12-2012

The Effects of Social and Environmental Enrichments on Leg Strength and Welfare of TomTurkeys

Patricia A. Weber
University of Nebraska-Lincoln, trishgoodrich@yahoo.com

The Effects of Social and Environmental Enrichments on Leg Strength and Welfare of Tom Turkeys

By

Patricia A. Weber

A THESIS

Presented to the Faculty of

The Graduate College at the University of Nebraska

In Partial Fulfillment of Requirements

For the Degree of Master of Science

Major: Animal Science

Under the Supervision of Professor Sheila E. Purdum

Lincoln, Nebraska

December 2012

The Effects of Social and Environmental Enrichments on Leg Strength and Welfare of Tom Turkeys

Patricia Anne Weber, M.S.

University of Nebraska, 2012

Advisor: Sheila E. Purdum

Two trials (T1, T2) were conducted to determine the effects of enrichment: A) broiler chick addition on early mortality and B) providing environmental enrichments on leg strength and welfare of tom turkeys. Trial 1A utilized 248 1d poults and 8 3d broiler chicks. Four pens of 32 poults were placed for the control. Four pens of 30 poults and two 3d broiler chicks were placed for the trt group. Trial 2A utilized 296 1d poults and 24 3d broiler chicks. Four trts were randomly divided among 16 pens (20 birds/pen). Trt 1 brooders were placed with assistance finding resources. Trt 2 brooders were placed with no assistance. Trt 3 consisted of 18 poults and 2 broiler chicks and trt 4 consisted of 16 poults and 4 broiler chicks, both treatments were placed with no assistance. Body wt., feed intake, mortality and behavioral measurements were collected. Trial 1B utilized 256 14d turkeys randomly assigned into 8 pens (32 birds/pen). Four pens were enriched with a 1.5m^2 platform with an adjustable ramp. Trial 2B utilized 288 12d turkeys in eight pens (36 birds/pen). Four pens were enriched with a 1.5m^2 platform with a fixed ramp leading to a platform with side rails. The control pens in both trials remained barren. Body weight, feed intake, gait scores, bone quality, carcass quality, mortality and behavior measurements were collected. No significant treatment improvements were observed for feed intake, body wt. or mortality with the addition of broiler chicks in either trial.

Environmental enrichment resulted in no significant differences in body weight, feed intake, gait scores, carcass yield%, mortality or behavior due to the enrichments in either trial. At 5 wks of age 72% of the birds visited the enrichments and at 10 wks 39% visited the enrichments. No productivity parameters were improved with the addition of environmental enrichment; however the observation of use of the enrichment may show an intrinsic behavioral need.

Key Words: turkeys, welfare, enrichments

Table of Content:

Chapter 1: Literature Review

1.1 Introduction

The poultry industry is under constant scrutiny for its level of concern regarding bird welfare. Evidence of high mortality rates, leg disorders, breast blisters and visualizations of over-crowded dark barns that lack cognitive stimuli can markedly affect public perception, placing pressure on poultry producers to improve the quality of life for birds in their care.

For decades, the poultry industry has worked hard to produce large, fast growing and disease resistant birds, minimizing the number of birds necessary to supply the demand of society at an affordable price. Genetic advancements, nutrient supplementation and large integrated confinement systems have made the poultry industry the leading producer of affordable animal protein.

It is not uncommon for turkey producers to realize 10-13% mortality rates in a flock of birds. In 2010, 2.8 million turkey poults were hatched but only 2.5 million turkeys were raised to slaughter (USDA, 2010). With an average wholesale price of 61 cent per lb, mortality losses are estimated to be near 16.4 million dollars annually for the U.S. turkey industry.

Economic loss is only one of the concerns to address due to such a staggering mortality rate. Many welfare implications also become obvious; birds die of starvation and dehydration (Savory, 1982), others will die of exsanguinations when the femoral artery is severed by a spiral fracture fragment of the femur or when downer birds are killed by aggressive birds in the flock (Crespo et al., 1999; Julian, 2005). Many birds are simply culled because of mobility abnormalities and lack of growth performance.

Some of the mortality rate is due to starvation and dehydration in the first few days of life. Starvation and dehydration are painful and with proper management preventable (Aziz, 2002). Carver et al (1991) reported that up to 2.11% of early hen mortality and up to 5.76% of early tom mortality was due to poor management, placement practices and environment. Inadequate placement practices and poor environmental conditions may be one of the leading factors causing a condition called “starve out”. Starve out can be defined as death due to the failure to consume feed or water. This condition will peak at 3-5 days of age. Savory (1982) found that adding broiler chicks to a population of turkey poults decreased early mortality and stimulated early growth. Few researchers have studied the idea of social enrichments to stimulate early turkey poult feeding behavior.

As much as 5% of the mortality rate in high average gain tom turkeys is associated with leg problems (Ferket et al, 2009). Leg disorders observed in tom turkeys include: infected hocks, valgus-varus deformation, tibia dyschondroplasia, femoral head necrosis, spondylolisthesis, osteomyelitis and pododermatitis (Vaillancourt et al., 1999; Clark, 2002; Julian, 2005). It is estimated that leg abnormalities in turkey toms may exceed 15%, but are not always visible (Lilburn, 1994). Leg problems are not only an economic burden to the turkey producer, but are one of the most prevalent welfare problems facing the industry.

It has been reported in many species that physical activity improves bone mass and decreases bone abnormalities (Balog et al., 1997; Hiney et al., 2004a,b; Foutz et al, 2007). Increasing environmental complexity has shown promising results to promote activity and improve both the physical and psychological well-being in farm animals (Newberry, 1995; Wemelsfelder and Birke, 1997; Mench and Duncan, 1998). Poultry research has focused most of its efforts on the broiler chicken; less is known about the effects of increasing environmental complexity on the tom turkey.

The objective of this research are two fold: to determine the effects of broiler chick addition on early mortality due to starve-outs and the effects of providing environmental enrichments on leg strength and welfare of tom turkeys.

1.2 Early Poult Mortality

Early poult mortality is a major problem in the turkey industry. Factors affecting early mortality include: breeder flock, genetics, hatchery practices, poult nutrition, disease, environment and management (Kingstone, 1979; Fanguy et al., 1980; Denbow et al., 1984; Renner et al., 1989; Zander and Mallinson,1991;). Mortality due to breeder flock parameters is multifactorial; strain of bird, season of placement, age of breeder flock, and sex of poult can all contribute to the 7 day mortality rate (Carver et al, 2000). Research by Christensen et al. (2007) showed evidence that breeder flocks bred for higher than average egg production had offspring that seemed weak with reduced appetites and lower hatch weights. Strains selected for higher 16 week body weights had lower poult mortality with increased body weights at hatch, 3 and 7 days of age. Hatchery practices such as hatchery servicing procedures (beak trimming, desnooding, toe clipping, vaccination), prolonged holding without feed or water after hatch, variable incubation temperature and time of removal from the incubator can be traced back to some aspect of altered carbohydrate metabolism

(Donaldson and Christensen, 1994). Poult enteritis and mortality syndrome (PEMS) is one of the most devastating diseases that contribute to early poult mortality. Several organisms are involved in the PEMS disease process (Heggen-Peay et al., 2002). Viral agents such as coronavirus, adenovirus and reovirus as well as bacterial agents such as salmonella, campylobacter, clostridia and E. coli can also contribute to increased early poult mortality (Edens, et al., 1997a,b; Koci et al., 2000a,b; Qureshi et al., 2000; Yu et al.,2000a,b; Lin and Togashi, 2002;). Rearing environment and placement practices have futher confounding effects on all other previously mentioned factors (Carver et al. 2000).

1.3 Early poult nutrition

The first week after hatch is an extremely important time for young turkeys to maximize livability and ensure flock uniformity (Lilburn, 1998). Poults utilize the protein and lipid portion of the still available yolk to nourish their bodies after hatch until they can gain access to food and water. Within 5 to 6 days after hatch, nutrients from the yolk are depleted (Sell et al., 1991). Development of the gastrointestinal tract and endogenous enzymes are dependent on a very limited time interval to access dietary nourishment (Corless and Sell, 1999).

Hepatic glycogen concentration in 21-day turkey embryos is positively related to egg weight; however there is an inverse relationship between poult weight and hepatic glycogen stores at time of hatch. This suggests the larger the poult the greater the metabolic requirement is during the hatching process (Rosebrough et al., 1978). Furthermore, various hatchery processes such as sexing, desnooding, toe clipping and beak trimming can deplete the glycogen stores even further (Donaldson et al., 1991).

Post hatch poults have the capacity for considerable glycogenesis if given access to an early dietary carbohydrate supplementation (Rosebrough, et al., 1978; Moran, 1989; Donaldson, 1991).

The developing embryo is primarily reliant on the triglyceride and phospholipid portion of the yolk lipid as its principal source of energy (Donaldson et al., 1967; Freeman and Vince, 1974). In turkeys, 50% of the residual yolk lipid at hatch is composed of triglycerides which have always been assumed to be an important initial energy source, but this represents only 1 g of actual triglycerides (Ding, et al., 1995). This 1 g of triglyceride could provide 8-9 kcal of metabolizable energy, assuming 95% efficiency of utilization, compared to poults that consume 8 to 9 grams of feed for each of the first two days post-hatch will receive 25-30 kcal ME/day (Lilburn, 1998). Resorption of the residual yolk sac can be enhanced by early feed consumption (Moran, 1989). Early feed consumption has also been shown to increase the uptake of the approximately 400 mg of phospholipids remaining in the yolk sac post-hatch for structural development of cellular membranes (Ding et al., 1995).

1.4 Effects of Delayed Access to Feed and Water

Poults are often deprived of early access to feed and water due to distances and delays in shipment to their place of brooding and grow-out. Moran (1989) reported that depravation of feed and water for 24 hours posthatch led to reduced body weight through 14 weeks of age. Poults deprived of feed and water for 48 hours lost 10.7% of their initial posthatch weight (Pinchasov and Noy, 1993). Poults that did not consume feed or water by 54 hours posthatch had retarded development of the gastrointestinal tract including all segments of the small intestine, pancreas and gizzard, which in turn reduced the utilization of dietary nutrients and lowered body weights though 28 days of age (Corless and Sell, 1999).

1.5 Definition of "Starve-out"

It is imperative to the poults well being and future productive state to consume feed and water as soon as physically possible. However, even in the most ideal situations some poults fail to initiate feeding and drinking behaviors, this condition is commonly called "starve-out" (Savory, 1982). Some cases of early poult mortality that are classified as starve-outs may be due to other causes such as poor egg quality, infected yolk, inadequate hatchery practices and inferior rearing practices.

1.6 Clinical signs of Starvation

There are no specific clinical signs to suspect "starve-out" over many other poultry diseases. Affected birds are weak and look noticeably smaller than flock mates. Often one will find these birds pecking at the litter or objects not related to feeders or waterers. At the terminal stage, poults will be reluctant to move and can die at three to five days of age. The skin will appear dark and dry especially over the shank and the skin will stick to the muscles. Swollen kidneys and distension of ureters is common in acute starvation. Urates can be found adhered to ureters, liver and the surface of the heart. The gallbladder is usually large and distended with bile. The digestive tract is empty of food and evidence of litter may be found in the gizzard (Aziz, 2002).

1.7 Stimulants of Feeding Behavior

Bright lighting and flashing colored lights have been shown to stimulate turkey poults to find feed and water by attracting them to the troughs (Lewis and Hurnik, 1979). Cooper (1971) found that the addition of brightly colored objects or colored food would help initiate feeding behavior in turkey poults. Strobel and MacDonald (1974) used moving artificial hens to induce pecking behavior of newly hatched chicks. Sounds and vocalizations have been investigated and have had limited success to evoke feeding behavior in both turkey poults and broiler chicks (Tolman, 1967; Bate, 1992; Greenless, 1993).

Savory (1982) investigated the possibility of rearing turkey chicks together with broiler chicks in an effort to stimulate feeding behavior. Mortality was reduced in mixed species treatments but the differences were not significant. At four weeks of age, turkeys reared with broiler companions were significantly heavier, however at 8 weeks of age these effects had diminished. Little research has been published since to establish the effects of social facilitated behavior in turkey poults.

1.8 What is Welfare?

The most debated question in animal production practices of today is "What constitutes good welfare?" The Council of Europe (1998), recommends the basic requirements for good welfare concerning turkeys include:

"good stockmanship, husbandry methods appropriate to the biological needs of the animals and suitable environmental factors, so that the conditions under which turkeys are kept fulfill the needs for appropriate nutrition and methods of feeding, freedom of movement, physical comfort, social contact; the need to perform normal behavior in connection with getting up, lying down, resting and sleeping postures, wing-flapping, walking and running, roosting, grooming, eating, drinking, defecating, social interaction, other behaviors such as dust-bathing and egg-laying; the need for protection against adverse climatic conditions, injury, fear and distress, infestation and disease or behavioral disorder; as well as other requirements as may be identified by established practice or scientific knowledge."

Duncan and Petherick (1991) put forth the argument that "animal welfare is dependent solely on the cognitive needs of the animals concerned and if these cognitive needs are met, they will protect the animals' physical needs."

The Farm Animal Welfare Council (1992) defines the obligations of humans to ensure the welfare of farm animals in what is called the "Five Freedoms" which includes: Freedom from hunger and thirst; Freedom from discomfort; Freedom from pain, injury and disease; Freedom to express normal behavior; and Freedom from fear and stress.

1.9 Measuring Welfare

Several measures can be used to evaluate the welfare state of the animal. These evaluations should be based on multi-criteria approaches, since no single measure can indisputably be related to the level of welfare (Mormede and Hay, 2003). Physiology, ethology, pathology and psychology together can best determine the true welfare of the farm animal.

Since the 1950's when Selye defined stress as "General Adaptation Syndrome (GAS)" which is "physiologically and psychologically a stressor, by definition, is a stimulus which evokes an endocrine response mediated though the hypothalamus/pituitary/adrenal (HPA) axis”; welfare scientists have been using catecholamine, corticosteroid and ACTH levels to determine stress levels. Webster (1994) argues that HPA responses are not specific to the stressors and cannot be used alone as an indication of stress. They do not differentiate between physical and psychological stresses such as cold and fear and may not even differentiate pain over pleasure. HPA responses can be useful if combined with other physiological and ethological indices, however one must avoid preconception (Webster, 1994).

Consumer demand or motivation testing and preference studies as well as knowledge of physical and social aspects of evolutionary environment can indicate what kind of resources are needed to improve welfare (Newberry, 1995). Care should be taken to differentiate between positive environmental enrichment and behavior altering stimuli (Olsson and Dahlborn, 2002).

Consumer demand or motivation research is gaining promise in the area of animal welfare research. Motivation can be defined as follows: “The internal state of the animal, which is the net result of stimuli arising from both inside and outside its body, constitutes its ‘motivation’” (Manning and Dawkins, 1998). This technique was developed using adaptations of human microeconomics. One can access the demand for a resource by determining how the animal behavior changes with increased cost of access or utilization of that resource (Mason et al., 2001). The level of motivation can be accessed by the amount of time interacting with the resource, the amount of work required to gain access to the resource or the extent of an aversive stimulus endured to gain the resource (Cooper and Appleby, 2003; MacCaluim et al. 2003; Mason et al., 2001).

Preference tests are the simplest measurement of animal priorities. When animals are housed in systems that mirror industry, preference test are highly valuable as a first step in understanding animal priorities in relation to resources (Fraser and Mathews, 1997). There are limitations involved in preference tests which include: 1) short-term priority choices may not reflect long term priorities (Duncan and Fraser, 1997), and 2) animals in most systems studied rarely have one choice option, but rather have many stimuli to interact with such as pen mates and food resources (Kristensen, 2000).

1.10 Why Measure Animal Behavior

The direct observation of animal behavior is useful for many purposes. These observations may help us to understand cognition, biology of adaptation and neurophysiology. Without the knowledge gained by behavior measurements – meaning the actions and reactions of whole organisms – one cannot fully understand the neural elements underlying behavior. For example: behavioral study of imprinting in birds led to extensive analyses of the neural mechanism involved in the recognition process. This raised questions about the role of neural mechanisms involved in classical and operant conditioning that occur in parallel with imprinting. Attention was then drawn back to what happens at the behavioral level (Bateson, 2005).

1.11 Measuring Animal Behavior

Like all experimental procedures the study of behavior follows numerous steps. The basic steps of research are: hypothesize, design, experiment, analyze and interpret. However, in the field of behavior science there are a few more steps that precede the design stage which include: informal observations of the animals, choosing precise measurements and choosing the method of recording. These steps are very important to understand both the subject and the behavior you intend to measure (Marten and Dateson, 2007).

Before one begins collecting behavior data one must describe the behaviors of interest. Behaviors can be structural in nature -- appearance, physical form or temporal patterning; consequential – effects of the subject's behavior on the environment, on others and on itself; or have spatial relationships to the features of the environment or other individuals. Categories must be clearly defined, independent of each other, numerous enough to be used to describe the behavior and homogeneous -- all acts included in the same category should share the same properties. Types of measurements can include: latency, frequency, duration and intensity.

1.12 The Natural Habitat and Behavior of the Turkey

The domestic production turkey was derived from the native wild turkey of North America (Meleagris gallopavo). The natural habitat of the wild turkey varies with the seasons. The wild type turkey can be found in open plains, woodlands, thick shrub, treetops and even in lakes and streams. The walking speed of the wild turkey is approximately 5 km/h and it can run short distances at a speed up to 30 km/h. Unlike their production counterparts, the wild turkey is capable of short duration flight to accomplish roost in treetops. Wild turkeys will travel 2-3 km in a day's time and their home range may cover 200 to 1000 acres (Williams, 1981).

The social behavior of the turkey is very complex. In the spring several broods will join together to form a large flock. At this time, males will display their feathers and strut in a ritualistic pattern among the congregation of other males of the flock. After hatching, the family will form a basic social unit, with the young firmly imprinted on the hen. The hen will use a series of displays and clucks to teach its young what is suitable to eat and what is not. In the winter, the flock will disperse into four types of social units: (1) old hens without broods, (2) brood hens with female offspring, (3) young males recently separated from mothers and (4) older males (Schorger ,1966).

1.13 Domestication of the turkey

The domesticated production type turkey is a descendant of only a few strains of the wild type. Most have completely white plumage, though some producers have "heritage strains" which still exhibit the mottled feathering; both strains have been selected for rapid growth and large breasts to the point of only being capable of reproduction through artificial insemination to protect the welfare of the hen. Commercially, domestic male turkeys are grown to approximately 20 weeks of age and will weigh over 20 kg at time of slaughter in comparison to its wild ancestors, which on average will only weigh 9 kg at maturity. Females are raised to 14-16 weeks of age and will weigh anywhere from 5-10 kg at market age.

This genetic change of the turkey has affected various aspects of their adaptive traits, including behavior. Comparing domestic animals and their ancestors, we can see that the behavioral differences are limited. New behaviors are not observed and none have completely disappeared, however strategies have been modified (Price, 1997). For example, domesticated pigs and poultry that are provided food and protection have different behavioral strategies then the wild boar and jungle fowl during food search, which is an indication of adaption of strategies to the conditions (Schutz and Jensen 1999; Gustafsson et al., 1999a).

1.14 Effects of Environmental Enrichments on Welfare and Production Parameters

In modern production settings, the environment in which we raise animals are devoid of complexity and cognitive stimuli (Dawkins,1999; Manser 1996; Wemelsfelder, 1993;Wemelsfelder and Birke, 1997). One may be able to improve physical health and psychological well being by altering the provisions of social, physical or sensory stimuli in the environment. Environmental enrichments should provide positive social interactions between conspecifics, constructive human interaction, predictable sensory stimuli in regards to lighting and thermo-regularity and provisions of complex and novel stimuli with which the animal is motivated to interact (King, 2003).

Broiler chicken environments that have been enriched with ramps have shown positive results in terms of increased productivity traits such as body weight gain and feed:gain ratios and decreased incidence of skeletal abnormalities such as tibial dyschondroplasia (Balog et.al., 1997). Broiler breeder environments have been successfully enriched with cover panels to improve reproductive performance and reduce signs of stress (Leone and Estevez, 2008). Pipes, panels and other wall like structures that act as protective barriers can help maintain litter quality, reduce the incidence of piling up and allow opportunities to rest undisturbed (Newberry and

Estevez, 2006). In a study using a treadmill to force activity for broilers, 33% of birds exposed to the treadmill had increased tissue near the bifurcation indicating an improvement in leg strength (Foutz et al., 2007).

1.15 Bone Formation and Factors Regulating Maturation and Strength

The avian bone is made up of compact or cortical bone, cancellous or trabecular bone and marrow space. The compact or cortical bone is the hard, white exterior of the bone. It gives the bone structure and is 80% of the bone mass. It is comprised of mostly Ca and P in the form of hydroxyapatite, which constitutes 60-70% of the bone weight and provides stiffness and compressional strength (Rath et al., 2000). The cancellous or trabecular bone comprises the remaining 20% of the bone mass; it is less calcified, plays a larger role in metabolic function and undergoes continuous remodeling (Seifert and Watkins, 1997). Bone is made up of a matrix of organic and inorganic parts. Collagen is the major component of the organic matrix, contributing to the tensile strength of bone and providing support to the mineral matrix (Riggs, et al., 1993).

There are many factors that regulate bone strength including: growth, gender, age, genetics, physical activity and mechanical stress, nutrition, disease, endocrine responses, and toxins. Growth is an important determinant of bone strength because bone mass increases with growth and bone strength are directly proportional to its mass (Frost, 1997; Seeman, 1999). At 25 weeks of age, bone weight, length, diameter and pyridinium crosslink content is maximized, while maximum mineral content, density and breaking strength are not realized until 35 weeks of age. These results suggest that maturation of bone takes longer than the growth process. In laying hens it was noted that 75 week old hens had stronger bones than did 25 week old hens; however at 150 weeks there was no difference in bone strength compared to 75 weeks of age. This suggests that bone strength can be maintained throughout the production cycle (Rath et al. 2000). Bone mass and strength is gender specific. When comparing young male and female birds, males have larger length and diameters with no differences in bone strength. At 72 weeks of age however, bones in the females were significantly stronger than males possibly due to the presence of the medullary bone (Rath et al., 1999). The genetic contribution to bone strength in poultry is not well known, however the incidence of tibial dyschondroplasia has been shown to be heritable (Leach and Nesheim, 1965; Wong-Valle et al., 1993). Physical activity and mechanical stress increase the modeling and remodeling function of bone and has been shown to enhance bone strength (Lanyon, 1993; Whitehead, 1996; Newman and Leeson, 1997). Numerous nutrition factors affect bone strength in poultry. The most widely studied nutrient effects on bone strength have been calcium, phosphorous and vitamin D deficiencies and the effects of the calcium to phosphorous ratio. Infections such as osteomyelitis and osteonecrosis cause focal bone loss leading to bone weakness (Reece, 1992). Hormones have a profound effect on bone metabolism, growth and remodeling and therefore, are consequential to their strength (Rath et al, 2000). Finally, toxins such as mycotoxin can affect growth and cause bone fragility and decrease bone strength (Huff et al., 1980; Maurice et al., 1983).

1.16 Skeletal Disorders in Turkeys

Skeletal disorders are one of the primary welfare and economic problems in turkey production. Welfare declines due to pain and stress associated with lameness that impairs movement or causes bone breakage during catching and transportation (Julian, 2004; Mench, 2004). Leg disorders can also be the most expensive disease in terms of financial costs at the farm and the processing plant. Resources are wasted on culled birds, production expenses are increased through cost of treatment and prevention and condemnations occur during processing because of bone fragility and porosity which causes bone fragments in the meat and discoloration due to blood leakage that is less attractive to the consumer (Gregory and Wilkins, 1992;Pattison, 1992; Bennet et al, 2002; Whitehead et. Al., 2004).

Leg disorders that affect production turkeys include femur spiral fractures (brittle bone), pododermatitis (bumble foot), tibial dyschondroplasia, osteomyelitis, valgus/varus and infectious agents that affect the musculoskeletal system such as Staphylococcus, Mycoplasmas and Ornithobacterium. Femur spiral fractures are often seen as a flock problem. This disease is usually contributed to a nutritional problem (Julian, 2005). Valgus/varus deformities can be identified by observation of bones that exhibit some degree or combination of lateral, medial, anterior, or posterior bend. They also show some rotation about their long axis of the bone. The most common abnormalities are valgus deformity of the intertarsal joint and excessive external rotation of the tibiotarsus. Valgus/varus deformity is associated with rapid growth and limited exercise. The incidence can be reduced by slowing growth rate at an early age by feed restriction or lighting programs (Merck Vet. Manual online, 2010).

Tibial dyschondroplastic lesions are masses of avascular cartilage extending from the growth plate into the metaphysis and are attributed to the failure of chondrocytes to differentiate. This results in a focal thickening of the growth plate in the proximal tibiotarsus or sometimes the proximal tarsometatarsus. The lesion in the proximal tibiotarsus is often associated with anterior bowing of the tibiotarsus and sometimes fractures below the plug of cartilage. Factors shown to influence the incidence and severity of dyschondroplasia include genetic selection, calcium:phosphorus ratios in feed, metabolic acidosis through excess chloride in feed, acid/base balance, and mycotoxins (Merck Vet. Manual online, 2010).

Pododermatitis (bumble foot) ulceration of the metatarsal and digital footpads is a common cause of lameness in meat-type poultry. Wet or poor quality litter is the common cause, although a biotin deficiency will cause plantar pododermatitis even when litter quality is good. Ulcerated footpads may become secondarily infected and caked with litter (Merck Vet. Manual online, 2010).

Some of the infectious agents that cause musculo-skeletal problems in turkeys are as follows: *M. gallisepticum* (MG) and *M. synoviae* (MS) cause neurological signs in turkeys due to vasculitis in the brain and *M. melagridis* which will cause swelling of the hock joint, bowing of tarsometatorsus and deformation of cervical vertebrae. Staphylococcosis *aureus* can cause lesions such as: omphalitis, synovitis, arthritis, osteomyelitis, green liver, gangrenous dermatitis, cellulitis, endocarditis, abscesses (bumble-foot), etc. (Reece, 1992).

1.17 Effects of Physical Activity on Leg Strength

The body is a very dynamic entity. Bones, tendons, ligaments and muscle all adapt to changes in physical loading and activity by modeling and remodeling. In short, bone mass and strength increases with use (Lanyon, 1993). Several studies have indicated that altering an animal's environment to encourage physical activity will have strengthening benefits to the structural integrity of the body (Whitehead, 1996; Newman and Leeson, 1997; Balog et al., 1997).

The extracellular matrix (ECM) plays an important role in ensuring the structural integrity of the body, especially in tendons, ligaments, bone and muscle. The ECM turnover is positively influenced by physical activity. Collagen synthesis and degrading metalloprotease enzymes increase with mechanical loading. Transcription, posttranslational modifications and increased release of growth factors are enhanced following physical activity. Exercise increases metabolic activity, circulation and collagen turnover. These modified properties will strengthen the viscoelastic characteristics of the tissue, decrease its stress and make the structure more load resistant (Kjaer, 2004).

It has been demonstrated with weanling horses that exercise stimulates the skeleton at an early age to model for intense activity and may exhibit better adaptation for training than those confined during growth (Hiney et al., 2004a,b). In human children, exercise has been shown to encourage the development of the articular hyaluline cartilage in the knee and increase bone mass which decreases future injuries (Jones, et al., 2003).

1.18 Summary

Millions of dollars in revenue are lost each year to early poult mortality and mortality due to leg disorders. Compounding these losses is the increasing demand by the consumer, for the producer to provide a healthy stimulating environment for the bird's welfare. Social stimulation using broiler chicks could reduce early poult mortality by encouraging feeding behavior by setting an example. Further reduction of mortality due to leg disorders could be realized by providing environmental stimuli that encourages activity and thus increases bone strength.

1.19 References

Aziz, T., 2002. Early mortality and starve-out in poults can be reduced. World Poultry Vol. 17, No. 2 ’01.

Balog, J. M., B. R. Bayyari, N. C. Rath, W. E. Huff, N. B. Anthony, 1997. Effect of intermittent activity on broiler production parameters. Poult. Sci. 76, 6-12.

Bate, L. A. 1992. Sound stimuli to enhance ingestive behavior of young turkeys. Appl. Anim. Behav. Sci. 34:189–194.

Bateson, P., 2005 Ethics and Behavioral Biology. Advances in the Study of Behavior, 35, 211-233.

Bennett C.D., H. L. Classen, K. Schwean, and C. Riddell. 2002. Influence of whole barley and grit on live performance and health of turkey toms. Poultry Sci. 81(12):1850-1855.

Carver, D. K., D. P. Wages, and P. Cowen. 1991. Effects of poult source on turkey production parameters. Avian Dis. 35:231–234.

Christensen, V. L., D. T. Ort, K. E. Nestor, S. G. Velleman and G. B. Havenstein, 2007. Genetic control of neonatal growth and intestinal maturation in turkeys. Poult Sci 2007. 86:476-487

Clark S., G. Hansen, P. McLean, P. Bond Jr, W. Wakeman, R. Meadows, and S. Buda. 2002. Pododermatitis in turkeys. Avian Dis. 46(4):1038-44.

Corless, A. B. and J. L. Sell, 1999. The effects of delayed access to feed and water on the physical functional development of the digestive system of young turkeys. Poultry Science 78:1158-1169.

Cooper, J. B., 1971. Colored feed for turkey poults. Poultry Science, 50: 1892-1893.

Cooper, J.J. and M. A. Appleby, 2003. The value of environmental resources to domestic hens: A comparison of the work-rate for food and for nests as a function of time. Anim Welfare 12:39-52.

Council of Europe (1998). https://wcd.coe.int/ViewDoc.jsp?id=402285&Site=COE&BackColorInternet=DBDCF2&BackColorIntranet=FDC864&BackColorLogged=FDC864

Crespo, R., S. M. Stover, R. Droual, R.P. Chin, and H. L. Shivaprasad, 1999. Femoral fractures in a young male turkey breeder flock. Avian Dis. 43:150-154.

Dawkins MS. 1999. The role of behaviour in the assessment of poultry welfare. World's Poultry Sci J 55:295-304.

Denbow, D. M., A. T. Leighton, Jr., and R. M. Hulet. 1984. Behavior and growth parameters of large white turkeys as affected by floor space and beak trimming. I. Males. Poultry Sci. 63:31–37.

Ding, S.T., K.E. Nestor, and M.S. Lilburn, 1995. The concentration of different lipid classes during late embryonic development in a random bred turkey population and a subline selected for increased body weight at sixteen weeks of age. Poultry Sci. 74:374-382.

Donaldson, W. E., and V. L. Christensen. 1994. Dietary carbohydrate effects on some plasma organic acids and aspects of glucose metabolism in turkey poults. Comp. Biochem. Physiol. 100A:423–430.

Donaldson, W. E., V. L. Christensen, and K. K. Krueger. 1991. Effects of stressors on blood glucose and hepatic glycogen concentrations in turkey poults. Comp. Biochem. Physiol. 100A:945–947.

Donaldson, W. E., 1967. Lipid composition of chick embryo and yolk as affected by stage of incubation and maternal diet. Poultry Science 46:693-697.

Ducan, J.H. and J. Carol Petherick. 1991. The implications of cognitive processes for animal welfare. *J Anim Sci* 69:5017-5022.

Duncan IJH, and D. Fraser. 1997. Understanding animal welfare. In: Appleby M, Hughes BO, eds. Animal Welfare. Wallingford UK: CAB International. p 19-32.

Edens, F. W., C. R. Parkhurst, I. A. Casas, and W. J. Dobrogosz. 1997a. Principles of ex ovo competitive exclusion and in ovo administration of Lactobacillus reuteri. Poult. Sci. 76:179–196.

Edens, F. W., C. R. Parkhurst, M. A. Qureshi, I. A. Casas, and G. B. Havenstein. 1997b. Atypical *Escherichia coli* strains and their association with poult enteritis and mortality syndrome. Poult. Sci. 76:952–960.

Farm Animal Welfare Council, 1992. FAWC updates the five freedoms. The Veterinary Record 131:357. http://www.fawc.org.uk/freedoms.htm

Ferket, P. R., E. O. Oviedo-Rondon, P. L. Mente, D. V. Bohorquez, A. A. Santos Jr, J. L. Grimes, J. D. Richards, J. J. Dibner, and V. Felts. 2009. Organic trace minerals and 25-hydroxycholecalciferol affect performance characteristics, leg abnormalities, and biomechanical properties of leg bones of turkeys. Poultry Science 88:118-131.

Fanguy, R. C., L. K. Misra, K. V. Vo, C. C. Blohowiak, and W. F. Krueger. 1980. Effect of delayed placement on mortality and growth performance of commercial broilers. Poult. Sci. 59:1215–1120.

Fraser, D and L. R. Matthews. 1997. Preference and motivation testing. In: Appleby M, ed. Animal Welfare. Wallingford UK: CAB International. p 159-174.

Foutz, T.L., A. K. Griffin, J. T. Halper, and G. N. Rowland. 2007. Effects of activity on avian gastrocnemius tendon. Poultry Science 86:211-218.

Freeman, B.M. and M.A. Vince, 1974. Development of the Avian Embryo. Chapman and Hall, London, England.

Frost, H. M., 1997. Obesity and bone strength, and mass: a tutorial based on insight from new paradigm. Bone 21:211–214.

Greenless, B. 1993. Effects of enriching the acoustic environment during incubation on hatching and post-hatch chick responses. M.Sc. Thesis. University of Guelph, Canada.

Gregory, N. G., and L. J. Wilkins, 1992. Skeletal damage and bone defects during catching and processing. Pages 313–328 *in*: Bone Biology and Skeletal Disorders in Poultry. C. C.
Whitehead, ed. Carfax Publishing Co., Oxford, UK.

Gustafsson, M., P. Jensen, F. De Jonge, and T. Schuurman. 1999a. Domestication effects on foraging strategies in pigs (Sus scrofa). Applied Animal Behaviour Science, 62(4), 305-317.

Heggen-Peay, C. L., M. A. Cheema, R. A. Ali, K. A. Schat, and M. A. Qureshi. 2002. Interactions of poult enteritis and mortality syndrome-associated reovirus with various cell types in vitro. 2002 Poultry Science 81:1661-1667

Hiney, K.M., B.D. Nielsen, M.W. Orth, D.S. Rosenstein and B.P. Marks. 2004a. Short duration, high intensity exercise alters bone density and shape. J. Anim. Sci. 82(6):1612- 1620.

Hiney, K.M., B.D. Nielsen and D.S. Rosenstein. 2004b. Short-duration exercise and confinement alters bone mineral content and shape in weanling horses. J. Anim. Sci. 82(8):2313-2320.

Huff, W. E., J. A. Doerr, P. B. Hamilton, D. D. Hamann, P. E. Peterson, and A. Ciegler, 1980. Evaluation of bone strength during aflatoxicosis and ochratoxicosis. Appl. Microbiol. 40:102–107.

Jones, G., K. Bennell, and F. M. Cicuttini. 2003. Effect of physical activity on cartilage development in healthy kids. Br J Sports Med 2003;37:382-383 doi:10.1136/bjsm.37.5.382

Julian, R. J. 2004. Production and growth related disorder and other metabolic diseases of poultry – A review. The Veterinary Journal 169: 350-369.

Julian, R. J. 2005. Production and growth-related disorders and other metabolic diseases of poultry—A review. Vet. J. 169:350–369.

King, L.A.. 2003. Behavioral Evaluation of the Psychological Welfare and Environmental Requirements of Agricultural Research Animals: Theory, Measurement, Ethics, and Practical Implications. ILAR J. 2003;44(3):211-21.

Kingston, D. J.. 1979. Some hatchery factors involved in early chick mortality. Aust. Vet. J. 55:418–421.

Kjaer, M. 2004. Role of Extracellular Matrix in Adaptation of Tendon and Skeletal Muscle to Mechanical Loading. Physiol Rev 84:649–698

Koci, M. D., B. S. Seal and S. Schultz-Cherry. 2000a. Development of an RT-PCR diagnostic test for avian astrovirus. J. Virol. Methods 90:79–83.

Koci, M. D., B. S. Seal and S. Schultz-Cherry. 2000b. Molecular characterization of an avian astrovirus. J. Virol. 74:6173–6177.

Kristensen, H. H. 2000. The preferences of laying hens for different concentrations of ammonia. Appl Anim Behav Sci 68:307-318.

Lanyon, L. E., 1993. Skeletal response to physical loading. Pages 485–505 *in*: Physiology and Pharmacology of Bone. Handbook of Experimental Pharmacology. Vol. 107. G. R. Mundy and T. J. Martin ed. Springer Verlag, New York, NY.

Leach, R. M., and M. C. Nesheim, 1965. Nutritional, genetic, and morphological studies of an abnormal cartilage formation in young chicks. J. Nutr. 86:236–244.

Leone, E. H. and I. Estevez. 2008. Econmic and welfare benefits of environmental enrichment for broiler breeders. Poultry Science 87:14-21.

Lewis, N.J. and J. F. Hurnik. 1979. Stimulation of feeding in neonatal turkeys by flashing lights. Applied Animal Ethology, 5: 161-171.

Lilburn, M.S., 1994. Skeletal growth of commercial poultry species. Poultry Sci. 73:897-903.

Lilburn, M.S., 1998. Practical Aspects of Early Nutrition for Poultry. J. Appl. Poult. Res. Winter, 1998 vol. 7 no. 4 420-424

Lin, C.Y. and K. Togashi, 2002. Genetic improvement in the presence of genotype by environment interaction. Anim. Sci. J., 73: 3-11.

MacCaluim, J.M., S. M. Abeyesinghe, R. P. White, and C. M. Wathes. 2003. A contimuous-choice assessment of the domestic fowl's aversion to concurrent transport stressors. Anim. Welf. 12: 95-107

Manning, A. and M. S. Dawkins. 1998. An Introduction to Animal Behavoir. Cambridge University Press, UK.

Manser, C.E. 1996. Effects of lighting on the welfare of domestic poultry: A review. Anim Welfare 5:341-360.

Marten, P. and P. Dateson. 2007. Measuring Behaviour An Introductory Guide. Cambridge University Press 2007

Mason, G., J. Cooper and C. Clarebrough. 2001. The welfare of fur-farmed mink. Nature 410: 35 - 36.

Maurice, D. V., A. B. Bodine, and N. J. Rehrer, 1983. Metabolic effects of low aflatoxin B1 on broiler chickens. Appl. Environ. Microbiol. 45:980–984.

Mench, J. 2004. Lameness. Pages 3-17. in: *Measuring and Auditing Broiler Welfare*. Eds. C. Weeks and A. Butterworth. CAB International.

Mench J.A. and I. J. H. Duncan. 1998. Poultry Welfare in North America: Opportunities and Challenges Poultry Science 77:1763-1765.

Merck Veterinary Manual Online: www.merckvetmanual.com/mvm/index.jsp

Moran. E.T., Jr., 1989. Effects of post-hatch glucose on poults fed and fasted during yolk sac depletion. Poultry Scil 68:1141-1147.

Mormède P. and M. Hay. 2003. Behavioural changes and adaptations associated with weaning. In Pluske J.R., Le Dividich J., Verstegen M.W.A. (eds.), Weaning the Pig. Concepts and Consequences. Wageningen (The Netherlands), Wageningen Academic Publishers, 53-60.

Newberry, R.C., 1995. Environmental enrichment: Increasing the biological relevance of captive environments. Applied Anim. Behav. Sci., 44: 229-243.

Newberry, R. C. and I. Estevez. 2006.Species specific enrichment – poultry. The Scientists Center for Animal Welfare and The Federation of Animal Science

Societies Conference on The Humane Care and Use of Agricultural Animals in Research, 22-23 May 2006, St. Louis MO, 5/23/06.

Newman, S., and S. Leeson, 1997. Skeletal integrity in layers at the completion of egg production. World's Poult. Sci. J. 53:265–277.

Olsson, I. A. S. and K. Dahlborn. 2002 Improving housing conditions for laboratory mice: a review of 'environmental enrichment'. Laboratory Animals 36, 243–70.

Pattison, M. 1992. Impacts of bone problems on the poultry meat industry. In: Bone Biology and Skeletal Disorders of Poultry. Whitehead, C.C. Ed. Carfax Publishing Co., Abingdon, UK.

Pinchasov, Y. and Y. Noy. 1993. Comparison of post-hatch holding time and subsequent early performance of broiler chicks and turkey poults. *Br. Poult. Sci.* 34:111–120.

Price, E.O., 1997. Behavioral genetics and the process of animal domestication. In: Genetics and the behavior of domestic animals (Ed. by Grandin, T.), pp. 31-65: Academic Press.

Qureshi, M. A., M. Yu, and Y. M. Saif,. 2000. A novel "small round virus" inducing poult enteritis and mortality syndrome and associated immune alterations. Avian Dis. 44:275–283.

Rath, N. C., G. R. Huff, W. E. Huff, and J. M. Balog. 2000. Factors regulating bone maturity and strength in poultry. Poult. Sci. 79:1024–1032.

Rath, N. C., J. M. Balog, W. E. Huff, G. R. Huff, G. B. Kulkarni, and J. F. Tierce,1999. Comparative differences in the composition and biomechanical properties of tibiae of seven- and seventy-two-week-old male and female broiler breeder chickens. Poultry Sci. 78:1232–1239.

Reece, R. L., 1992. The role of infectious agents in leg abnormalities in growing birds. Pages 231–263 *in*: Bone Biology and Skeletal Disorders in Poultry. C. C. Whitehead, ed. Carfax Publishers, Abingdon, UK.

Renner, P. A., K. E. Nestor, and G. B. Havenstein. 1989. Effects on turkey mortality and body weight of type of beak trimming, age at trimming, and injection of poults with vitamin and electrolytes solution at hatching. Poult. Sci. 68:369–373.

Riggs, C. M., L. C. Vaughan, G. P. Evans, L. E. Lanyon, and A. Boyde, 1993. Mechanical implication of collagen fibre orientation in cortical bone of equine radius. Anat. Embryol. 187:239–248.

Rosebrough, R.W., E. Geis, K. Henderson, and L. T. Frobish, 1978. Glycogen metabolism in the turkey embryo and poult. Poultry Sci. 57:747-751.

Savory, C.J.,1982. Effects of broiler companions on early performance of turkeys. British Poultry Science, 23: 81-88.

Schorger, A. W. 1966 The Wild Turkey: its History and Domestication. University of Oklahoma Press, Norman, OK.

Schütz, K. and P. Jensen. 1999. Foraging behaviour and activity in red junglefowl (Gallus gallus) and in domesticated breeds. In: 33rd International Congress of the International Society for Applied Ethology (Ed. by Böe, K. E., Bakken, M. and O, B. B.), pp. 92. Lillehammer, Norway: NLH, Agricultural University of Norway.

Seeman, E., 1999. The structural basis of bone fragility in men. Bone 25:143–147.

Seifert, M. F., and B. A. Watkins. 1997. Role of dietary lipid and antioxidants in bone metabolism. Nutr. Res. 17:1209-1228.

Sell, J. L., C. R. Angel, F. J. Piquer, E. G. Mallarino, and H. A. Al-Batshan, 1991. Developmental patterns of selected characteristics of the gastrointestinal tract of young turkeys. Poultry Science. 70-1200-1205.

Selye, H., 1950. Stress and the General Adaptation Syndrome. British Medical Journal.

Strobel, M. G. and G. E. Mac Donald. 1974. Induction of eating in newly hatched chicks. Journal of Comparative and Physiological Psychology, 86: 493-502.

Tolman, C. W. 1967. The effects of tapping sounds on feeding behavior of domestic chicks. Anim. Behav. 15:145–148.

USDA, 2010. www.nass.usda.gov/quickstats/index2.jsp.

Vaillancourt J-P, P.C., L. Ivy, J. Barnes, D. Wages, and L. Baucom. 1999. Causes of mortality in male turkeys during the last part of grow-out. Pages 87-88 In: Proceedings of 48th Western Poultry Disease Conference, April 25-27, 1999.

Webster, A. 1994. Animal welfare: a cool eye towards Eden. Blackwell Science, UK.

Wemelsfelder, F., and L. Birke. 1997. Environmental challenge. Pages 35-47 in Animal Welfare. M. C. Appleby and B. O. Hughes, ed. CAB International, Wallingford, UK.

Wemelsfelder, F. 1993. The concept of animal boredom. In: Lawrence AB, Rushden J, editors. Stereotypic animal behaviour: fundamentals and applications to welfare. Oxford: CAB International. p 65-95.

Whitehead, C. C., 1996. Nutrition and bone disorder. Pages 161–171 *in*: Proceedings of the World's Poultry Congress. Vol. II. WPSA, New Delhi, India.

Whitehead, C.C., H.A. McCormack, L. McTeir, and R.H. Fleming. 2004. High vitamin D3 requirements in broilers for bone quality and prevention of tibial dyschondroplasia and interactions with dietary calcium, available phosphorus and vitamin A. *Br. Poult. Sci*. 45(3):425-36

Williams, L.E., 1981. The Book of the Wild Turkey. Winchester Press, Tulsa, Oklahoma.

Wong-Valle, J., G. R. McDaniel, D. L. Kuhlers, and J. E. Bartels, 1993. Correlated responses to selection for high or low incidence of tibial dyschondroplasia in broilers. Poultry Sci. 72:1621–1629.

Yu, M., M. M. Ismail, M. A. Qureshi, R. N. Dearth, H. J. Barnes and Y. M. Saif ,2000a. Viral agents associated with poult enteritis and mortality syndrome: The role of a small round virus and a turkey coronavirus. Avian Dis. 44:297–304.

Yu, M., Y. Tang, M. Guo, Q. Zhang, and Y. M. Saif. 2000b. Characterization of a small round virus associated with the poult enteritis and mortality syndrome. Avian Dis. 44:600–610.

Zander, D.V. and E. T. Mallinson. 1991. Principles of disease prevention: Diagnosis and control. Pages 45-71 in Diseases of Poultry. 9th Edition B. W. Calnek, H.J Barnes, C.W. Beard, W.M. Reid, and H.W. Yoder, Jr., eds. Iowa State University Press.

Chapter 2: The Effects of Social and Environmental Enrichments on Leg Strength and Welfare of Tom Turkeys

2.1 Introduction

The poultry industry is under constant scrutiny for its level of concern regarding bird welfare. Evidence of high mortality rates, leg disorders, breast blisters and visualizations of over-crowded dark barns that lack cognitive stimuli can markedly affect public perception, placing pressure on poultry producers to improve the quality of life for birds in their care.

For decades, the poultry industry has worked hard to produce large, fast growing and disease resistant birds, minimizing the number of birds necessary to supply the demand of society at an affordable price. Genetic advancements, nutrient supplementation and large integrated confinement systems have made the poultry industry the leading producer of affordable animal protein.

It is not uncommon for turkey producers to realize 10-13% mortality rates in a flock of birds. In 2010, 2.8 million turkey poults were hatched but only 2.5 million turkeys were raised to slaughter (USDA, 2010). With an average wholesale price of 61 cent per lb, mortality losses are estimated to be near 16.4 million dollars annually for the U.S. turkey industry..

Economic loss is only one of the concerns to address due to such a staggering mortality rate. Many welfare implications also become obvious; birds die of starvation and dehydration (Savory, 1982), others will die of exsanguinations when the femoral artery is severed by a spiral fracture fragment of the femur or when downer birds are killed by aggressive birds in the flock (Crespo et al., 1999; Julian, 2005). Many birds are simply culled because of mobility abnormalities and lack of growth performance.

Some of the mortality rate is due to starvation and dehydration in the first few days of life. Starvation and dehydration are painful and with proper management preventable (Aziz, 2002). Carver et al (1991) reported that up to 2.11% of early hen mortality and up to 5.76% of early tom mortality were due to poor management, placement practices and environment. Inadequate placement practices and poor environmental conditions may be one of the leading factors causing a condition called "starveout". Starve-out can be defined as death due to the failure to consume feed or water. This condition will peak at 3-5 days of age. Savory (1982) found that adding broiler chicks to a population of turkey poults decreased early mortality and stimulated early growth. Few researchers have studied the idea of social enrichments to stimulate early turkey poult feeding behavior.

As much as 5% of the mortality rate in high average gain tom turkeys is associated with leg problems (Ferket et al, 2009). Leg disorders observed in tom turkeys include: infected hocks, valgus-varus deformation, tibia dyschondroplasia, femoral head necrosis, spondylolisthesis, osteomyelitis and pododermatitis (Vaillancourt et al., 1999; Clark, 2002; Julian, 2005). It is estimated that leg abnormalities in turkey toms may exceed 15%, but are not always visible (Lilburn, 1994). Leg problems are not only an economic burden to the turkey producer, but are one of the most prevalent welfare problems facing the industry.

It has been reported in many species that physical activity improves bone mass and decreases bone abnormalities (Balog et al., 1997; Hiney et al., 2004a,b; Foutz et al, 2007). Increasing environmental complexity has shown promising results to promote activity and improve both the physical and psychological well-being in farm animals (Newberry, 1995; Wemelsfelder and Birke, 1997; Mench and Duncan, 1998). Poultry research has focused most of its efforts on the broiler chicken; less is known about the effects of increasing environmental complexity on the tom turkey.

The objective of this research are two fold: to determine the effects of broiler chick addition on early mortality due to starve-outs and the effects of providing environmental enrichments on leg strength and welfare of tom turkeys.

2.2 Materials and Methods

2.2.1 Birds and Environment

Two trials were conducted 15 months apart, each consisting of two different and independent enrichments. Trial 1, enrichment A, utilized 248 one-day-old broad breasted Hybird white tom turkey poults and 8 three-day old Ross cross broiler chicks. Birds were wing-banded and randomly assigned to 8 pens containing 32 birds each (4 replicates for each treatment). Trial 2, enrichment A, utilized 296 one-day-old broad breasted Hybrid white tom poults and 24 three-day old Ross cross broiler chicks were randomly assigned to 16 pens containing 20 birds per pen (4 replicates for each treatment). Each flock was kept in a 3 m^2 floor pen with a 70 cm draft shield. Wood-shavings were used as bedding. A brooding lamp was placed above each pen and remained on 24 hours a day for the first 2 weeks. Temperature at head height of the poults was set at 95°F for the first week and was decreased by 5° F the second week by raising the heat lamps approximately 15 cm. Trial 1, enrichment B, started at 14 days of age. The draft shields and broiler chicks were removed from the pens. Birds were re-randomized into eight 34.75 m^2 pens containing 30 birds per pen (1.15 m^2/ bird). Birds were reared to 20 weeks of age. All birds were provided ad libitum access to a five phase feeding program (Table 1). Trial 2, enrichment B, started at 12 days of age and consisted of 288 broad breasted Hybrid white tom turkeys randomly assigned to 8 pens containing 36 birds per pen (4 replicates for each treatment). Birds were reared to 12 weeks of age. At the start of enrichment B for both trials a 20 hour light: 4 hour dark lighting program was implemented. Room temperature at the start of experiment 2 for both trials was 85°F and was decreased by 5°F each week until 70°F was obtained. All birds in trial 2 were provided ad labium access to a three phase feeding program (Table 2).

2.2.2 Experimental Design

Trial 1, enrichment A, consisted of two treatments: control and socially enriched. The control group utilized 32 turkey poults per pen. Placement procedure included dipping each poults beak into the water and then into the feed to acclimate the poults to resource location. The socially enriched groups consisted of 30 turkey poults and 2 three-day-old broiler chicks placed together with no assistance in finding feed or water for the treatment groups. Trial 2, enrichment A, consisted of four treatments: control, unassisted, socially enriched low and socially enriched high. Control and unassisted groups consisted of 20 one-day-old poults. Control birds were reared using the placement procedure as described above. Unassisted poults were place in their pens and left to their own cognition to find resources. Socially enriched low groups consisted of 18 poults and 2 three-day-old broiler chicks. Socially enriched high group consisted of 16 poults and 4 broiler chicks. Socially enriched poults received no assistance in finding resources. Trial 1, enrichment B, consisted of two treatments: control and environmentally enriched. Four pens of 30 poults were used as control groups. These pens were barren except for two 60 cm round feeders and an automatic hanging waterer positioned approximately in the same place as the enriched pens. Four pens of 30 poults were enriched with a 1.2m^2 platform placed in the center of the pen. To accommodate access to the platform two adjustable ramps (1.2m long), one on each side of the platform at opposite corners (Figure 1) were available for poults to utilize. Ramps were set at 46 cm in height from 2 to 6 weeks of age and then raised to 77 cm for the remainder of the trial. One 60 cm round feeder was placed 15 cm above the platform enrichment and another feeder was placed 15 cm above the floor on the opposite side of the pen along with an automatic hanging bell waterer. Trial 2, enrichment B, consisted of 36 birds per pen with two treatments similar to trial one with the exception of enrichment design and placement. Trial 2 enrichment design consisted of a 1.5 m^2 platform with a fixed 1.65 m ramp leading to the platform with side rails placed in the back half of the pen opposite the door (Figure 2). Two perches were provided, 1 x 73 cm above the platform and 1 x 55 cm above the floor. A 4.4 m rope was attached to the ceiling with knots and a doughnut toy attached to it to stimulate play in the enriched pens.

2.2.3 Body Weights, Feed Consumption and Mortality

Body weights were measured at 1, 7 and 14 days of age in Trial 1, enrichment A and reported as weekly weight gain. Trial 2, enrichment A body weights were individually measured on day 1, 4, 8 and 12. Average g/bird gained was calculated and reported. Feed intake was measured daily and reported as average total feed consumed per bird per day for Trial 1, enrichment A. Trial 2, enrichment A feed intake was measured daily and calculated as average daily intake. Daily intake calculation for socially enriched groups was as follows: grams of feed consumed – (average daily broiler intake * number of broilers)/number of poults in the pen. Body weights were individually measured at the beginning of both Trials for enrichment B and were conducted monthly until the end of each trial. Feed consumption for both trials was collected weekly and calculated as average g/bird/day and grams consumed by location of feeders. Feed intake was calculated by: total feed per pen consumed weekly/number birds per pen. Mortality for both trials and experiments was collected daily and reported as percent mortality.

2.2.4 Behavior Observations

Trial 1, Enrichment A time budgets were collected by scan sampling and were conducted at 2, 8 and 14 days of age. Video recorders were set at 0900 h and allowed to record for 8 consecutive hours. The number of poults observed performing one of four exclusive activities (eating, drinking, active or resting) were scanned and recorded every 10 minutes. Definitions of each category were as follows: eating- time spent within one inch of feeder and standing; drinking- time spent within one inch of waterer and standing; active-a bird that was standing, moving or interacting with a pen mate while standing; resting-a bird that was laying down with no discernable movement. Trial 1, enrichment B time budgets were collected by scan sampling and were conducted at monthly intervals starting at one month of age. Procedures followed the same rules and definitions as Trial 1, enrichment A. Trial 2, enrichment A time budget measurements were conducted live at 0900 hours for 1 hour and again at 1400 hours for 1 hour with scan samples taken at 10 minute intervals. Measurements were taken daily for the first 7 days of age and calculated as percent time spent eating, drinking, active and resting per day. Trial 2, enrichment B time budget collection was conducted as previously described at 2, 7 and 11 weeks of age. At 5 and 10 weeks of age, birds were counted and marked with a green colored sharpie to indicate the presence on the platform enrichment. At one hour intervals birds were counted and marked for 6 consecutive hours. Birds that were found on the enrichment that were already marked with a green sharpie were then marked with a red sharpie. Frequency of use was calculated by number of birds on the enrichment per day divided by the number of birds in the pen. Repeated use was calculated by number of times a marked bird was counted on the enrichment.

2.2.5 Leg Strength and Dressing Percentage Data

Monthly gait scores were determined using a scale ranging from 1 to 3. A score of 1 indicated a severe abnormality in walking pattern and refusal to run, a score of 2 indicated a slight abnormality in walking pattern and a hesitation to run and a score of 3 represented no detectable impairment of walking and able to run when encouraged (scale adapted from Kestin et al, 1992). At the end of Trial 1, ten birds per pen and at the end of Trial 2 five birds per pen were euthanized by electric stunning followed by exanguinations and processed in the UNL Animal Science Poultry facility. One tibia bone was excised from each of the turkeys processed. Bone quality measurements were determined using tibial dyschondroplasia scores (TD), percent bone ash, and bone tibial length and diameter. Tibial dyschondroplasia scores were determined using the right tibias and scored by amount of cartilage proliferations ranging from 0 to 3. A score of 0 = no TD lesions present, 1 = lesions less than 4.5 mm, 2 = lesions greater than 4.5 mm and less than 10 mm and 3 = lesions greater than 10 mm (scale adapted from Edwards and Velmann, 1983). Carcass yield percentage was calculated for both trials as: Kg hot carcass weight/ Kg live weight. Heart weight was measured in Trial 2 only and calculated as % heart weight of live weight.

2.2.6 Statistical Analysis

Data were analyzed using repeated measures analysis of variance implemented in SAS PROC MIXED software (SAS® Institute, 2009), for all measurements excluding bone quality and dressing percent. Treatments were arranged in a randomized complete block design. Blocks were selected by location and were considered random effects. Treatments were considered fixed effects and evenly distributed between two blocks. Appropriate covariance structures were chosen based on the least of AIC/BIC best fit statistic. Mortality data were transformed by arc sin transformation. Bone quality and dressing percentage data were analyzed also using PROC MIXED software (SAS® Institute, 2009).

2.3 Results

2.3.1 Trial 1 Enrichment A

2.3.1.1 Production Parameters

There were no significant treatments or time by treatment effects with regards to feed intake. Weight gain was significantly higher for the control group when compared to the broiler added group in the second week of production at 192.4g and 181.2g, respectfully (P=0.0895) (Table 3). Overall feed to gain ratio was nearly identical for each treatment group. Mortality was significantly higher in the broiler added group when compared to the control, 0.0%, 2.5%, respectfully (P=0.0046) (Table 3).

2.3.1.2 Behavior

Poults spent more time being active, not including time spent eating or drinking, in both treatment groups at days 2 and day 14, than at day 8 (P=0.0818) (Table 4). The control poults spent 5.9% more time being active, not including time spent eating and drinking, than the broiler added group; however this effect was not significant (P=0.2091). Time spent active including time spent eating and drinking was not significantly different throughout the fourteen day period (P=0.7039); however at day fourteen the broiler added group spent 4.1% more time active including eating and drinking than the control and this effect was significant (P=0.0123) (Table 4). There were no significant differences in time spent eating for either treatment groups or at any time. Time spent drinking was not significantly different between treatment groups (P=0.8354); however both treatment groups spent more time on day 2 drinking than at either day 8 or 14 (P=0.0266). Overall, time spent resting was not significantly different between treatment groups (P=0.7039); however at day 14 the control group spent 4.1% more time resting than the broiler added group (P=0.0123)(Table 4).

2.3.2 Trial 1 Enrichment B

2.3.2.1 Production Parameters

There were no treatment differences between the control groups and the enriched groups for average daily feed intake (P=0.5913)(Table 5). There was a significant difference in feed intake with regard to location of feeders for both the control and the enriched groups (P<0.0001). Feeders located in the front of the pens were preferred to the feeders in the back of the pen regardless of enrichment presence. There was no differences in overall weight gain for either groups (P=0.2627)(Table 5); however there was a significant decrease in weight gain for the enriched groups in the last month of production (P=0.0294)(Figure 3). Feed to gain ratio was nearly identical in both groups. Percent mortality was 3.3% higher in the control groups; however this effect was not significant (P=0.4496)(Table 5)

2.3.2.2 Behavior

There were no significant differences in average time spent active, not including eating and drinking for the control groups or the enriched groups (P=0.8139)(Table 6). There was a significant increase in activity in the fourth month of production in both the control and the enriched groups (P<0.0001). Average time spent drinking was also significantly increased in the fourth month of production (P=0.0109) for both treatment groups (Table 6). There were no significant treatment difference in average time spent eating or time effects. Time spent active, including eating and drinking, was significantly increased in the fourth month of production (P=0.0004) (Table 6). There were no differences between treatments in time spent active, including eating and drinking. There were no treatment differences in average time spent resting (P=0.3915)(Table 6.). There was a significant reduction in time spent resting in the last month of production (P=0.0004) for both treatment groups.

2.3.2.3 Leg Quality and Dressing Percent

There was no evidence of tibial dyschondroplasia in any of the turkeys sampled. There was no effect of environmental enrichment on gait score, dressing percent or bone diameter (Table 7) Bone length tended to be longer in the enriched group averaging 238.15 cm when compared to the control group which averaged 236.29 cm (P=0.2732). Percent bone ash was slightly higher in the control group than the enriched group; however this effect was not significant (P=0.1678) (Table 7).

2.3.3 Trial 2 Enrichment A

2.3.3.1 Production Parameters

There were no significant overall treatment differences in feed intake (P=0.2111) (Table 8) There was a significant higher feed intake when comparing the single species groups (235.4g, 232.3g) to the broiler add groups, (223.6g, 227.4g), respectfully (P=0.0543). The higher density broiler added group (4:16 B:T) had a higher total feed intake then the lower density broiler added group (2:18 B:T); however this effect was not significant (P=0.5173) (Table 8). There were no overall treatment differences in weight gain (P=0.4551) (Table 8). There were also no differences in broiler added groups when compared to none broiler added groups. There were no differences in weight gain with level of assistance (P=0.3644). Feed to gain ratio was significantly lower for the broiler added groups (P=0.0195); however density of broiler addition was not a factor (P=0.4376). There was no treatment by time interactions for any of the production parameters measured. The treatment group that received no assistance did have a higher mortality percentage; however this effect was not significant (P=0.5780) (Table 8).

2.3.3.2 Behavior

There was no overall significant difference in average time spent active, not including eating and drinking between treatments (P=0.4497) (Table 9,10). Day 1 time spent active, not including eating or drinking was significantly higher than any other days measured (P=0.0001). On day 2 and then again on day 7, there was a significantly higher percentage of poults that were active, not including eating and drinking, in the higher broiler density group (4:16 B:T) then the lower density (2:18 B:T) group (P=0.0404), (P=0.0127), respectfully (Table 10). Average time spent active, including eating and drinking, was significantly higher in the higher broiler density groups (4:16 B:T) then the lower density (2:18 B:T) group day 2 and day 7. There was no overall time x treatment interactions for percent time active not including eating and drinking or time spent active including eating and drinking, (P=0.2732), (P=0.3353), respectfully. There was a significant overall treatment effects for average time spent eating (P=0.0975). On day 3 there was a significantly higher percent time eating in the all of the assisted groups, whether it be assisted by human intervention or assisted by broiler addition, when compared to the unassisted group (P=0.0148) (Table 10). Time spent eating in all treatment groups were higher on day 1, than on any other day measured (P=.0001). Time spent drinking was significantly higher in the non-assisted poults on day 1 and 2 (P=0.0572), (P=0.0854), respectfully, then any of the assisted groups. On day 2 poults in the broiler added groups spent less time drinking then the poult only groups (P=0.0184) (Table 10). Poults spent less time resting on day 1 in all treatments than any other time measured (P=.0001). The higher density broiler added group spent less time resting than the lower density broiler added group on day 1 and on average (P=0.0543), (P=0.0625), respectfully.

2.3.4 Trial 2 Enrichment B

2.3.4.1 Production Parameters

Feed intake was nearly identical in the control and the enriched groups at 138.5g and 139.2g, respectfully (P=0.8804) (Table 11). Weight gain was higher in the enriched group (3.15 kg), than the control group (3.10 kg); however this effect was not significant (P=0.2867). Feed to gain was slightly lower in the enriched group then the control at 2.06 g:g and 2.08 g:g, respectfully; however this was not significant (P=0.8098). Mortality was 2.1% higher in the control group than the enriched group, however this effect was not significant (P=0.4221) (Table 11).

2.3.4.2 Behavior

There were no significant treatment differences between the control groups and the enriched groups in average time spent active, not including or including eating and drinking (P=0.5595),(P=0.6485), respectfully. There was a significant decrease in time spent active, not including and including eating and drinking, as the turkeys aged (P=0.0497), (P=0.0341), respectfully (Table 12). There was no treatment by time effects for either activity calculation measurement. Time spent eating was significantly higher in the enriched groups when compared to the control on week 2 and 7, (P=0.0632), (P=0.0619), respectfully. Overall time spent eating was significantly greater in the enriched groups compared to the control group (P=0.0040). Again, time spent drinking was significantly greater in the enriched groups for week 2 and 7, (P=0.0231), (P=0.0569), respectfully. Overall, time spent drinking was also greater in the enriched groups compared to the control (P=0.0067). There were no significant treatment differences for time spent resting, nor were there any treatment by time interaction, (P=0.6488), (P=0.5170), respectfully. There was a significant increase in time spent resting as the turkeys aged (P=0.0341) (Table 12). At 5 weeks of age 72% of the turkeys visited the enrichment and 46% of the turkeys that visited the enrichment repeated the behavior. At week 10, 39% of the turkeys visited the enrichment with 25% of those turkeys repeated this behavior (Table 13).

2.3.4.2 Leg Quality and Dressing Percent

Turkeys exposed to the enriched environment had greater tibial bone length, when compared to non-enriched environments, 23.2 and 22.8, respectfully (P=0.0683). Cortical bone area was also slightly increased in groups exposed to the enrichment when compared to the control groups, 103.3 and 98.31; respectfully. However, this effect was not significant (P=0.3961). No effect of enrichment was found for gait score, dressing percent, percent heart weight, bone diameter, bone ash or mean cortical bone thickness (Table 14).

2.4 Discussion

It has been reported that the addition of broiler chicks to a group of day old turkey poults will stimulate feeding behavior and hence increase body weight gain and reduce early mortality (Savory 1982). These effects were reported using day old broiler chicks where as in the trial present here, three day old broiler chicks were utilized. The hypothesis was if day old broiler chicks could stimulate feeding behavior, then older broiler chicks that have had more experience in finding resources could be even more effective. This trial found no evidence that broiler chick addition influenced body weight gain or improved seven day mortality. Therefore it is possible that the benefit of broiler addition is reliant on the age of the broiler chick placed with the poults. In this trial, activity was greatest on the first day after placement. It was observed that the more experienced older broiler chick spent more of its time resting during the day of the poult placement than the day old poults. There may be metabolic triggers that stimulate the broiler chick to search for resources during the first days after hatch that are turned off after feed consumption. Broiler to poult density could also contribute to the difference in these observations. In the Savory trial, broiler to poult density was at 1:3 ratio; our trials had ratios of 1:15, 1:9 and 1:4 ratio. There were no consistent improvements demonstrated in either of our trials, except for a small improvement in feed to gain ratio in trial 2. This effect could be due to the differences in feed intake calculation in trial 2. When feed intake was calculated as total consumption in trial 2, feed intakes were greater in the broiler treatment groups; however, it is to be expected since the broiler chick is known to have a higher feed consumption rate than turkey poults at that age and the advanced age of the broiler chick probably compounded this affect. Mortality was significantly higher in the broiler enriched groups in Trial 1; however this may have been confounded by placement of two of the broiler enriched treatment groups in pens that had higher mortality throughout both trials and both enrichments. It is possible that the experimental design of the blocking constrains were not strong enough to eliminate this response.

In conclusion, more trials will need to be done to make a clear conclusion on the effectiveness of this method of rearing. Furthermore, in a large commercial setting this method of rearing may be impractical because of the need for early harvesting of the broiler in comparison to the turkeys. The stress of removal of the broilers may reduce the increased body weight of the turkeys at the end of the production period found in other trials (Savory 1982).

The addition of environmental enrichments has been studied in several species. The most frequently studied areas in poultry investigating environment enrichments have been in laying hens and broilers. Numerous studies have suggested that the inclusion of environmental enrichments will increase activity and therefore increase bone strength in both laying hens and broilers (Knowes and Broom, 1990, Hughes and Appleby, 1989, and Mench et.al., 2002). In a trial involving enriched laying hen facilities, mortality was increased in the enriched groups (Tactacan et.al., 2009). However, the benefits such as increased bone strength and the ability to express natural behaviors are believed to outweigh this effect. In the trials presented here activity was not affected by the enrichment. Therefore, the lack of improvement in bone quality was to be expected. If the enrichment had been large enough to ensure every turkey had to use it, it is possible that increased bone strength would have been realized. Production parameters may have improved if the enrichments were physically demanding enough to improve the mechanical loading of the body (Kjaer, 2004, Lanyon, 1993, Hiney et al., 2004a,b).

These current trials focused on increasing activity to improve leg strength; however the inclusion of the environment enrichment could provide some intrinsic behavioral needs as well. It was observed that the inclusion of enrichments in a group of turkeys' environment indicated a desire to perch, climb and/or play, showing a possible "need" to improve the health and well-being of the turkeys. Very few trials have been conducted looking at the basic behavioral needs of the turkey. In nature a turkey will roost in trees, hide in the brush and forage for food. It is possible that providing access to places to perch, hide and forage would deter turkeys from being destructive to their environment, reduce aggressive behavior toward pen mates and encourage activity to help develop bone structure and muscle deposition. The first trial's enrichment was designed to encourage activity by providing ramps to a food source. The platform was placed at a height that minimized the possibility of injury of falling from an excessively elevated position. However the square edges to the design proved to be injurious to the birds despite the low incline. After finding that the enrichment did not improve bone quality, a new design was developed for Trial 2. A steeper incline to the platform was provided and a barrier side were added to the platform to reduce injuries due to falling. Still no improvement were observed in regards to bone quality or production parameters. However, since the enrichment was not large enough to provide access to all of the turkeys at any given time it is possible that improvement could be realized if one could guarantee every turkey used the enrichment.

In conclusion, the design and application of environmental enrichments for turkeys needs to be refined. Consumer demand is strong for producers to ensure that production animals have everything they need to be healthy and comfortable. Because enrichments have been found to improve production and health related issues in other species it would be beneficial to continue to design enrichments to realize these benefits in turkeys. Further attention to the intrinsic behavioral needs of the turkey may give light to the most appropriate designs.

2.5 References

Aziz,T., 2002. Early mortality and starveout in poults can be reduced. World Poultry Vol. 17, No. 2 '01.

Balog, J.M., B. R. Bayyari, N. C. Rath, W. E. Huff and N. B. Anthony. 1997. Effect of intermittent activity on broiler production parameters. Poult. Sci. 76, 6-12.

Carver, D. K., J. Fetrow, T. Gerig, M. T. Correa, K. K. Krueger and Barnes, H. J. 2000. Use of Statistical Modeling to Assess Risk for Early Poult Mortality in Commercial Turkey Flocks. J. Appl. Poult. Res. 9: 303-318.

Clark S., G. Hansen, P. McLean, P. Bond Jr, W. Wakeman, R. Meadows, and S. Buda. 2002. Pododermatitis in turkeys. Avian Dis. 46(4):1038-44.

Crespo, R., S. M. Stover, R. Droual, R. P. Chin, and H. L. Shivaprasad. 1999. Femoral fractures in a young male turkey breeder flock. Avian Dis. 43:150-154.

Ferket, P. R., E. O. Oviedo-Rondon, P. L. Mente, D. V. Bohorquez, A. A. Santos .Jr., J. L. Grimes, J. D. Richards, J. J. Dibner, and V. Felts. 2009. Organic trace minerals and 25-hydroxycholecalciferol affect performance characteristics, leg abnormalities, and biomechanical properties of leg bones of turkeys. Poultry Science 88:118-131.

Foutz, T.L., A. K. Griffin, J. T. Halper, and G. N. Rowland. 2007. Effects of activity on avian gastrocnemius tendon. Poultry Science 86:211-218.

Hiney, K.M., B.D. Nielsen, M.W. Orth, D.S. Rosenstein and B.P. Marks. 2004a. Short duration, high intensity exercise alters bone density and shape. J. Anim. Sci. 82(6):1612- 1620.

Hiney, K.M., B.D. Nielsen and D.S. Rosenstein. 2004b. Short-duration exercise and confinement alters bone mineral content and shape in weanling horses. J. Anim. Sci. 82(8):2313-2320.

Hughes, B. O., and M. C. Appleby. 1989. Increase in bone strength of spent laying hens housed in modified cages with perches. Vet. Rec. 124:483–484.

Julian, R. J. 2005. Production and growth-related disorders and other metabolic diseases of poultry—A review. Vet. J. 169:350–369.

Kjaer, M. 2004. Role of Extracellular Matrix in Adaptation of Tendon and Skeletal Muscle to Mechanical Loading. Physiol Rev 84:649–698.

Knowles, T. G., and D. M. Broom. 1990. Limb bone strength and movement in laying hens from different housing systems. Vet. Rec. 126:354–*356.*

Lilburn, M.S., 1994. Skeletal growth of commercial poultry species. Poultry Sci. 73:897-903.

Mench J.A., Duncan I.J.H. (1998) Poultry Welfare in North America: Opportunities and Challenges Poultry Science 77:1763-1765.

Mench J.A., J.P. Garner and C. Falcone. 2002. Behavioural activity and its effects on leg problems in broiler chickens. British Poultry Science 43(3): 355-363.

Newberry, R.C., 1995. Environmental enrichment: Increasing the biological relevance of captive environments. Applied Anim. Behav. Sci., 44: 229-243.

Repeated Measures Analysis of SAS® software (Proc Mixed, SAS® Institute, 2009)

Savory, C.J.,1982. Effects of broiler companions on early performance of turkeys. British Poultry Science, 23: 81-88.

Strobel, M. G. and G. E. Mac Donald. 1974. Induction of eating in newly hatched chicks. Journal of Comparative and Physiological Psychology, 86: 493-502.

Tactacan, G.B., W. Guenter, N. J. Lewis, J. C. Rodriguez-Lecompte and J. D. House. 2009. Performance and welfare of laying hens in conventional and enriched cages. Poult. Sci. 88:698-707.

USDA, 2010. www.nass.usda.gov/quickstats/index2.jsp.

Vaillancourt J-P, P.C., L. Ivy, J. Barnes, D. Wages, and L. Baucom. 1999. Causes of mortality in male turkeys during the last part of grow-out. Pages 87-88 In: Proceedings of 48th Western Poultry Disease Conference, April 25-27, 1999.

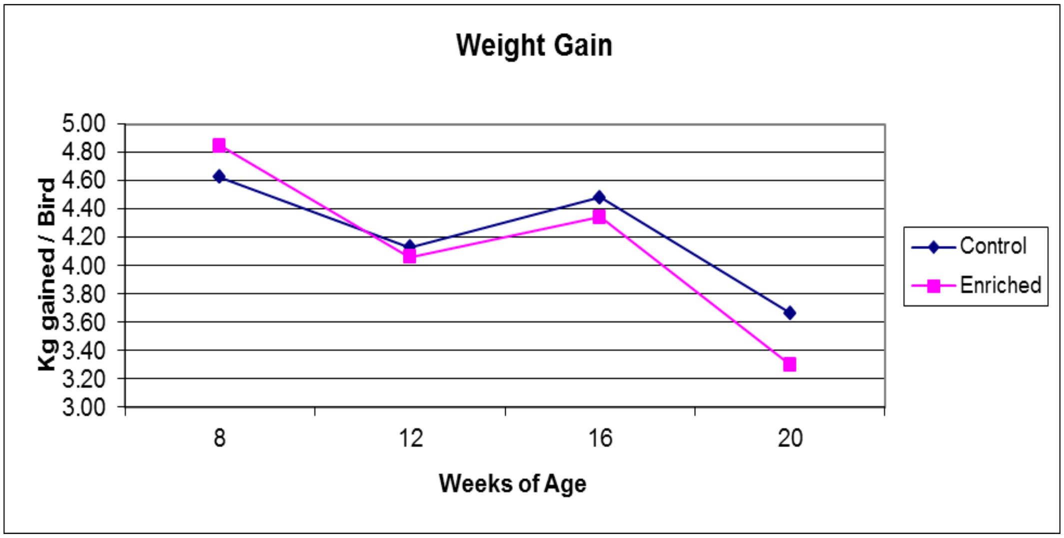
Wemelsfelder, F., and L. Birke. 1997. Environmental challenge. Pages 35-47 in Animal Welfare. M. C. Appleby and B. O. Hughes, ed. CAB International, Wallingford, UK.

2.6 Figures

Figure 1. (Trial 1 Enrichment B)

Figure 2. (Trial 2 Enrichment B)

Figure 3. Weight Gain by Month (Trial 1, Enrichment B).



	Weeks of Age			
Treatment	8	12	16	20
Control	4.63	4.13	4.48	3.67
Enriched	4.85	4.06	4.34	3.30
P-value	0.1690	0.6528	0.3753	0.0294
SEM	0.1527	0.1527	0.1527	0.1527

2.7 Tables

Table 1. Feed composition for a 5 phase feeding program. Trial 1.

	Starter 1	Starter 2	Grower	Developer	Finisher
Fine ground corn	45.01	40.05	57.8	65.91	73.72
Soybean meal - 47%	49.34	48.89	34.54	24.76	18.50
Corn oil	0.93	5.10	3.21	5.90	4.70
Dical. Phos.	1.90	3.78	2.61	1.80	1.60
Limestone	2.28	1.50	0.90	1.16	1.05
Salt	0.37	0.32	0.40	0.17	0.10
Lysine	0.03	0.10	0.30	0.08	0.14
Methionine	0.14	0.16	0.14	0.12	0.09
Vitamin/Mineral premix	0.10	0.10	0.10	0.10	0.10
Calculated Composition:					
ME, kcal/kg	2698.00	2926.90	3016.00	3253.40	3275.10
CP %	27.41	26.80	22.05	18.13	16.03
Ca, %	1.41	1.50	0.99	0.90	0.80
NPP, %	0.51	0.85	0.61	0.45	0.40

Table 2. Feed composition for a 3 phase feeding program. Trial 2.

	Starter 1	Grower	Finisher
Fine ground corn	45.01	57.8	73.72
Soybean meal - 47%	49.34	34.54	18.50
Corn oil	0.93	3.21	4.70
Dical. Phos.	1.90	2.61	1.60
Limestone	2.28	0.90	1.05
Salt	0.37	0.40	0.10
Lysine	0.03	0.30	0.14
Methionine	0.14	0.14	0.09
Vitamin/Mineral premix	0.10	0.10	0.10
Calculated Composition:			
ME, kcal/kg	2698.00	3016.00	3275.10
CP %	27.41	22.05	16.03
Ca, %	1.41	0.99	0.80
NPP, %	0.51	0.61	0.40

Table 3. Feed intake, weight gain, feed:gain, and mortality of single-species and mixed species groups to 14 days of age (Trial 1, Enrichment A).

Main Effects	Treatment Control	Broiler-added	P-value	SEM	Trt*Time P-value
Feed Intake (g/poult/day)					
Day 3	7.3	7.3	0.8987	0.530	
Day 6	15.5	16.6	0.1291	0.618	
Day 10	28.9	29.4	0.7782	1.704	
Day 14	52	49.8	0.2391	1.456	
Overall Average	25.92	25.79	0.8664	0.533	0.2765
Weight gain (g/poult/week)					
1 to 7 Days	101.3	108.0	0.2074	6.510	
8 to 14 days	192.4	181.2	0.0895	2.230	
Overall Average	146.84	144.59	0.3092	1.927	0.1237
Feed:Gain (g feed/ g gained)	1.28	1.27	0.7150	0.026	---
Mortality %	0	2.5	0.0046	0.014	---

*Mortality was analyzed using an arc sin transformation.
*Values are presented as lsmeans with SEM being the standard error of the lsmeans.

Table 4. Behavior of single-species and mixed species groups (Trial 1, Enrichment A).

Behavior:	Day of Age 2	8	14	Average	Time P-value	Trt*Time P-value
% Active not Eating/Drinking						
Control	27.8	20.9	26.8	25.2	0.0820	0.5513
Broiler added	21.9	20.7	26.5	23.0		
P-value	0.2091	0.9726	0.8644	0.2328		
SEM	5.9200	4.3570	1.7132	1.6110		
% Active including Eating/Drink						
Control	58.3	38.3	40.5	45.7	0.1128	0.5369
Broiler added	50.5	37.6	44.6	44.2		
P-value	0.4863	0.8925	0.0123	0.7039		
SEM	10.5642	5.1736	1.1053	3.7977		
% Eating						
Control	24.3	13.3	12.4	16.6	0.1117	0.6290
Broiler added	22.6	12.9	13.4	16.3		
P-value	0.7719	0.9293	0.7564	0.8404		
SEM	5.3034	4.1937	2.6246	1.7246		
% Drinking						
Control	6.6	4.7	5.5	5.6	0.0266	0.3154
Broiler added	5.9	4.0	7.7	5.9		
P-value	0.6042	0.5580	0.3441	0.8354		
SEM	1.3220	1.1678	2.1135	1.2755		
% Resting						
Control	41.7	61.7	59.5	54.3	0.1128	0.5369
Broiler added	49.5	62.4	55.4	55.8		
P-value	0.4863	0.8925	0.0123	0.7039		
SEM	10.5642	5.1736	1.1053	3.7977		

*Values are presented as lsmeans with SEM being the standard error of the lsmeans.

Table 5. Feed intake, weight gain, feed:gain, and mortality. (Trial 1, Enrichment B).

	Treatment				Trt*Time
	Control	Enriched	P-value	SEM	P-value
Feed Intake (g/bird/day)	226.6	229.8	0.5913	4.046	0.2834
Feed Intake by Location					
Front	236.1	239.2	0.5284	4.929	
Back	217.1	220.5	0.4943	4.929	
Weight gain (kg/bird/month)	4.23	4.14	0.2627	0.054	0.0968
Feed:Gain (kg/kg)	3.12	3.14	0.8448	0.065	---
Mortality (%)	0.2787	0.2224	0.4496	0.048	---

*Mortality was analyzed using an arc sin transformation.
*Values are presented as lsmeans with SEM being the standard error of the lsmeans.

Table 6. Behavior: (Trial 1, Enrichment B).

Behavior:	Month of Age 1	2	3	Average	Time P-value	Trt*Time P-value
% Active not Eating/Drinking						
Control	20.8	18.8	36.5	25.3	0.0001	0.3222
Erinched	22.3	22.7	33.8	26.3		
P-value	0.737	0.5363	0.5405	0.8139		
SEM	4.2976	6.0581	4.1945	3.7160		
% Active including Eating/Drink						
Control	41.6	36.0	62.5	46.7	0.0004	0.9589
Erinched	48.6	42.2	67.0	52.6		
P-value	0.4197	0.5910	0.5832	0.3915		
SEM	8.3608	11.2432	7.9238	6.4013		
% Eating						
Control	16.1	13.4	19.7	16.4	0.1440	0.8134
Erinched	24.2	15.7	26.9	22.3		
P-value	0.1816	0.7671	0.2012	0.1440		
SEM	5.6380	7.5371	5.3144	3.6320		
% Drinking						
Control	4.7	4.0	6.6	5.1	0.0109	0.4453
Erinched	2.6	4.2	6.1	4.3		
P-value	0.1910	0.9306	0.7239	0.5133		
SEM	1.4862	2.1927	1.4749	1.1790		
% Resting						
Control	58.4	63.8	38.3	53.5	0.0114	0.5761
Erinched	37.4	55.1	28.9	40.5		
P-value	0.0530	0.4843	0.3103	0.1049		
SEM	7.297	11.964	8.677	6.784		

*Values are presented as lsmeans with SEM being the standard error of the lsmeans.

Table 7. Gait Score, dressing percent, bone length, bone diameter and bone ash. (Trial 1,Enrichment B).

	Treatment			
	Control	Enriched	SEM	P-value
Gait Score	2.93	2.96	0.0283	0.5645
Dressing Percent (%)	81.4	81.6	0.8985	0.9171
Bone Diameter (mm)	16.7	16.7	0.1336	0.7179
Bone Length (mm)	23.63	238.1	1.1790	0.2732
Bone Ash (%)	39.8	39.1	0.3226	0.1678

*Values are presented as lsmeans with SEM being the standard error of the lsmeans.

Table 8. Feed intake, weight gain, feed:gain, mortality and behavior of single-species and mixed species groups to 12 days of age (Trial 2, Enrichment A).

	Treatment						
	Assisted	No-Assistance	2:18 B:T	4:16 B:T	P-value	SEM	Trt*Time P-value
Feed Intake	235.4	232.3	223.6	227.4	0.2111	0.3663	0.1357
Contrasts							
Broiler added vs. None					0.0543		
Assisted vs. None					0.4586		
2:18 vs. 4:18 B:T					0.5173		
Weight gain	205.7	203.1	204	209.9	0.4551	1.0240	0.4291
Contrasts							
Broiler added vs. None					0.4254		
Assisted vs. None					0.3644		
2:18 vs. 4:18 B:T					0.2102		
Feed:Gain (g:g)	1.05	1.05	1.01	0.99	0.0941	0.0160	0.8626
Contrasts							
Broiler added vs. None					0.0195		
Assisted vs. None					0.1826		
2:18 vs. 4:18 B:T					0.4376		
Mortality (%)	1.25	5.00	1.25	1.25	0.5780	0.0750	---

[1]Feed intake was calculated as g consumed/poult
[2]Weight gain was calculated as g gained/poult.
[3]Feed: Gain was calculated as grams fed to grams gain.
[4] Mortality was analyzed using an arc sin transformation.
[5]Values are presented as lsmeans with SEM being the standard error of the lsmeans.

Table 9. Behavior of single-species and mixed species groups (Trial 2, Enrichment A).

	Day of Age							
Behavior:	1	2	3	4	5	6	7	Average
% Active not Eating/Drinking								
Assisted	43.7	17.8	15.1	17.2	20.6	12.7	13.8	20.1
No-Assistance	40.8	25.8	15.1	21.2	27.0	19.9	12.0	23.1
2:18 B:T	49.6	11.9	16.2	20.7	32.0	23.3	11.9	23.7
4:16 B:T	45.0	26.4	20.0	20.5	18.6	18.7	17.5	23.8
% Active including Eating/Drink								
Assisted	68.3	27.9	34.8	40.2	45.8	37.3	28.3	40.4
No-Assistance	77.0	36.2	28.7	38.7	46.8	50.2	28.5	43.7
2:18 B:T	68.8	19.0	34.0	42.5	54.5	47.4	25.3	41.6
4:16 B:T	76.3	35.7	35.3	42.2	45.8	48.7	39.0	46.1
% Eating								
Assisted	28.4	17.6	12.0	13.3	17.7	13.8	10.3	16.2
No-Assistance	34.2	14.4	6.0	10.8	17.3	16.9	10.3	15.7
2:18 B:T	21.9	11.7	10.5	14.6	18.0	14.5	11.1	14.6
4:16 B:T	30.4	11.2	9.3	11.7	19.4	17.3	14.1	16.2
% Drinking								
Assisted	3.3	2.8	3.4	3.0	3.0	5.2	4.7	3.6
No-Assistance	6.9	3.1	3.5	3.7	3.5	4.5	2.3	3.9
2:18 B:T	1.6	1.0	2.7	3.4	3.4	5.6	3.3	3.0
4:16 B:T	3.1	2.2	4.2	3.4	5.6	4.1	3.6	3.8
% Resting								
Assisted	31.5	72.4	65.1	60.1	52.4	62.7	71.7	59.4
No-Assistance	22.8	64.1	71.3	61.3	52.0	49.5	71.7	56.1
2:18 B:T	31.0	81.7	65.9	57.7	45.8	52.4	74.9	58.5
4:16 B:T	24.7	64.4	64.7	57.9	54.1	51.4	59.3	53.8

*Values are presented as lsmeans.

Table 10. Behavior of assisted and none assisted poults (Trial 2, Enrichment A) (Statistical probabilities).

	Day of Age							
Behavior:	1	2	3	4	5	6	7	Average
% Active not Eating/Drinking								SEM
Main Effect								2.365
Treatment	0.8223	0.0909	0.7984	0.9421	0.6683	0.2092	0.0336	0.4497
Time x Treatment								0.2732
Contrast								
Broiler vs No	0.2530	0.3564	0.4242	0.6501	0.5592	0.5162	0.3311	0.3071
Assisted vs No	0.4744	0.3412	0.3741	0.5701	0.3841	0.2641	0.6371	0.8451
2:18 vs. 4:18	0.7331	0.0404	0.3573	0.6631	0.3421	0.9341	0.0127	0.3170
% Active including Eating/Drink								SEM
Main Effect								1.7430
Treatment	0.8902	0.1322	0.4421	0.8584	0.8403	0.3401	0.0740	0.1262
Time x Treatment								0.3353
Contrast								
Broiler vs No	0.9642	0.1734	0.3713	0.4512	0.4791	0.5592	0.2534	0.3842
Assisted vs No	0.5912	0.1523	0.1061	0.4272	0.4071	0.2963	0.8234	0.9301
2:18 vs. 4:18	0.6822	0.0825	0.7920	0.9950	0.8112	0.8462	0.0228	0.0150
% Eating								SEM
Main Effect								0.5800
Treatment	0.1352	0.3000	0.0370	0.1256	0.8564	0.6892	0.7854	0.0975
Time x Treatment								0.0433
Contrast								
Broiler vs No	0.3452	0.5642	0.6489	0.7543	0.9213	0.8567	0.7582	0.7621
Assisted vs No	0.1254	0.6457	0.0148	0.7584	0.8958	0.7594	0.6423	0.7894
2:18 vs. 4:18	0.4222	0.8823	0.5502	0.3872	0.7662	0.5724	0.4812	0.0150
% Drinking								SEM
Main Effect								0.305
Treatment	0.2650	0.1201	0.4462	0.9731	0.1402	0.5903	0.3442	0.9682
Time x Treatment								0.3864
Contrast								
Broiler vs No	0.8520	0.0184	0.6702	0.9761	0.0723	0.9721	0.7593	0.6852
Assisted vs No	0.0572	0.0854	0.4583	0.8523	0.4911	0.6371	0.1923	0.8502
2:18 vs. 4:18	0.3802	0.1053	0.2402	0.6793	0.0658	0.2302	0.7282	0.3423
% Resting								SEM
Main Effect								2.485
Treatment	0.9063	0.0814	0.4444	0.8602	0.8931	0.3413	0.0759	0.1525
Time x Treatment								0.3433
Contrast								
Broiler vs No	0.9212	0.1601	0.3672	0.4513	0.6382	0.5594	0.2533	0.8623
Assisted vs No	0.6971	0.1462	0.1063	0.4274	0.4723	0.2962	0.8233	0.0983
2:18 vs. 4:18	0.7272	0.0543	0.7923	0.9954	0.7923	0.8464	0.0502	0.0625

* SEM being the standard error of the lsmeans.
*P-values considered significant at the P<.1.

Table 11. Feed intake, weight gain, feed:gain, and mortality. (Trial 2, Enrichment B).

	Treatment				Time*Trt
	Control	Enriched	P-value	SEM	P-value
Feed Intake (g/bird/day)	138.51	139.15	0.8804	2.9735	0.8600
Weight gain (kg/bird/month)	3.10	3.15	0.2867	0.0313	0.6564
Feed:Gain (g feed:g gain)	2.08	2.06	0.8098	0.0703	--
Mortality	9.02	6.94	0.4221	0.0969	--

*Mortality was analyzed using an arc sin transformation.
* Values are presented as lsmeans with SEM being the standard error of the lsmeans.

Table12. Behavior. (Trial 2, Enrichment B).

Behavior:		Week of Age 2	7	11	Avg.	Time P-value	Time*trt P-value
% Active not Eating/Drinking							
	Control	38.7	35.4	32.0	35.4	0.0497	0.4682
	Erinched	37.6	31.5	33.7	34.3		
	P-value	0.7416	0.2275	0.6021	0.5595		
	SEM	3.2802	3.989	3.2802	1.3494		
% Active including Eating/Drink							
	Control	51.8	48.5	45.8	48.7	0.0341	0.5174
	Erinched	53.5	46.4	48.8	49.6		
	P-value	0.5955	0.5282	0.3687	0.6485		
	SEM	3.2595	3.2546	3.2595	1.3512		
% Eating							
	Control	11.9	11.3	11.8	11.7	0.5066	0.8647
	Erinched	13.4	12.7	12.7	12.9		
	P-value	0.0632	0.0619	0.2264	0.0040		
	SEM	0.7918	0.7905	0.7918	0.3200		
% Drinking							
	Control	1.4	1.6	2.1	1.7	0.4940	0.4220
	Erinched	2.3	2.3	2.3	2.3		
	P-value	0.0231	0.0569	0.5952	0.0067		
	SEM	0.4076	0.4074	0.4079	0.1654		
% Resting							
	Control	48.2	51.5	54.2	51.3	0.0341	0.5170
	Erinched	46.5	53.6	51.2	50.4		
	P-value	0.5955	0.5280	0.3686	0.6488		
	SEM	3.2597	3.2548	3.2597	1.3512		

*Values are presented as lsmeans with SEM being the standard error of the lsmeans.

Table 13. Percentage of birds that used the Enrichment. (Trial 2, Enrichment B).

Week of Age	% Birds Visited Enrichment	% Birds Repeated Visits
5 Weeks	72%	46%
10 Weeks	39%	25%

Table 14. Dressing percent, heart wt, bone length, bone diameter, bone ash, cortical bone area and mean cortical bone thickness (Trial 2, Enrichment B).

	Treatment			
	Control	Enriched	P-value	SEM
Gait Score	2.93	2.91	0.4258	0.5987
Dressing percent (%)	78.6	79.1	0.3360	0.3582
Heart Wt. (% BW)	0.46	0.44	0.7108	0.0218
Bone length (cm)	22.8	23.2	0.0683	0.1564
Bone diameter (mm)	16.8	17.1	0.3033	0.1925
Bone ash (%)	55.8	56.0	0.7974	0.3521
Cortical bone area (mm2)	98.62	103.31	0.3961	3.8566
Mean cortical bone thickness (mm)	2.36	2.44	0.4826	0.0800

*Heart weight is recorded as a percentage of body weight.
*Values are presented as lsmeans with SEM being the standard error of the lsmeans.