of age. Feeding behavior was characterized using a specialized instrumentation system and computational algorithm for each cage of six poults during four (48-poult) trials. Statistics reveal no significant difference among the eight treatments of beak trim method and feed form with regard to daily feed intake (42.89-45.81 g/poult), cumulative feed intake (528-561 g/poult), bird-hours spent feeding per cage (2.00-3.65 bird-hours/day), average daily feeding time per poult (0.36-0.64 h/day), ending body weight at 21 days of age (522-573 g), body weight gain from 0 to 7 days of age (92-106 g, for beak trim factor only), body weight gain from 8 to 14 days of age (85-136 g), body weight gain from 15 to 21 days of age (251-301 g), and overall weight gain during the study period from 0 to 21 days of age (449-
Other characteristics measured and reported include average daily feeding time per poult for days 9 and 20, simultaneous feeding behaviors, and daily group feeding patterns as influenced by beak trim method and feed form. Quantification of specific responses such as feeding behavior to potential stressors (i.e. beak trimming method and feed form) may yield better management decisions based upon scientific data to improve animal welfare.

**Keywords.** animal welfare, ingestion, poultry housing.

**Introduction**

Commercial market turkeys undergo beak trimming at the hatchery prior to placement on the farm. Beak trimming is conducted to decrease aggressive activities that result in feather picking and cannibalism leading to late mortality losses, especially in tom flocks grown to heavy weights. While the issue of farm animal welfare continues to be a controversy both in the United States and abroad, the practice of beak trimming turkey poultts may come under scrutiny by animal rights groups, private companies, and the public as has occurred with the laying hen industry. There is a perception that the beak trimming process results in more than just temporary distress. One concern is that beak trimming may interfere with normal feeding behavior due to a pain response or the inability to pick certain-sized feed particles.

Many studies have been conducted on chickens regarding beak trimming (Andrade and Carson, 1975; Cunningham et al. 1992; Deaton et al. 1987; Gentle et al., 1982; Gentle, 1986; Gentle and Breward, 1986; Gentle et al., 1990; Hughes and Gentle, 1995; Persyn et al. 2003, 2004). Research to date has been limited on the subject of beak trimming in turkeys. Much of the research has dealt with hot blade cutting of the upper beak, which has been associated with blood loss, stress and early poult mortality. Newer methods of beak
trimming include electric arc and infrared, which kill tissue resulting in loss of the beak tip at about one week of age, followed by a healing process. However, no work to date has focused on determining whether these procedures are less stressful than hot blade trimming, and how much influence the healing process has on feed intake and bird performance.

Turkey performance (weight gain and feed conversion) is greatly affected by the form of feed (mash vs. pellets). Some of the response may be due to an influence of particle size on feed intake. Nixey (1989) has long promoted starting poults on crumble as opposed to mash feed. Cunningham's (1992) review on beak trimming in chickens concluded that properly performed beak trimming was effective in reducing mortality in flocks while having little or no effect on other production parameters. The most consistent positive production effect noted in the literature for beak trimming in turkeys was an improvement in feed conversion when turkeys were beak trimmed (Cunningham et al., 1992; Noble et al., 1994).

Noble and Nestor (1997) demonstrated less feed wastage in large-bodied turkeys but not medium-sized turkeys with no effect on feed conversion. Noble et al. (1994) noted reduced feed intake in beak-trimmed turkeys less than 8 weeks of age. Cunningham et al. (1992) and Denbow et al. (1984) found reduced mortality with trimmed males. Noble et al. (1994) found that injuries were greater with birds with intact beaks in one of two strains of turkeys, which also correlated with mortality and culling rates. However, Renner et al. (1989) found that severe arc beak trimming resulted in greater poult mortality than hot blade trimming at 11 days of age, but a comparison to an untrimmed control was not made. The above results suggest a similar conclusion to Cunningham's (1992), being that positive benefits have been shown as a result of beak trimming but these are not consistent from study to study, and improper beak trimming can have devastating effects on poult mortality. A
study by Gentle et al. (1995) on behavior and potential pain associated with beak trimming in turkeys found no evidence of neuroma formation (a mass of nerve tissue growing from the severed nerves) as has been seen with chickens, perhaps because turkeys are beak trimmed as young birds. Results of this study indicate that beak trimming in turkeys has fewer negatives associated with the process.

Continuous, automated measurement of feeding behavior has proven to be a useful tool for differentiating and quantifying the impacts of different environments or management practices on poultry. At the same time, this method has proven to be less time consuming, tedious, costly, and error-prone than direct human observation or video analysis (Gates and Xin, 2001; Persyn, et al., 2003, 2004; Puma et al., 2001; Xin and Ikeguchi, 2001; Xin et al., 2002). Using this method allows an objective, quantitative, and non-invasive means of measuring an indicator of animal welfare. The objective of this research was to investigate the effects of beak trimming method (non-trimmed control, hot blade, electric arc, or infrared) and feed form (mash or crumble) on the feeding behavior of turkey poults from 8 to 21 days of age.

**Materials and Methods**

**Equipment and Setup**

This study was conducted in environmentally controlled testing rooms (4.6L x 2.7W x 2.6H m; 15L x 9W x 8.5H ft) at the Livestock Environment and Animal Physiology (LEAP) Lab II at Iowa State University. Environmental conditions in the rooms were monitored and recorded every one minute using portable data loggers (HOBO H8 Pro Series RH/Tem. Onset Computer Corp., Pocasset, MA, USA). The following temperature set points were scheduled in the laboratory during the study period: seven days of age – 35°C
(95°F), 8-14 days of age – 33.3°C (92°F), and 15-21 days of age – 30°C (86°F). Fluorescent illumination at 10 lux (1.0 fc) throughout the rooms was provided for an intermittent lighting schedule of 2 hours light – 4 hours dark. Room lighting values were checked at the beginning of the study using a digital light meter (model DLM2, Cole Parmer Instrument Company, Vernon Hills, IL, USA).

The testing room held ten cages, each measuring 40.6 cm (16 in) H x 46 cm (18 in) W x 46 cm (18 in) D. Eight cages were instrumented for data collection, and the remaining two cages held spare poults. The eight treatments were randomly assigned to the test cages for each trial in a full factorial design, with each treatment consisting of a trim type and feed form combination.

Each cage holding six poults was equipped with one nipple drinker and a feed trough spanning the front width of the cage. Each feed trough rested across an electronic balance (2200 ± 0.1 g, model GX 2000, A&D Company Limited, Tokyo, Japan) with the base secured to the balance with Velcro strips. The balances had automatic response adjustment to compensate for vibration and drafts, with an analog output of 0-2.2 VDC corresponding to the weighing capacity. The eight balances were connected to an electronic data logger (model CR10X, Campbell Scientific Inc., Logan, UT, USA).

Six access openings were available for feeding across the front of each cage, with each opening equipped with an infrared (IR) sensor pair to detect the presence of a poult eating at that particular location. This setup allowed the recording of the number of poults feeding at any given time. These sensor pairs consisted of an IR light emitting diode (LED) (model OP165A, Optek Technology, Inc., Carrollton, TX, USA) below the opening and an IR phototransistor (model OP505A, Optek Technology, Inc., Carrollton, TX, USA) above the
opening. (See Figure 1 for IR sensor circuit diagram.) The 48 pairs of IR sensors were connected to the CR10X datalogger via a multiplexer (model AM416, Campbell Scientific, Inc., Logan, UT, USA) with an output between 0-2.5 VDC. Data from both the balances and from the IR sensor pairs were recorded every two seconds. The data were automatically downloaded to a computer every ten minutes via the datalogger’s associated PC208W software, and the files were retrieved and saved once every 24 hours.

Four video cameras (Panasonic wv-CP410) were mounted in the testing room to capture images of all ten cages. The images from the four cameras were recorded using a time-lapse videocassette recorder (model AG-6730, Panasonic, set to 72 hr/tape recording mode) and were viewable on a color monitor simultaneously using a quad-system (model WJ-420, Panasonic). Real-time viewing allowed undisturbed monitoring of the birds from outside the testing room, and the recorded images were used to validate the data acquisition system and computational algorithm (see Figure 2 for photos of the experimental setup).

**Experimental Poultst**

The experimental poultst were commercial Large White male turkeys group-weighed by beak type on the day of hatch (day zero) with an average body weight of about 60 g (0.03 lbs). The poultst were beak trimmed in four groups at the hatchery: non-trimmed control, hot blade, electric arc, or infrared. Figure 3 shows photos of the beaks subjected to the different trim types at three weeks of age. The poultst were housed at the ISU Poultry Research Center in pens separated by beak trim type for the first seven days. During the first week, the poultst were not separated by feed form and all were fed the same diet. At seven days of age, the poultst were transferred to the LEAP Lab II and assigned to test cages. Data collection was continuous and lasted for two weeks, from 8 to 21 days of age. Feed troughs were refilled.
every other day during data collection. A commercial turkey prestarter feed was used for both the mash and crumble diets (see Table 1 for feed label composition). Group-weights were obtained by beak type and feed form treatment group on day seven, day 14, and day 21. The poult were also weighed individually on day 21.

**Analysis of Feeding Characteristics**

Feeding behaviors of the turkey poult and the effects of beak trim type and feed form were evaluated by an analysis protocol adapted from that used by Xin and Ikeguchi (2001), Persyn et al. (2003, 2004). The characterized feeding behaviors included average daily feed intake per poult, daily time spent feeding in hen-hours per cage and average hours per poult, distribution of simultaneous feeding activity, and daily feeding patterns relative to the intermittent lighting schedule. To obtain these values, the start and stop time of each feeding event was determined. A twelve hour sample of feeding event signals from the eight balances is shown in Figure 4. The IR sensor signals were used to determine the presence of a poult feeding at a particular feeder opening. A high signal indicated the presence of a poult, with a high signal generally defined as any reading within 10% of the maximum reading for a particular sensor. The 10% value was manually adjusted for some sensors as needed after reviewing the responses. Based on review of the video recordings, a poult fully obstructed the IR sensors to reach the feed trough, giving a full high reading during feeding. The readings that are in-between a full high or low signal seem to be a result of partial obstruction of the sensors during other activities, such as a poult entering or exiting a feeder opening to eat, a poult quickly putting its head through the opening and pulling it back without feeding, etc. A twelve-hour sample of IR sensor signals is shown in Figure 5.
Based on trial and error optimization, a threshold change in total feeder weight of >1 gram between two adjacent readings was chosen to signal a feeding event, allowing one gram of variation in the signal from each balance during a period of no feeding activity. A time span of at least 16 seconds (8 readings) in which the feeder weight remained stable (<1 g in feeder weight change) was used to define the breaks between feeding events. All of the analyses were conducted on the pooled data from the four groups of birds. Data was collected continuously, but where poult mortality or instrumentation problems occurred, a full day (24 hours) of data was removed from the dataset for the particular balance in question.

A mixed model analysis was conducted in SAS that included factors for the fixed effects of beak trim type, feed form, and bird age, and the random effect of trial. Bird age was implemented as a repeated measure on the experimental unit which was a beak trim type/feedform/trial combination. For body weight and weight gain measures, a mixed model analysis was also conducted including the fixed effects of beak trim type and feed form where appropriate and the random effect of trial. Data for daily bird-hours spent feeding per cage and average daily feeding time per poult were square-root transformed to obtain approximately equal variances for the analysis. The p-values presented are based on this transformed data; however, for clarity the estimated times and standard errors are presented in their original form. A p-value of 0.05 or less would indicate a significant effect of the factor on a response variable.

**Results and Discussion**

Table 2 displays p-values corresponding to the effects of trim type, feed form, and trim type by feed form interaction. The feeding characteristics and body weight
measurements of the poults are summarized in Table 3, where the mean and standard errors are shown for each treatment combination of beak trim type and feed form. Table 4 indicates the mean and standard error values averaged across feed forms for each trim type and averaged across trim types for each feed form. From the data shown, it can be concluded that no significant differences exist among the treatments as a result of trim type, feed form, or trim type by feed form interactions for the feeding behavior characteristics and body weights recorded during these four trials.

Figure 6 displays average daily feed intake per poult in grams throughout the study period for each treatment combination of trim type and feed form. Figure 7 displays average daily feed intake per poult by beak trim type averaged over the feed forms, and Figure 8 displays daily feed intake data by feed form averaged over the beak trim types. Daily feeding patterns for each treatment are shown in Figure 9, where feeding activity is clearly correlated with the four-hour off, two-hour on lighting schedule. Figure 10 displays the feeding patterns by beak trim type averaged over the feed forms, and Figure 11 displays the feeding patterns by feed form averaged over beak trim type. These points represent the percent of each hour spent feeding by each cage of poults throughout a 24-hour period averaged over all the days of data collection. Simultaneous feeding behavior data for each treatment group are shown in Figure 12 as the percentage of total feeding time that different numbers of birds were present at the feeder for each cage. This simultaneous feeding data represents the entire study period. Data for weeks two and three were also reviewed separately, but no differing trends could be detected at these different bird ages.

It is acknowledged that the cage system used to conduct this study does not represent common rearing practices. The cage environment itself, the wire floor, and the nipple
drinkers may all have some effect on the responses and behaviors of the poults as compared to a typical littered floor pen system. However in this case, housing the poults in cages in the laboratory allowed the use of the specialized feeding behavior monitoring system, which provides information that could not readily be obtained from a larger-scale pen system.

**Conclusion**

This experiment investigated the effects of beak trim method (non-trimmed control, hot blade, electric arc, infrared) and feed form (mash, crumble) on the feeding behavior of turkey poults from 8-21 days of age. The data revealed that daily feeding behaviors and body weight measures of poults subjected to all combinations of beak trim method and feed form were not significantly different. Hence, from the standpoint of feeding behavior as an animal welfare indicator, the beak trimming methods and feed forms examined in this study did not compromise the poults' welfare by restricting their ability to feed normally.

**Acknowledgements**

Funding for this research was provided in part by the U. S. Poultry and Egg Association and by multi-state research project NE-1022 “Biophysical Models for Poultry Production”.

**References**


Table 1. Composition of commercial turkey prestarter, the diet used for both mash and crumble feed forms in the study. This diet is recommended for use on birds aged 0-5 weeks.

<table>
<thead>
<tr>
<th>Component</th>
<th>%</th>
<th>Component</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude Protein, min</td>
<td>27</td>
<td>Calcium (Ca), min.</td>
<td>1.1</td>
</tr>
<tr>
<td>Lysine, min.</td>
<td>1.7</td>
<td>Calcium (Ca), max.</td>
<td>1.6</td>
</tr>
<tr>
<td>Methionine, min.</td>
<td>0.6</td>
<td>Phosphorus (P), min.</td>
<td>1.0</td>
</tr>
<tr>
<td>Crude fat, min.</td>
<td>2.5</td>
<td>Salt (NaCl), min.</td>
<td>0.1</td>
</tr>
<tr>
<td>Crude Fiber, max.</td>
<td>6.0</td>
<td>Salt (NaCl), max.</td>
<td>0.6</td>
</tr>
<tr>
<td>Bacitracin Methylene</td>
<td></td>
<td>Disalicylate</td>
<td>50 g/ton</td>
</tr>
</tbody>
</table>

Table 2. P-values for effects of beak trim type, feed form, and trim type by feed form interactions on feeding characteristics for the four groups of 48 pouls subjected to eight treatment combinations of beak trim method (non-trimmed control - C, hot blade - HB, electric arc - EA, or infrared - IR) and feed form (mash or crumble). Statistics show no significant differences between treatments.

<table>
<thead>
<tr>
<th>Feeding Characteristic</th>
<th>Trimtype</th>
<th>Feedform</th>
<th>Trimtype*Feedform interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily feed intake per poult, g</td>
<td>0.61</td>
<td>0.56</td>
<td>0.97</td>
</tr>
<tr>
<td>Cumulative feed intake per poult, g (9-20 days age)</td>
<td>0.73</td>
<td>0.90</td>
<td>0.89</td>
</tr>
<tr>
<td>Daily bird-hours spent feeding per cage</td>
<td>0.66</td>
<td>0.23</td>
<td>0.54</td>
</tr>
<tr>
<td>Average daily feeding time per poult, hr/poult-d</td>
<td>0.59</td>
<td>0.31</td>
<td>0.46</td>
</tr>
<tr>
<td>Ending weight (21 days), g</td>
<td>0.71</td>
<td>0.76</td>
<td>0.86</td>
</tr>
<tr>
<td>*Weight gain 0-7 days, g</td>
<td>0.11</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Weight gain 8-14 days, g</td>
<td>0.68</td>
<td>0.96</td>
<td>0.27</td>
</tr>
<tr>
<td>Weight gain 15-21 days, g</td>
<td>0.39</td>
<td>0.58</td>
<td>0.29</td>
</tr>
<tr>
<td>*Weight gain 0-21 days, g</td>
<td>0.67</td>
<td>0.87</td>
<td>0.82</td>
</tr>
</tbody>
</table>

*Note that pouls in each replication were fed the same diet (not separated by feed form) during the first week of growth.
Table 3. Estimated means and standard error (in parentheses) for feeding characteristics and body weight gains for the four groups of 48 poults subjected to eight treatment combinations of beak trim method (non-trimmed control - C, hot blade - HB, electric arc - EA, or infrared - IR) and feed form (mash or crumble).

<table>
<thead>
<tr>
<th>Feeding Characteristic</th>
<th>Control</th>
<th>Hot Blade</th>
<th>Electric Arc</th>
<th>Infrared</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mash</td>
<td>Crumble</td>
<td>Mash</td>
<td>Crumble</td>
</tr>
<tr>
<td>Daily feed intake per poult, g (9-20 days age)</td>
<td>45.3 (2.17)</td>
<td>45.8 (2.17)</td>
<td>42.9 (1.87)</td>
<td>42.9 (1.87)</td>
</tr>
<tr>
<td></td>
<td>44.0 (1.87)</td>
<td>45.1 (1.88)</td>
<td>43.3 (1.86)</td>
<td>44.9 (1.86)</td>
</tr>
<tr>
<td>Cumulative feed intake per poult, g (9-20 days age)</td>
<td>576</td>
<td>546</td>
<td>518</td>
<td>537</td>
</tr>
<tr>
<td></td>
<td>553</td>
<td>564</td>
<td>545</td>
<td>531</td>
</tr>
<tr>
<td>Daily bird-hours spent feeding per cage (9-20 days age)</td>
<td>2.39 (0.81)</td>
<td>2.75 (0.81)</td>
<td>2.67 (0.70)</td>
<td>2.11 (0.70)</td>
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<tr>
<td></td>
<td>2.00 (0.75)</td>
<td>3.52 (0.70)</td>
<td>2.55 (0.70)</td>
<td>3.65 (0.70)</td>
</tr>
<tr>
<td>Avg. daily feeding time per poult, hr/poult-d, 9 days age</td>
<td>0.11 (0.19)</td>
<td>0.35 (0.19)</td>
<td>0.15 (0.16)</td>
<td>0.20 (0.16)</td>
</tr>
<tr>
<td></td>
<td>0.12 (0.16)</td>
<td>0.16 (0.16)</td>
<td>0.19 (0.16)</td>
<td>0.24 (0.16)</td>
</tr>
<tr>
<td>Avg. daily feeding time per poult, hr/poult-d, 20 days age</td>
<td>0.65 (0.18)</td>
<td>0.40 (0.18)</td>
<td>0.53 (0.16)</td>
<td>0.41 (0.16)</td>
</tr>
<tr>
<td></td>
<td>0.45 (0.15)</td>
<td>0.36 (0.15)</td>
<td>0.58 (0.15)</td>
<td>0.65 (0.15)</td>
</tr>
<tr>
<td>Avg. daily feeding time per poult, hr/poult-d (9-20 days age)</td>
<td>0.48 (0.14)</td>
<td>0.46 (0.14)</td>
<td>0.46 (0.12)</td>
<td>0.36 (0.12)</td>
</tr>
<tr>
<td></td>
<td>0.36 (0.12)</td>
<td>0.60 (0.13)</td>
<td>0.45 (0.12)</td>
<td>0.64 (0.12)</td>
</tr>
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<td>Starting weight, g (0 days age)</td>
<td>61 (2)</td>
<td>61 (2)</td>
<td>61 (2)</td>
<td>61 (2)</td>
</tr>
<tr>
<td>Ending weight, g (21 days age)</td>
<td>543 (35)</td>
<td>562 (35)</td>
<td>538 (30)</td>
<td>526 (30)</td>
</tr>
<tr>
<td></td>
<td>532 (30)</td>
<td>522 (30)</td>
<td>542 (30)</td>
<td>573 (30)</td>
</tr>
<tr>
<td>*Weight gain 0-7 days, g</td>
<td>106 (10)</td>
<td>106 (10)</td>
<td>97 (10)</td>
<td>97 (10)</td>
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<tr>
<td></td>
<td>92 (10)</td>
<td>128 (10)</td>
<td>85 (10)</td>
<td>128 (10)</td>
</tr>
<tr>
<td>Weight gain 8-14 days, g</td>
<td>92 (10)</td>
<td>128 (10)</td>
<td>85 (10)</td>
<td>128 (10)</td>
</tr>
<tr>
<td></td>
<td>116 (10)</td>
<td>119 (10)</td>
<td>116 (10)</td>
<td>136 (10)</td>
</tr>
<tr>
<td>Weight gain 15-21 days, g</td>
<td>301 (26)</td>
<td>259 (26)</td>
<td>251 (22)</td>
<td>269 (22)</td>
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<tr>
<td></td>
<td>282 (22)</td>
<td>298 (22)</td>
<td>298 (22)</td>
<td>298 (22)</td>
</tr>
<tr>
<td>*Weight gain 0-21 days, g</td>
<td>481 (37)</td>
<td>500 (37)</td>
<td>478 (32)</td>
<td>466 (32)</td>
</tr>
<tr>
<td></td>
<td>472 (32)</td>
<td>449 (32)</td>
<td>482 (32)</td>
<td>513 (32)</td>
</tr>
</tbody>
</table>

*Note that poults in each replication were fed the same diet (not separated by feed form) during the first week of growth.
Table 4. Estimated means and standard error (in parentheses) for feeding characteristics and body weight gains for four groups of 48 poults. Beak trim methods shown (non-trimmed control - C, hot blade - HB, electric arc - EA, or infrared - IR) are averaged over the two feed forms, and the feed forms shown (mash or crumble) are averaged for all beak trim methods.

<table>
<thead>
<tr>
<th>Feeding Characteristic</th>
<th>Control</th>
<th>Hot Blade</th>
<th>Electric Arc</th>
<th>Infrared</th>
<th>Mash</th>
<th>Crumble</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily feed intake per poult, g (9-20 days age)</td>
<td>45.6 (1.56)</td>
<td>42.9 (1.37)</td>
<td>44.6 (1.45)</td>
<td>44.1 (1.35)</td>
<td>43.9 (1.02)</td>
<td>44.7 (1.06)</td>
</tr>
<tr>
<td>Cumulative feed intake per poult, g (9-20 days age)</td>
<td>561 (29)</td>
<td>528 (25)</td>
<td>558 (20)</td>
<td>538 (20)</td>
<td>548 (16)</td>
<td>545 (16)</td>
</tr>
<tr>
<td>Daily bird-hours spent feeding per cage (9-20 days age)</td>
<td>2.57 (0.57)</td>
<td>2.39 (0.49)</td>
<td>2.76 (0.51)</td>
<td>3.10 (0.49)</td>
<td>2.40 (0.36)</td>
<td>3.01 (0.37)</td>
</tr>
<tr>
<td>Avg. daily feeding time per poult, hr/poult-d, 9 days age</td>
<td>0.23 (0.13)</td>
<td>0.18 (0.11)</td>
<td>0.14 (0.12)</td>
<td>0.16 (0.11)</td>
<td>0.12 (0.08)</td>
<td>0.24 (0.09)</td>
</tr>
<tr>
<td>Avg. daily feeding time per poult, hr/poult-d, 20 days age</td>
<td>0.53 (0.13)</td>
<td>0.47 (0.11)</td>
<td>0.40 (0.12)</td>
<td>0.62 (0.11)</td>
<td>0.55 (0.08)</td>
<td>0.46 (0.08)</td>
</tr>
<tr>
<td>Avg. daily feeding time per poult, hr/poult-d (9-20 days age)</td>
<td>0.48 (0.10)</td>
<td>0.41 (0.08)</td>
<td>0.48 (0.09)</td>
<td>0.54 (0.08)</td>
<td>0.44 (0.06)</td>
<td>0.52 (0.08)</td>
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<tr>
<td>Starting weight, g (0 days age)</td>
<td>61 (2)</td>
<td>61 (2)</td>
<td>60 (2)</td>
<td>61 (2)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ending weight, g (21 days age)</td>
<td>552 (25)</td>
<td>532 (21)</td>
<td>527 (22)</td>
<td>558 (21)</td>
<td>539 (16)</td>
<td>546 (16)</td>
</tr>
<tr>
<td>*Weight gain 0-7 days, g</td>
<td>106 (10)</td>
<td>97 (10)</td>
<td>92 (10)</td>
<td>98 (10)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Weight gain 7-14 days, g</td>
<td>110 (25)</td>
<td>107 (23)</td>
<td>122 (23)</td>
<td>127 (23)</td>
<td>117 (21)</td>
<td>116 (21)</td>
</tr>
<tr>
<td>Weight gain 14-21 days, g</td>
<td>280 (21)</td>
<td>260 (18)</td>
<td>290 (18)</td>
<td>283 (18)</td>
<td>274 (16)</td>
<td>282 (16)</td>
</tr>
<tr>
<td>*Weight gain 0-21 days, g</td>
<td>490 (26)</td>
<td>472 (23)</td>
<td>461 (23)</td>
<td>497 (23)</td>
<td>478 (17)</td>
<td>482 (17)</td>
</tr>
</tbody>
</table>

*Note that poults in each replication were fed the same diet (not separated by feed form) during the first week of growth.
Figure 1. Circuit diagram of infrared emitter detector pairs used to detect bird presence at a feeder opening.
Figure 2. Photo views of the experimental setup: floor pens used from days zero to six (A); view of crumble (top) versus mash (bottom) feed (B); poults feeding through instrumented feeder openings (C); close-up view of feeder access openings with IR sensor pairs above and below each opening (D).
Figure 3. Photos of two sample turkey beaks of each trim type at three weeks (21 days) of age: non-trimmed control (A, B); hot blade (C, D); electric arc (E, F) and infrared (G, H).

Figure 4. 12-hour time series example of raw feeding event signals from the electronic balances indicating the dynamic feeder weight in grams. Readings from the balances are recorded every two seconds.
Figure 5. Sample of two raw infrared sensor signals used to determine the presence of a poult at a particular feeder opening. Readings from the IR sensors are recorded every two seconds. A high signal for a given two-second reading indicates that a poult was present at that opening during the two-second interval.
Figure 6. Average daily and cumulative feed intake values for turkey poults subjected to four beak trim methods (non-trimmed control, hot blade, electric arc, or infrared) and two feed forms (mash or crumble). Based on averages from four replicates.
Figure 7. Average daily and cumulative feed intake values for turkey poults subjected to four beak trim methods (non-trimmed control, hot blade, electric arc, or infrared) averaged over the two feed forms. Based on averages from four replicates.
Figure 8. Average daily and cumulative feed intake values for turkey poults subjected to two feed forms (mash or crumble) averaged over the four beak trim methods. Based on averages from four replicates.

Figure 9. Daily feeding patterns of turkey poults subjected to four beak trim methods (non-trimmed control, hot blade, electric arc, or infrared) and two feed forms (mash or crumble). Chart displays average percent of time spent feeding in each hour. Based on averages from four replicates. Lighting schedule was intermittent 2h light and 4h dark.
Figure 10. Daily feeding patterns of turkey poults subjected to four beak trim methods (non-trimmed control, hot blade, electric arc, or infrared) averaged over two feed forms. Chart displays average percent of time spent feeding in each hour. Based on averages over the two feed forms for four replicates. Lighting schedule was intermittent 2h light and 4h dark.
Figure 11. Daily feeding patterns of turkey poults subject to two feed forms (mash or crumble) averaged over four beak trim methods. Chart displays average percent of time spent feeding in each hour. Based on averages over the beak trim methods for four replicates. Lighting schedule was intermittent 2h light and 4h dark.

Figure 12. Distribution of simultaneous feeding behavior of poults subjected to four beak trim methods (non-trimmed control, hot blade, electric arc, or infrared) and two feed forms (mash or crumble) expressed as the percentage of the total feeding time of the cage when a particular number of poults were at the feeder simultaneously. Standard error bars are shown. Based on pooled data from four replications.
CHAPTER 4. GENERAL CONCLUSIONS

Summary of Research

Animal welfare is a driving force behind evaluation of existing practices in the modern livestock industry, as well as for suggestions or requirements to change these practices. Science-based research is needed to quantify animal welfare to determine whether or not suggested changes will have any impacts on the well-being of livestock. This thesis presented two studies in the area of animal welfare research using continuous, automated monitoring of feeding behaviors as an indicator of animal well-being. The first study examined the effects of four cage stocking densities on the feeding behaviors of mature group-housed laying hens. The second study examined the effects of three beak trimming methods compared with non-trimmed controls and two feed forms on the feeding behaviors of turkey poults to 21 days of age. Quantification of specific responses such as feeding behavior to potential stressors (i.e. cage stocking density, beak trimming method, feed form) may yield better housing design and management decisions based upon scientific data to improve animal welfare.

The major finding of the first study concerning stocking density of laying hens was that no significant differences in hen feeding behaviors could be detected between the four stocking densities studied (54, 60, 66, and 72 in² per hen). Statistics showed no significant difference among the stocking densities under thermoneutral conditions with regard to daily feed intake (97-101 g/hen, p=0.37), hen-hours spent feeding per cage (17.8-24.0 hen-hours/day, p=0.32), average daily feeding time per hen (3.0-4.0 h/day, p=0.32), number of meals ingested per day per cage (117-181 meals/day, p=0.18), meal size (1.6-2.6 g/meal-hen, p=0.09), average meal duration (174-258 sec/meal, p=0.40), and ingestion rate (0.47-0.77...
g/min-hen, p=0.06). Other characteristics measured and reported included simultaneous feeding behaviors and diurnal group feeding patterns. As a result of cage dimension variation to obtain the stocking densities studied using six birds in each cage, the feeder space varied from 3 to 4 in. per hen. However, simultaneous feeding behavior data indicated that two birds eating simultaneously per meal was most common regardless of feeder space allowance (number of hens feeding per meal (1.9-2.0 hens/meal, p=0.72), with larger feeder spaces not appearing to encourage more birds to eat simultaneously. Feeding was strongly impacted by the lighting schedule (16 hours on, 8 hours off), with no feeding activity occurring during the dark hours of each day.

The second study focused on the effects of beak trimming method (non-trimmed control, hot blade, electric arc, or infrared) and feed form (mash or crumble) on the feeding behaviors of turkey poultls to 21 days of age. This study detected no significant differences between the eight treatment combinations with regard to daily feed intake (42.89-45.81 g/poult), cumulative feed intake (528-561 g/poult), bird-hours spent feeding per cage (2.00-3.65 bird-hours/day), average daily feeding time per poult (0.36-0.64 h/day), ending body weights at 21 days of age (522-573 g), body weight gain from 0-7 days of age (92-106 g), body weight gain from 7-14 days of age (85-136 g), body weight gain from 14-21 days of age (251-301 g), and overall weight gain during the study period from 0-21 days of age (449-513 g). Other characteristics measured and reported include average daily feeding time per poult for days 9 and 20, simultaneous feeding behaviors, and daily group feeding patterns as influenced by beak trim method and feed form.
Practical Implications and Recommendations for Future Research

Changing the stocking density of an entire house of animals can have many implications to the producer. Not only is the economic loss of housing fewer birds in the same space substantial, but other implications such as the possible need for adding supplemental heat in winter can be significant. This study could not detect any changes in feeding behaviors for the stocking densities studied, which may indicate that the bird welfare is not significantly affected by stocking density. However, before this conclusion can be drawn and put into practice, additional studies are needed. For example, research is needed to determine the responses at different temperatures to mimic the seasons of the year. Summer heat stress at higher stocking density or winter cold at lower stocking density may show a much different response than this study conducted at thermoneutral conditions. In addition, long-term, farm-scale studies are needed to delineate differences over the full production cycle. Differences may exist over the long term that could not be detected by short-term monitoring.

In both studies presented in this thesis, the birds were monitored in a group-housed setting. This is important to obtaining practical results as the group social order has a strong impact on behavior. However, group-housed measurement places a limitation on the study because individual behaviors cannot be delineated. It is suggested that a method for the data acquisition system to identify individual feeding activity be implemented in any future study of the same type. This would allow better quantification of feeding activity, as all of the response variables studied could be quantified for each individual bird, resulting in a solid dataset and allowing individual variation in behaviors to be evaluated.
The results of the turkey study provide some insight for the producer into choosing a beak trimming method for a flock. No significant differences in feeding behaviors or weight gains were detected, so a beak trim method can be chosen based on other factors. For example, re-growth of the beak can be a problem for birds that are trimmed by hot blade, causing a second trim to be necessary in some cases. Since re-growth of the beak does not seem to pose such a problem for the other two methods studied (electric arc and infrared), perhaps producers could consider these newer options with less concern about impacts on performance. Further study on beak trimming in turkeys is needed to determine the long-term effects on a flock, and the collaborators on this project at the University of Minnesota are currently working to help address these issues.

For further study of the turkey poults, it is suggested that a method for monitoring the poults from 0-7 days be devised. In this study, we determined that the cage system used presented too many challenges and was not appropriate for the birds at this age. The birds performed much better during the first week in the pens which had heat lamps available (allowing them to move in and out of the heat as they preferred) as opposed to the warm room brooding used in the laboratory’s cage system. In addition, some of the poults had difficulty reaching the feed trough from inside the cage during the first few days. The body proportions of the poults at this age also presented a challenge to find a feeder opening size that was appropriate. If the opening was made large enough for the poults to get their heads through to the feeder, most were then able to get their entire bodies through the opening and escape from the cages. Therefore, a system tailored to poults at this age is needed to obtain feeding behavior data for the critical first few days of life following beak trimming.
APPENDIX A. ADDITIONAL DATA FOR LAYING HEN STOCKING DENSITY STUDY

Sample Visual Basic code used for hen stocking density study data processing

Private Sub CommandButton1_Click()
'Calculate!! button. Does feeding event flags, meals and breaks, and feeder weight at meal start/stop.

'Feeding event flag button calculations

Dim colcounter As Single
Dim rowcounter As Single
Dim currweight As Variant
Dim lastweight As Variant

'initialize variables
colcounter = 48
rowcounter = 5

'Columns of interest are 48 through 51 Possible Feeding Event Flag
'check the value of this reading and the previous reading
'the the absolute value of the difference is greater than 2 grams, flag the
'possible feeding event
Worksheets("Data Light").Range("AV5:AY28801").ClearContents

For colcounter = 48 To 51
    For rowcounter = 5 To 28801
        currweight = Worksheets("Data Light").Cells(rowcounter, (colcounter - 4)).Value
        lastweight = Worksheets("Data Light").Cells((rowcounter - 1), (colcounter - 4)).Value
        If Abs(currweight - lastweight) > 2 Then
            Worksheets("Data Light").Cells(rowcounter, colcounter) = "feeding"
        Else
            Worksheets("Data Light").Cells(rowcounter, colcounter) = ""
        End If
    Worksheets("Data Light").Cells(1, 49) = rowcounter
    Worksheets("Data Light").Cells(1, 51) = colcounter
Next rowcounter
Next colcounter

'Meals & Breaks Button

'initialize variables
colcounter = 52: rowcounter = 5
Columns of interest are 52 to 55. True Meals/meal breaks
If there are 8 non feeding flags in a row, then show break, or
If the last row was a break and this row has no feeding flag, then show break, or
If the last row was a break and the next row has no feeding flag, then show break
Worksheets("Data Light").Range("AZ5:BC28801").ClearContents

For colcounter = 52 To 55
For rowcounter = 5 To 28801
If Worksheets("Data Light").Cells(rowcounter, (colcounter - 4)).Value = 
"" Then
    If Worksheets("Data Light").Cells((rowcounter + 1), (colcounter - 4)).Value = 
"" Then
        If Worksheets("Data Light").Cells((rowcounter + 2), (colcounter - 4)).Value = 
"" Then
            If Worksheets("Data Light").Cells((rowcounter + 3), (colcounter - 4)).Value = 
"" Then
                If Worksheets("Data Light").Cells((rowcounter + 4), (colcounter - 4)).Value = 
"" Then
                    If Worksheets("Data Light").Cells((rowcounter + 5), (colcounter - 4)).Value = 
""
                    Then
                        If Worksheets("Data Light").Cells((rowcounter + 6), (colcounter - 4)).Value =
""
                    Then
                        If Worksheets("Data Light").Cells((rowcounter + 7), (colcounter - 4)).Value =
""
                        Then
                            Worksheets("Data Light").Cells(rowcounter, colcounter) = "break"
                            End If
                        End If
                    End If
                End If
            End If
        End If
    End If
End If
Else
    If Worksheets("Data Light").Cells((rowcounter - 1), colcounter).Value = "break" Then
        If Worksheets("Data Light").Cells(rowcounter, (colcounter - 4)).Value = 
"" Then
            Worksheets("Data Light").Cells(rowcounter, colcounter) = "break"
        End If
    End If
End If
Else
    If Worksheets("Data Light").Cells((rowcounter - 1), colcounter).Value = "break" Then
        If Worksheets("Data Light").Cells((rowcounter + 1), (colcounter - 4)).Value = 
"" Then
            Worksheets("Data Light").Cells(rowcounter, colcounter) = "break"
        End If
    End If
End If
Worksheets("Data Light").Cells(1, 53) = rowcounter
Worksheets("Data Light").Cells(1, 55) = colcounter

Next rowcounter
Next colcounter

End Sub

Private Sub CommandButton2_Click()
    'Meal Size Calculator Button
    Dim rowcounter As Single
    Dim colcounter As Single
    Dim counter As Single
    Dim startrow As Single
    Dim endrow As Single
    Dim totalsec As Single
    Dim hensec As Single
    Dim TWAhens As Single
    Dim mealsize As Single

    'initialize variables
    rowcounter = 5: colcounter = 68:

    'Columns of colcounter are 68 to 71, labeled Meal Duration
    Worksheets("Data Light").Range("BP5:CA28801").ClearContents

    For colcounter = 68 To 71
        startrow = 0: endrow = 0: totalsec = 0.1: hensec = 0:
        counter = 0: TWAhens = 0: mealsize = 0

        For rowcounter = 5 To 28801
            'find the starting row of a meal
            If Worksheets("Data Light").Cells((rowcounter - 1), (colcounter - 16)).Value = "break" Then
                If Worksheets("Data Light").Cells(rowcounter, (colcounter - 16)).Value = "" Then
                    startrow = rowcounter
                    End If

            'find the ending row of a meal
            If Worksheets("Data Light").Cells(rowcounter, (colcounter - 16)).Value = "" Then
                endrow = rowcounter
            End If

End If

End Sub
End If

'when startrow and endrow are found, add up the two-second intervals to determine meal duration
If startrow > 0 Then
    If endrow > 0 Then
        totalsec = (endrow - startrow + 1) * 2

'add up the hen-seconds of feeding during the meal
For counter = startrow To endrow
    hensec = hensec + Worksheets("Data Light").Cells(counter, (colcounter - 4)).Value
Next counter

'calculate time weighted average number of hens feeding during the meal
If hensec > 0 Then
    TWAhens = hensec / totalsec

'calculate average meal size per hen for that meal
mealsize = (Worksheets("Data Light").Cells(startrow, (colcounter - 12)).Value - Worksheets("Data Light").Cells(endrow, (colcounter - 12)).Value) / TWAhens
If mealsize > 0 Then
    Worksheets("Data Light").Cells(rowcounter, colcounter) = totalsec
    Worksheets("Data Light").Cells(rowcounter, (colcounter + 4)) = TWAhens
    Worksheets("Data Light").Cells(rowcounter, (colcounter + 8)) = mealsize
End If
    totalsec = 0
End If
End If
End If

If totalsec = 0 Then
    startrow = 0
    endrow = 0
    totalsec = 0.1
    hensec = 0
End If

Worksheets("Data Light").Cells(1, 69) = rowcounter
Worksheets("Data Light").Cells(1, 71) = colcounter

Next rowcounter
Next colcounter

Dim nummeals As Single
Dim totaldur As Single
Dim numhens As Single
Dim totalmeal As Single
'initialize variables
nummeals = 0: totaldur = 0: numhens = 0: totalmeal = 0: avgduration = 0: avghens = 0:
avgsize = 0:

For colcounter = 68 To 71
For rowcounter = 5 To 28801
    If Worksheets("Data Light").Cells(rowcounter, colcounter).Value > 0 Then
        nummeals = nummeals + 1
        totaldur = totaldur + Worksheets("Data Light").Cells(rowcounter, colcounter).Value
        numhens = numhens + Worksheets("Data Light").Cells(rowcounter, (colcounter + 4)).Value
        totalmeal = totalmeal + Worksheets("Data Light").Cells(rowcounter, (colcounter + 8)).Value
    End If
Next rowcounter
avgduration = totaldur / nummeals
avghens = numhens / nummeals
avgsize = totalmeal / nummeals
Worksheets("Data Light").Cells(3, (colcounter + 14)) = nummeals
Worksheets("Data Light").Cells(4, (colcounter + 14)) = avgduration
Worksheets("Data Light").Cells(5, (colcounter + 14)) = avghens
Worksheets("Data Light").Cells(6, (colcounter + 14)) = avgsize
nummeals = 0: totaldur = 0: numhens = 0: totalmeal = 0: avgduration = 0: avghens = 0:
avgsize = 0:
Next colcounter
End Sub

Private Sub CommandButton3_Click()
'Feeder Weight Calculator Button
'calculates feeder weight at the beginning and ending of each meal

Dim weight1 As Single
Dim weight2 As Single
Dim weight3 As Single
Dim weight4 As Single
Dim weight5 As Single
Dim weight6 As Single
Dim weight7 As Single
Dim weight8 As Single
Dim begweight As Single
Dim endweight As Single
'initialize variables
rowcounter = 12: colcounter = 56: weight1 = 0: weight2 = 0: weight3 = 0: weight4 = 0:
weight5 = 0:
weight6 = 0: weight7 = 0: weight8 = 0: begweight = 0: endweight = 0

'Columns of interest are 56 to 59, Feeder weights at start/stop of each meal
'if it is the beginning of a meal, calculate the beginning weight by averaging the last eight
readings
'if it is the end of a meal, calculate the ending weight by averaging the next eight readings
Worksheets("Data Light").Range("BD12:BG28801").ClearContents

For colcounter = 56 To 59
begweight = 0: endweight = 0
For rowcounter = 12 To 28801
If Worksheets("Data Light").Cells(rowcounter, (colcounter - 4)).Value = "" Then
If Worksheets("Data Light").Cells((rowcounter - 1), (colcounter - 4)).Value = "break" Then
If begweight = 0 Then
weight1 = Worksheets("Data Light").Cells((rowcounter - 8), (colcounter - 12)).Value
weight2 = Worksheets("Data Light").Cells((rowcounter - 7), (colcounter - 12)).Value
weight3 = Worksheets("Data Light").Cells((rowcounter - 6), (colcounter - 12)).Value
weight4 = Worksheets("Data Light").Cells((rowcounter - 5), (colcounter - 12)).Value
weight5 = Worksheets("Data Light").Cells((rowcounter - 4), (colcounter - 12)).Value
weight6 = Worksheets("Data Light").Cells((rowcounter - 3), (colcounter - 12)).Value
weight7 = Worksheets("Data Light").Cells((rowcounter - 2), (colcounter - 12)).Value
weight8 = Worksheets("Data Light").Cells((rowcounter - 1), (colcounter - 12)).Value
begweight = ((weight1 + weight2 + weight3 + weight4 + weights + weight6 + weight7 + weight8) / 8)
Else:
begweight = endweight
End If
Worksheets("Data Light").Cells(rowcounter, colcounter) = begweight
End If
End If

If Worksheets("Data Light").Cells(rowcounter, (colcounter - 4)).Value = "" Then
If Worksheets("Data Light").Cells((rowcounter + 1), (colcounter - 4)).Value = "break" Then
weight1 = Worksheets("Data Light").Cells((rowcounter + 8), (colcounter - 12)).Value
weight2 = Worksheets("Data Light").Cells((rowcounter + 7), (colcounter - 12)).Value
weight3 = Worksheets("Data Light").Cells((rowcounter + 6), (colcounter - 12)).Value
weight4 = Worksheets("Data Light").Cells((rowcounter + 5), (colcounter - 12)).Value
weight5 = Worksheets("Data Light").Cells((rowcounter + 4), (colcounter - 12)).Value
weight6 = Worksheets("Data Light").Cells((rowcounter + 3), (colcounter - 12)).Value
weight7 = Worksheets("Data Light").Cells((rowcounter + 2), (colcounter - 12)).Value
weight8 = Worksheets("Data Light").Cells((rowcounter + 1), (colcounter - 12)).Value
endweight = (weight1 + weight2 + weight3 + weight4 + weight5 + weight6 + weight7 + weight8) / 8
    If endweight > begweight Then
        endweight = begweight
    End If
    Worksheets("Data Light").Cells(rowcounter, colcounter) = endweight
End If
Worksheets("Data Light").Cells(1, 57) = rowcounter
Worksheets("Data Light").Cells(1, 59) = colcounter
Next rowcounter
Next colcounter
End Sub
APPENDIX B. ADDITIONAL DATA FOR TURKEY POULT BEAK TRIMMING METHOD AND FEED FORM STUDY

Sample Visual Basic code used for turkey beak trimming/feed form study data processing

Private Sub CommandButton1_Click()
 'Calculate!! button. Does feeding event flags, meals and breaks, and feeder weight at meal start/stop.

 'Feeding event flag button calculations

 Dim colcounter As Single
 Dim rowcounter As Single
 Dim currweight As Variant
 Dim lastweight As Variant

 'initialize variables
 colcounter = 68
 rowcounter = 5

 'Columns of interest are 68 through 75 Possible Feeding Event Flag
 'check the value of this reading and the previous reading
 'the the absolute value of the difference is greater than 2 grams, flag the
 'possible feeding event
 Worksheets("Midnight-Noon").Range("BP5:BW21603").ClearContents

 For colcounter = 68 To 75
  For rowcounter = 5 To 21603
   currweight = Worksheets("Midnight-Noon").Cells(rowcounter, (colcounter - 56)).Value
   lastweight = Worksheets("Midnight-Noon").Cells((rowcounter - 1), (colcounter - 56)).Value
   If Abs(currweight - lastweight) > 2 Then
    Worksheets("Midnight-Noon").Cells(rowcounter, colcounter) = "feeding"
   Else
    Worksheets("Midnight-Noon").Cells(rowcounter, colcounter) = ""
   End If
  Next rowcounter
 Next colcounter

 'Meals & Breaks Button
'initialize variables
colcounter = 76: rowcounter = 5

'Columns of interest are 76 to 83, True Meals/meal breaks
'if there are 8 non feeding flags in a row, then show break, or
'if the last row was a break and this row has no feeding flag, then show break, or
'if the last row was a break and the next row has no feeding flag, then show break
Worksheets("Midnight-Noon").Range("BX12:CE21595").ClearContents

For colcounter = 76 To 83
For rowcounter = 12 To 21595
If Worksheets("Midnight-Noon").Cells(rowcounter, (colcounter - 8)).Value = "" Then
  If Worksheets("Midnight-Noon").Cells((rowcounter + 1), (colcounter - 8)).Value = "" Then
    If Worksheets("Midnight-Noon").Cells((rowcounter + 2), (colcounter - 8)).Value = "" Then
      If Worksheets("Midnight-Noon").Cells((rowcounter + 3), (colcounter - 8)).Value = "" Then
        If Worksheets("Midnight-Noon").Cells((rowcounter + 4), (colcounter - 8)).Value = "" Then
          If Worksheets("Midnight-Noon").Cells((rowcounter + 5), (colcounter - 8)).Value = "" Then
            If Worksheets("Midnight-Noon").Cells((rowcounter + 6), (colcounter - 8)).Value = "" Then
              If Worksheets("Midnight-Noon").Cells((rowcounter + 7), (colcounter - 8)).Value = "" Then
                Worksheets("Midnight-Noon").Cells(rowcounter, colcounter) = "break"
                End If
              End If
            End If
          End If
        End If
      End If
    End If
  End If
End If
End If
End If
End If
End If
End If

If Worksheets("Midnight-Noon").Cells((rowcounter - 1), colcounter).Value = "break" Then
  If Worksheets("Midnight-Noon").Cells((rowcounter - 8), colcounter).Value = "" Then
    Worksheets("Midnight-Noon").Cells(rowcounter, colcounter) = "break"
    End If
  End If
End If

If Worksheets("Midnight-Noon").Cells((rowcounter - 1), colcounter).Value = "break" Then
  If Worksheets("Midnight-Noon").Cells((rowcounter + 1), (colcounter - 8)).Value = "" Then
    End If
  End If
End If
Worksheets("Midnight-Noon").Cells(rowcounter, colcounter) = "break"
End If
End If

Worksheets("Midnight-Noon").Cells(1, 77) = rowcounter
Worksheets("Midnight-Noon").Cells(1, 79) = colcounter

Next rowcounter
Next colcounter

'Feeder Weight Calculator Button
'calculates feeder weight at the beginning and ending of each meal

Dim weight1 As Single
Dim weight2 As Single
Dim weight3 As Single
Dim weight4 As Single
Dim weight5 As Single
Dim weight6 As Single
Dim weight7 As Single
Dim weight8 As Single
Dim begweight As Single
Dim endweight As Single

'initialize variables
rowcounter = 12: colcounter = 84: weight1 = 0: weight2 = 0: weight3 = 0: weight4 = 0:
weight5 = 0:
weight6 = 0: weight7 = 0: weight8 = 0: begweight = 0: endweight = 0

'Columns of interest are 84 to 91, Feeder weights at start/stop of each meal
'if it is the beginning of a meal, calculate the beginning weight by averaging the last eight readings
'if it is the end of a meal, calculate the ending weight by averaging the next eight readings
Worksheets("Midnight-Noon").Range("CF12:CM21603").ClearContents

For colcounter = 84 To 91
begweight = 0: endweight = 0
For rowcounter = 12 To 21603
If Worksheets("Midnight-Noon").Cells(rowcounter, (colcounter - 8)).Value = "" Then
If Worksheets("Midnight-Noon").Cells((rowcounter - 1), (colcounter - 8)).Value = "break" Then
If begweight = 0 Then
weight1 = Worksheets("Midnight-Noon").Cells((rowcounter - 8), (colcounter - 72)).Value
Else
begweight = (begweight + weight1) / 8:
End If
End If
Next rowcounter
Next colcounter
weight2 = Worksheets("Midnight-Noon").Cells((rowcounter - 7), (colcounter - 72)).Value
weight3 = Worksheets("Midnight-Noon").Cells((rowcounter - 6), (colcounter - 72)).Value
weight4 = Worksheets("Midnight-Noon").Cells((rowcounter - 5), (colcounter - 72)).Value
weight5 = Worksheets("Midnight-Noon").Cells((rowcounter - 4), (colcounter - 72)).Value
weight6 = Worksheets("Midnight-Noon").Cells((rowcounter - 3), (colcounter - 72)).Value
weight7 = Worksheets("Midnight-Noon").Cells((rowcounter - 2), (colcounter - 72)).Value
weight8 = Worksheets("Midnight-Noon").Cells((rowcounter - 1), (colcounter - 72)).Value
begweight = ((weight1 + weight2 + weight3 + weight4 + weight5 + weight6 + weight7 + weight8) / 8)

Else:
    begweight = endweight
End If
Worksheets("Midnight-Noon").Cells(rowcounter, colcounter) = begweight
End If
End If

If Worksheets("Midnight-Noon").Cells(rowcounter, (colcounter - 8)).Value = "" Then
If Worksheets("Midnight-Noon").Cells((rowcounter + 1), (colcounter - 8)).Value = "break" Then
weight1 = Worksheets("Midnight-Noon").Cells((rowcounter + 8), (colcounter - 72)).Value
weight2 = Worksheets("Midnight-Noon").Cells((rowcounter + 7), (colcounter - 72)).Value
weight3 = Worksheets("Midnight-Noon").Cells((rowcounter + 6), (colcounter - 72)).Value
weight4 = Worksheets("Midnight-Noon").Cells((rowcounter + 5), (colcounter - 72)).Value
weight5 = Worksheets("Midnight-Noon").Cells((rowcounter + 4), (colcounter - 72)).Value
weight6 = Worksheets("Midnight-Noon").Cells((rowcounter + 3), (colcounter - 72)).Value
weight7 = Worksheets("Midnight-Noon").Cells((rowcounter + 2), (colcounter - 72)).Value
weight8 = Worksheets("Midnight-Noon").Cells((rowcounter + 1), (colcounter - 72)).Value

endweight = (weight1 + weight2 + weight3 + weight4 + weight5 + weight6 + weight7 + weight8) / 8
If endweight > begweight Then
    endweight = begweight
End If

Worksheets("Midnight-Noon").Cells(rowcounter, colcounter) = endweight
End If
End If

Worksheets("Midnight-Noon").Cells(1, 85) = rowcounter
Worksheets("Midnight-Noon").Cells(1, 87) = colcounter

Next rowcounter
Next colcounter
End Sub

Private Sub CommandButton2_Click()
'Meal Size Calculator Button
Dim rowcounter As Single
Dim colcounter As Single
Dim counter As Single
Dim startrow As Single
Dim endrow As Single
Dim totalsec As Single
Dim hensec As Single
Dim TWAhens As Single
Dim mealsize As Single

'initialize variables
rowcounter = 5: colcounter = 108:

'Columns of colcounter are 108 to 115, labeled Meal Duration
Worksheets("Midnight-Noon").Range("DD5:DK21603").ClearContents

For colcounter = 108 To 115
    startrow = 0: endrow = 0: totalsec = 0.1: hensec = 0:
    counter = 0: TWAhens = 0: mealsize = 0

For rowcounter = 5 To 21603
    'find the starting row of a meal
    If Worksheets("Midnight-Noon").Cells((rowcounter - 1), (colcounter - 32)).Value = "break" Then
        If Worksheets("Midnight-Noon").Cells(rowcounter, (colcounter - 32)).Value = ""
            Then
                startrow = rowcounter
            End If
End If

'find the ending row of a meal
If Worksheets("Midnight-Noon").Cells(rowcounter, (colcounter - 32)).Value = "" Then
    If Worksheets("Midnight-Noon").Cells((rowcounter + 1), (colcounter - 32)).Value = "break" Then
        endrow = rowcounter
    End If
End If

'when startrow and endrow are found, add up the two-second intervals to determine meal duration
If startrow > 0 Then
    If endrow > 0 Then
        totalsec = (endrow - startrow + 1) * 2

'add up the hen-seconds of feeding during the meal
For counter = startrow To endrow
    hensec = hensec + Worksheets("Midnight-Noon").Cells(counter, (colcounter - 8)).Value
Next counter

'calculate time weighted average number of hens feeding during the meal
If hensec > 0 Then
    TWAhens = hensec / totalsec

'calculate average meal size per hen for that meal
mealsize = (Worksheets("Midnight-Noon").Cells(startrow, (colcounter - 24)).Value - Worksheets("Midnight-Noon").Cells(endrow, (colcounter - 24)).Value) / TWAhens
If mealsize > 0 Then
    Worksheets("Midnight-Noon").Cells(rowcounter, colcounter) = totalsec
    Worksheets("Midnight-Noon").Cells(rowcounter, (colcounter + 8)) = TWAhens
    Worksheets("Midnight-Noon").Cells(rowcounter, (colcounter + 16)) = mealsize
End If
End If
End If

If totalsec = 0 Then
    startrow = 0
    endrow = 0
    totalsec = 0.1
hensec = 0
End If

Worksheets("Midnight-Noon").Cells(1, 109) = rowcounter
Worksheets("Midnight-Noon").Cells(1, 111) = colcounter

Next rowcounter
Next colcounter

Dim nummeals As Single
Dim totaldur As Single
Dim numhens As Single
Dim totalmeal As Single

'initialize variables
nummeals = 0: totaldur = 0: numhens = 0: totalmeal = 0: avgduration = 0: avghens = 0:
avgsize = 0:

For colcounter = 108 To 115
For rowcounter = 5 To 21603
    If Worksheets("Midnight-Noon").Cells(rowcounter, colcounter).Value > 0 Then
        nummeals = nummeals + 1
        totaldur = totaldur + Worksheets("Midnight-Noon").Cells(rowcounter, colcounter).Value
        numhens = numhens + Worksheets("Midnight-Noon").Cells(rowcounter, (colcounter + 8)).Value
        totalmeal = totalmeal + Worksheets("Midnight-Noon").Cells(rowcounter, (colcounter + 16)).Value
    End If
Next rowcounter

avgduration = totaldur / nummeals
avghens = numhens / nummeals
avgsize = totalmeal / nummeals
Worksheets("Midnight-Noon").Cells(3, (colcounter + 26)) = nummeals
Worksheets("Midnight-Noon").Cells(4, (colcounter + 26)) = avgduration
Worksheets("Midnight-Noon").Cells(5, (colcounter + 26)) = avghens
Worksheets("Midnight-Noon").Cells(6, (colcounter + 26)) = avgsize
nummeals = 0: totaldur = 0: numhens = 0: totalmeal = 0: avgduration = 0: avghens = 0:
avgsize = 0:
Next colcounter

End Sub
Turkey Simultaneous Feeding Activity:
Week 2, Week 3, and Overall Collection Period

Week 2

Week 3
# Data Used for Turkey Beak Trimming/Feed Form Analysis

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* Shaded boxes indicate data not used due to bird escape from cage, instrumentation problems, bird mortality, etc.