EVALUATION OF NUTRITION AND MANAGEMENT FACTORS IN THE ETIOLOGY OF PODODERMATITIS IN BROILER CHICKENS

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EVALUATION OF NUTRITION AND MANAGEMENT FACTORS IN THE

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THESIS ABSTRACT

EVALUATION OF NUTRITION AND MANAGEMENT FACTORS IN THE ETIOLOGY OF PODODERMATITIS IN BROILER CHICKENS

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The influence of nutrition and management factors in the etiology of pododermatitis (paw burns) was evaluated in three trials. Broilers of mixed sex were raised on four experimental diets with varying protein levels (high vs. low) and source (all vegetable vs. vegetable plus animal) in Experiment 1. In a subsequent trial, the effect of supplementation of feed-grade enzyme in the diets mentioned above was evaluated. In addition, the efficacy of a litter amendment to improve footpad quality in broiler chickens was evaluated in Experiment 3. In all experiments, footpads were scored on a three point scale scoring system at various ages to assess the incidence and severity of pododermatitis. Litter samples were analyzed for total and ammonia nitrogen in Experiment 1 and 2. Volatile ammonia was measured weekly in Experiment 3.

Protein level, protein source and sex had significant effects on pododermatitis (Experiment1). Pododermatitis incidence and severity was increased with high protein and all vegetable diets. Enzyme supplementation reduced the incidence of pododermatitis in all vegetable diets in Experiment 2. In Experiment 3, sodium bisulfate used as a litter amendment reduced volatile ammonia levels and lowered ($P>0.05$) the incidence and severity of pododermatitis.

The role of nutrition in the etiology of pododermatitis was significant. Sex effects were prominent with male broilers showing footpads with severe lesions in all of the trials conducted. In this study, enzyme supplementation had little effect on litter total and ammonia nitrogen levels and pododermatitis in broilers. It was observed in this study that use of litter amendments to convert volatile ammonia to an inert form may help in a program designed to reduce pododermatitis in broilers. Chicken feet are one of the processing by-products that have become a viable export commodity over the past decade with expanding markets overseas. The production of healthy chicken feet not only improves financial gains but also helps broiler producers comply with the animal welfare guidelines. As demonstrated in this study, a multi-factorial approach, including fine-tuning of feeding programs and management factors may be necessary to reduce the prevalence of pododermatitis in broiler chickens.

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I. INTRODUCTION

The transition of broiler industry from the backyard flocks of 1950's to the current commercial form of intensive production system has led to production of poultry meat to supply for the domestic consumption as well as expanding export markets. Currently, the U.S. poultry industry is one of the world's leading producers and exporter of poultry meat. According to the National Chicken Council, per capita consumption of broiler meat is about 39.2 kg of the total poultry meat (47.4 kg) consumed [1]. The domestic market primarily consists of whole cuts and/or parts, boneless-skinless meat and further processed products. The growing demand for least-cost, wholesome and convenient food products has been the driver for the expansion and diversification of the poultry industry.

The value of broilers produced during 2004 was $20.4 billion, up 34 percent from 2003 in the U.S. [2]. The new data released by the Economic Research Service in 2006 indicates that nearly 14% of total poultry produced is being exported. The broiler meat exports in 2005 were around 4.9 billion pounds. The largest of the importers are Russia (including Baltic countries) and China (including Hong Kong) accounting for 44% of the broiler products exported [3]. With such a tremendous growth of the global meat market, broiler producers are in continuous search for novel and innovative products to meet the market needs.

Chicken feet or paws (the portion of the feet cut just below the spur), are one of the new processing by-products that has an intense demand in recent years from the Southeast Asia. The exports of paws to countries like China and Hong Kong alone amounts to over $200 million each year. The financial incentive and the increasing demand have led to efforts to maximize the yield and quality of the chicken feet harvested. More recently, the condition of chicken feet is used as a production criterion to evaluate the animal welfare programs implemented by commercial poultry companies [4]. Downgrading of chicken feet due to pododermatitis, results in rejects and associated loss in the sale value of the product. The National Chicken Council recommends < 30% incidence of footpad lesions (pododermatitis) in commercial broiler flocks to meet the current animal welfare guidelines. Hence, there is a great necessity for research into the etiology of pododermatitis in broiler chickens [5]. The objective of this study was to identify the effect of various feeding programs and management factors on the incidence and severity of pododermatitis in broiler chickens.

II. LITERATURE REVIEW

Nearly nine billion broilers are processed each year in the United States and most of the by-products of processing are rendered into animal by-product meals. Over the past decade there has been a tremendous demand for chicken feet (paw) in Asian markets including China and Hong Kong [6]. Increasing demand for chicken feet overseas has produced a significant value to this by-product of processing, thus offering a profitable export market for broiler industry. The export value of chicken feet depends on size: small (22-26 g), medium (27-35 g) and jumbo (36-45 g), as well as quality (A or B grade) [7], and whether the feet are inspected for wholesomeness by the Food Safety Inspection Service of the USDA. Downgrading and condemnation may result from injuries to the bones, bruises, pigmentation on the skin and various systemic diseases and localized infections, such as pododermatitis. Downgrading results in a precipitous drop in the quantity available for sale and the value received for the exported chicken feet.

Commercial broiler flocks raised today may exhibit a range of skeletal and locomotor problems. Among the various leg abnormalities, pododermatitis or paw burns is a type of contact dermatitis commonly observed in poultry. Pododermatitis incidences of 0 to 100% in different broiler flocks have been reported [8]. On the average, 5-10% of the flock is affected with the severe form of pododermatitis [9] and nearly 0.2-0.3 % with breast blisters, a condition commonly associated with the severe form of pododermatitis [10].

Pododermatitis is basically a type of contact dermatitis primarily affecting the surface of the footpad, the hock joint and in severe cases extends to the breast area [11]. Histological lesions associated include non specific dermatitic lesions with secondary infections [12]. The lesions are superficial in mild cases but progress into deep ulcers as the condition worsens, resulting in pain and discomfort to the bird [13]. In mild lesions, the scab, when peeled off, removes the superficial epidermis leaving the basal layer of the epidermis intact. In severe cases, the ulcer is filled with congealed exudates and litter [11]. Progressing deep ulcers may lead to chronic abscessation and fibrosis of underlying synovial structures. The lesions serve as a portal of entry for bacteria [12]. Bacteria are commonly seen on the surface of stratum corneum and in the superficial splits of this layer but rarely in deeper layers [13]. Birds with severe lesions show slower weight gain and reluctance to move as they are obviously lame and experience pain-induced reduction in appetite.

The birds with pododermatitis also show higher tonic mobility, indicating an increased fear response [14]. In 1992, the UK's Farm Animal Welfare Council (FAWC) declared leg problems to be a major welfare problem in broiler production. While various live and processing operations (ineffective handling, transport, bruises, fractures, equipment mutilation and cuticle remnants) can lead to downgrading of chicken feet, pododermatitis remains to be the primary cause [15]. Moreover, severity of footpad lesions at slaughter has also been used to gauge the housing conditions and animal welfare programs employed by the poultry companies [16, 17].

The exact cause of pododermatitis is unknown, but a multitude of factors, such as market weight, litter conditions, feeding and management programs have been incriminated.

RISK FACTORS IN THE ETIOLOGY OF PODODERMATITIS:

I. Age, Size and Gender of the bird

Pododermatitis is incident in broilers and turkeys as early as one week of age and further increase in prevalence and severity as the age progresses [11, 18]. It has been reported that increase in weight results in decreased activity, where birds spend more time in close contact with the litter. Skeletal deformities that result from rapid growth rate also reduce bird activity in the house. Rapid weight gain and constant contact with litter results in more pressure per area of foot and irritation to the skin in the sensitive areas due to fecal load in the litter [10, 19, 20]. Ekstrand *et al* [21] observed that birds slaughtered at an older age that were fed on less nutrient intense diets had less incidence of pododermatitis due to healing of the lesions. Some studies have indicated no direct correlation between the gender or weight and the footpad quality [9]; while others have attributed males to be more prone to this condition [10, 19, 22, 23, 24].

II. Strain crosses of Broilers

The incidence of pododermatitis among different commercial strain crosses has been varied, with certain crosses showing more susceptibility than others [8, 24, 25]. Other experimental studies have reported no differences in the incidence of pododermatitis among different strain crosses [21]. These discrepancies may be due to the differences in environmental and management conditions among the experiments.

III. Stocking density

Economic factors necessitate animal production systems to improve efficiency and to decrease cost. Rearing broilers at high stocking rates of < 0.48 sq ft/bird have been shown to cause a rapid deterioration of litter quality [20, 26]. Martrenchar *et al* [27] observed a direct correlation between incidence of pododermatitis and litter degradation due to high stocking densities. A higher stocking density also leads to less air circulation in the house and increases the chances of inflicting wounds and bruising in poultry flocks.

Some investigators have related the occurrence of footpad lesions to corrosive or irritant factors generated from high amounts of feces present in the litter due to high commercial stocking densities [28]. Cravener et al [23] and Harms *et al* [29] have also observed higher prevalence of pododermatitis and hock lesions in the above conditions. The influence of stocking density on the prevalence of pododermatitis is more pronounced in turkeys than broiler flocks [27]. Others have suggested either little or no relation between stocking density and the prevalence of pododermatitis [30]. A study by Dawkins *et al* [31] indicated that although very high stocking densities affect broiler welfare, there are other important factors in the birds' environment such as house size and age, litter moisture, air ammonia, temperature, humidity, ventilation and season that play an important role in the etiology of pododermatitis.

IV. Feeding programs

Diet density and nutrient composition have significant effects on broiler health and performance. Earlier investigators have stressed the importance of trace minerals, amino acids and vitamin supplementation in diets to improve the footpad quality. The occurrence of pododermatitis has also been linked to deficiencies of biotin [32, 33, 34], methionine [35], sulfur containing amino acids methionine and cystine [36] and zinc [37]. Whitehead and Bannister [38] defined the role of biotin in the metabolism and its role in maintenance of skin and footpad integrity and related the severity of lesions to available plasma biotin concentration. McGinnis and Carver [39] suggested that dermatitis could be prevented with riboflavin supplementation in turkey poults.

Use of commercial diets formulated with high nutrient density [24, 40] and salt [41] can result in higher incidence of pododermatitis. Whitehead and Bannister [38] noted that increasing dietary protein level negatively affected the plasma biotin availability and thus impaired footpad skin quality. Increase in dietary protein level has also been identified to cause uric acid overload in kidneys and thus wet litter conditions [42].

Inclusion of soybean meal as the primary source of protein has also received attention as, not only soybean meal is naturally deficient in biotin, but also produces sticky and high pH droppings and thus irritant litter [38, 43, 44, 45]. The indigestible oligosaccharides component of the soybean meal has been implicated as a factor in causing sticky droppings and wet litter problems [40, 46]. High levels of potassium in soybean meal can also lead to an electrolyte imbalance in poultry diets and increase water consumption, leading to a wet litter problem.

V. Factors associated with litter

Birds spend most of their productive life in close association with the bedding/litter material and hence the quality of the latter tells a lot about the skin quality of the bird. There is a wide range of bedding material (wood shavings, straw, peanut hulls, rice hulls, cardboard, etc.,) used in commercial poultry houses.

Bilgili *et al* [47, 48] observed that use of sand as an alternate bedding material reduced the incidence and severity of pododermatitis in broilers compared to pine shavings. Recently, it was reported that cardboard and straw due to their poor efficiency to soak up moisture are least preferred materials as litter for broiler houses [30]. Other investigators found no differences in the incidence of pododermatitis when peanut hulls and straw were used as bedding material instead of wood shavings [21, 22, 49]. The disparity in the incidence of pododermatitis in the above could have been due to differences in litter depth, type of drinker, season and other environmental factors.

Chickens are usually prone to peck, scratch and work the litter. This helps in aeration, further reducing the particle size of the litter by breaking down the clumps. However, overuse of litter, larger size of litter particles and excessive deterioration of litter quality results in less working up of the litter by the birds. Many investigators have defined the role of litter in producing wholesome chicken feet. Higher prevalence of pododermatitis is attributed to wet litter conditions [13, 29, 30, 50, 51, 52]. Martland [13, 51] observed that shifting birds from wet litter to dry litter resulted in healing of the lesions, further emphasizing the importance of litter moisture in the etiology of pododermatitis.

The type of drinker system also influences the litter moisture and hence the incidence of pododermatitis [53]. Use of small cup drinkers reduces wet litter conditions when compared to bell drinkers. Ekstrand *et al* [21] further confirmed that use of nipple drinkers, compared to small water cups, significantly reduced water spillage and water consumption. It was also observed that the prevalence of pododermatitis in broiler flocks was significantly reduced with the use of nipple drinkers [21, 53].

VI. Factors associated with environment

Poor management practices like ineffective ventilation systems and improper insulation can result in wet litter conditions. Improper ventilation increases the rate of ammonia production or other unspecified corrosive substances [13, 45] and relative humidity [54] in the broiler house. Ammonia is produced as a result of microbial activity on uric acid and wet litter conditions with high pH acts like a catalyst in this process. Generation of ammonia is a two-step process; initially the uric acid is converted to allantoin and then is further broken down to ammonia by microbial enzymes [55]. Higher level of ammonia volatilization is an environmental concern due to excessive atmospheric emissions [56]. It has been shown that nearly 40% of feed nitrogen in commercial broilers is lost to the atmosphere [57, 58, 59]. It has also been reported that 50% of poultry manure nitrogen is converted to volatile ammonia

[60]. A higher ammonia level in broiler houses increases not only susceptibility to respiratory diseases but also causes irritation to the skin of footpad resulting in pododermatitis [13, 29, 30, 50] occasionally hock burns and breast blisters [11, 13, 22]. The ammonia generated in grow-out houses can not only affect body weight gain but also the carcass yields in broilers [54]. The change in relative humidity is associated with seasonal variation, and this predisposes the birds to dermatitis during the winter months [22]. Thus, reduction of ammonia volatilization and relative changes in humidity are very important in improving broiler health and performance.

Effective management and feeding programs may be the key in improving chicken feet quality. However, there has been limited research in the area of pododermatitis in broilers [24, 40] and interactions among the various risk factors have to be explored. With both economics and animal welfare issues at stake, research into the causes and treatments for pododermatitis is of interest to poultry producers. Given the available literature, the objectives of the current sequence of experiments were aimed at further investigating the effect of gender, feed components and programs, and management factors on the incidence and severity of pododermatitis in broiler chickens.

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III. EFFECT OF HIGH PROTEIN AND ALL VEGETABLE DIETS ON THE INCIDENCE AND SEVERITY OF PODODERMATITIS IN BROILER CHICKENS

SUMMARY

The incidence and severity of pododermatitis in broiler chickens is of great concern to the broiler industry, both from product quality and animal welfare standpoints. A total of 1600 birds were raised on floor pens in a design involving 2x2x2 arrangement of protein level [High or Low], protein source [all vegetable (Veg) or vegetable plus animal (Veg+Ani)], and sex (Male and Female) on a four stage feeding program (50 birds per pen; 4 pens of males and females per treatment). In addition to live performance, the feet were scored on all birds on 29, 43 and 54 d and the severity of lesions was recorded as none, mild, and severe. A sub-sample of birds was processed at the end of the experiment to evaluate carcass yields. Pooled litter samples were collected on 29, 43 and 54 d for total and ammonia nitrogen analysis.

Protein level had a significant effect on body weight on 14, 29 and 43 d of age. At 43 and 54 d of age, body weight was significantly influenced by protein and sex. Chilled carcass yields did not differ between the treatments. Footpad lesions were significantly affected ($P<0.05$) by protein level, protein source and sex. At 29 d of age all lesions were mild in severity and varied significantly in incidence by protein source (31% for Veg vs. 41% for Veg+Ani). At 54 d of age, both protein level and source had a significant on the

incidence and severity footpad lesions. Incidence of pododermatitis was higher for males (61%) than females (55%). Litter total nitrogen was significantly affected by protein level and protein source. The litter ammonia-nitrogen content, although not significant, except for 29 d of age, showed an increasing trend for each feeding period. The incidence and severity of pododermatitis was significantly affected by protein level, protein source, sex and age. Hence, nutritional factors play a significant role in the etiology of pododermatitis in broilers.

DESCRIPTION OF PROBLEM

Pododermatitis is a common condition in broiler chickens, broiler breeders and turkeys. It is also referred to as paw burns or ammonia burns. Pododermatitis is a type of contact dermatitis characterized by lesions on the plantar region of the footpad, occasionally extending to the rear surface of the hock joint [1, 2, 3]. Gross signs include edema and thickening of the footpad and superficial to deep ulcers. The incidence and severity of pododermatitis that occur on the footpads of broiler chickens is of great concern to the broiler industry, both from product quality and animal welfare standpoints. Many factors have been implicated in the prevalence of pododermatitis, including nutrient deficiencies (especially biotin, methionine, pantothenic acid, riboflavin and zinc) in broiler diets [4], litter type [5, 6, 7], quality and moisture [2, 7, 8, 9, 10] and high stocking density [11]. Recently, Bilgili *et al* [12, 13] have reported a high incidence and severity of pododermatitis in broilers fed high nutrient density diets. A gender effect was also observed where males tended to exhibit higher severity than females.

It was also observed that feeding higher levels of dietary protein results in poor skin integrity and thus predisposes the birds to pododermatitis [14]. Protein sources in broiler diets arise from plant or animal sources and not all plant proteins are favorable for broilers. Soybean meal is the most abundant protein source for use in broiler feeds world wide. Earlier investigations have shown that use of soybean meal in poultry diets have detrimental effects on feet quality [15, 16]. The indigestible oligosaccharides in soybean meal have been implicated in causing sticky droppings and wet litter problems. [17]. Prolonged contact of feet with fecal material and high moisture in litter could contribute to the development of pododermatitis. The current experiment was aimed at evaluating the influence of different dietary protein levels (High vs. Low) and sources (Veg vs. Veg+Ani) on the incidence and severity of pododermatitis in male and female broiler chickens.

MATERIALS AND METHODS

A total of 1600 day-old broiler chicks were randomly allotted to 32 pens in an open sided, naturally ventilated, concrete floor house [18]. The cement floored pens were bedded with 8 cm of new pine shavings as litter. All the pens were equipped with tube feeders and bell drinkers. Experimental design involved 2x2x2 arrangement of protein level [High or Low], protein source [all vegetable (Veg) or vegetable plus animal (Veg+Ani)], and sex (Male and Female) on a four stage feeding program (50 birds per pen; 4 pens of males and females per treatment). The nutrient and ingredient composition of the experimental diets are shown in Tables 1 and 2. Feeding program consisted of crumbled starter (0-14 d), pelleted grower (15-29 d) finisher (30-43 d) and withdrawal (44-54 d) diets. Birds were reared on a 23:1h (Light: Dark) lighting program, in which they received feed and water continuously. All birds were weighed on a per pen basis at

14, 29, 43 and 54 d of age and body weights (BW), adjusted feed conversion (FC) and mortality were determined.

A sub-sample of ten birds were randomly chosen from each pen and processed on Day 54 at the Auburn University Processing facility to assess the effect of different treatments on carcass yield parameters. The feed was withdrawn approximately ten hours prior to processing. Carcass and fat yields were determined after immersion chilling. The incidence and severity of pododermatitis were scored on 29, 43 and 54 d of age by a visual ranking system [19]. Figure 1 illustrates the scoring of footpad lesions followed in this experiment. Litter samples (per pen basis) collected from each pen were pooled by each feeding program for litter total and ammonia nitrogen analysis on 29, 43 and 54 d of age [20, 21]. The data were statistically analyzed by GLM procedure of SAS [22, 23].

RESULTS AND DISCUSSION

In formulating the experimental diets, the poultry by-product meal (PBPM) levels were kept constant between the high and low protein levels. Within each diet, the soybean meal levels were adjusted to obtain the desired protein levels (Table 2). No differences ($P>0.05$) were detected in mortality between the treatments throughout the course of the study (Table 3). Protein level had a significant effect on body weight, but only at 14 and 29 d of age, where birds raised on high protein diets had higher body weights. The effect of protein level on feed efficiency was restricted to 29 d of age in favor of high protein diets. Gender effect for live performance was significant and favored males throughout the experiment. A significant protein level and protein source interaction at 43 d of age indicated a depressed BW for birds reared on low protein and all vegetable diets (Figure 2). At 43 and 54 d of age, significant protein source and sex interaction was present for body weight. Both male and female birds responded favorably to all vegetable diets. However, the magnitude of weight gain was greater for males than females (Figure 3). Chilled carcass yields did not differ between the treatments (Table 4). However, birds reared on all vegetable diets showed significantly lower abdominal fat levels (2.3%) compared to those reared on Veg+Ani diets (2.6%). As expected, females (2.7%) had higher abdominal fat yields than males (2.1%) [24].

Incidence and severity of pododermatitis was significantly affected by protein level, protein source and sex. Incidence and severity of pododermatitis increased with each feeding period (Table 5). At 29 d of age, all lesions were mild in severity and varied significantly in incidence only by protein source. Birds reared on Veg+Ani diets showed higher incidence of mild lesions than those reared on veg diets. At 43 d of age, lesions were again mild in nature and did not vary between the treatments ($P>0.05$). At 54 d of age, a significant interaction between protein level and protein source was detected for mild footpad lesions, where birds reared on low protein and Veg+Ani protein source diets showed the lowest incidence compared to other treatments (Figure 4). Severity of pododermatitis was high in male broilers and those raised on high protein and all vegetable diets. Males were more susceptible to severe footpad lesions following high levels of soybean meal inclusion in diets than females (Figure 5).

Wet litter conditions have been identified as one of the major causative agent in pododermatitis [2, 7, 8, 9, 10, 25]. However, no such association was evident in this study (data not shown). The analyses of the pooled litter samples are summarized in Table 6. Litter total nitrogen was significantly affected by protein level and protein source.

Analysis of litter samples from pens with high protein diets showed higher percentage of total nitrogen excretion at 29 and 43 d of age. Similarly, litter total nitrogen levels were higher in pens from all vegetable diet treatments at 43 and 54 d of age. The litter ammonia-nitrogen content showed an increasing trend for each feeding period. Protein level had a significant effect on ammonia-nitrogen at 29 d of age where litter from the pens where birds were fed with high protein diets had higher ammonia-nitrogen levels. Also, a significant interaction was observed between protein level and source for ammonia-nitrogen at 43 d of age, where, ammonia-nitrogen levels were higher in litter from high protein and all vegetable diet compared to other treatments (Figure 6).

Pododermatitis is one of the common causes of downgrading of chicken feet during processing. Whitehead and Bannister [14] reported that feeding high protein diets may lead to deficiency of biotin, due to a drop in plasma biotin levels. This results in impairment of biotin-dependent lipogenic pathways. The activity of Acetyl-CoA carboxylase enzyme is decreased and the synthesis of normal skin lipids is disrupted, thus leading to abnormal composition of skin lipids and increasing the susceptibility of skin to bruising, injury and dermatitis. Jensen et al [15] suggested that the complex carbohydrates of soybean meal that are not vulnerable to the endogenous enzymes are associated with footpad dermatitis in turkey poults. Use of soybean meal and its replacements in broiler diets have also been previously implicated as a cause of footpad dermatitis due to the generation of highly viscous feces and irritant litter [1, 17]. The current experimental results are consistent with previous studies and further verify that high levels of soybean meal inclusion in commercial broiler diets can result in high incidence of pododermatitis. Gender effect in the incidence of pododermatitis may be attributed to higher body weight gains in male birds compared to females. In this study 61% of males suffered with lesions categorized either as mild or severe type compared to 55% in females. It is clear from this experiment that feeding programs, in addition to litter quality and flock management, should be recognized as a significant contributor to pododermatitis in poultry.

CONCLUSIONS AND APPLICATIONS

1. Live performance of broilers were significantly affected by protein level (High>Low) and protein source (Veg >Veg+Ani)
2. Processing yields were not influenced by diet regimens or sex, except for the abdominal fat yields (Veg+Ani >Veg)
3. Footpad lesions were significantly affected by protein level (High>Low), protein source (Veg >Veg+Ani) and gender (Male>Female) at Day 54.
4. The severe pododermatitis lesions increased two-fold by protein level (21% for High protein vs. 10% for Low protein) and by sex (21% for Males vs. 10% for Females) and tripled by protein source (23% for Veg vs. 8% for Veg+Ani).
5. Litter nitrogen and ammonia-N were significantly affected by protein level (High>Low) and protein source (Veg >Veg+Ani)

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18. The chicks were sexed prior to placement and placed separately. The pens were 1.70 x 2.30m in dimension with a final stocking density of 12.14 birds per m^2.
19. The scoring system followed was a three point score where the footpad lesions were assigned to one of three values: 0 = footpads with no lesions, dermal ridges

intact within a central, with or without discoloration; 1 = footpads with mild lesions, dermal ridges not intact within a central, round to oval ulcer on the central plantar footpad surface, roughened lesion surface with small tag of crust < 1.5 cm in diameter, and 2 = footpads with severe lesions, a brown >1.5 cm in diameter adhered to the central plantar footpad, sometimes extending up to the hock joint.

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Table 1: Nutrient Composition of Experimental Diets[1]

	Starter				Grower				Finisher				Withdrawal			
	High protein		Low Protein		High protein		Low Protein		High protein		Low Protein		High protein		Low Protein	
	Veg	Veg+Ani	Veg	Veg+Ani	Veg	Veg+Ani	Veg	Veg+Ani	Veg	Veg+Ani	Veg	Veg+Ani	Veg	Veg+Ani	Veg	Veg+Ani
Crude Protein (%)	24.7	25.5	21.8	22.3	22.4	20.4	20.2	19.9	20.2	18.4	16.4	17.2	19.6	17.4	18.6	16.6
ME (kcal/kg)	3096	3100	3093	3098	3117	3116	3117	3118	3149	3149	3151	3149	3186	3186	3190	3189
Ca (%)	1.08	1.11	1.05	1.22	1.06	1.41	1.08	1.39	0.92	1.0	1.04	0.93	0.7	0.94	0.76	1.01
Available P (%)	0.52	0.47	0.48	0.48	0.5	0.51	0.52	0.5	0.47	0.47	0.47	0.4	0.45	0.44	0.46	0.46
Lysine (%)	1.38	1.38	1.2	1.2	1.18	1.18	1.07	1.07	1.0	1.0	0.92	0.92	0.9	0.9	0.82	0.82
Methionine (%)	0.56	0.54	0.55	0.53	0.55	0.57	0.53	0.55	0.57	0.58	0.52	0.53	0.45	0.46	0.4	0.4
Methionine+ Cystine (%)	0.95	0.95	0.91	0.91	0.88	0.88	0.83	0.83	0.86	0.86	0.78	0.78	0.75	0.75	0.68	0.68
Potassium (%)	1.1	0.89	0.96	0.78	0.97	0.73	0.89	0.67	0.86	0.77	0.74	0.65	0.86	0.69	0.81	0.6
Sodium (%)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.23	0.23	0.23	0.23
Vitamin premix[2]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.1	0.1	0.1	0.1
Trace mineral premix[3]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.1	0.1	0.1	0.1
DL-methionine	0.2	0.2	0.22	0.16	0.2	0.2	0.21	0.2	0.25	0.25	0.21	0.21	0.16	0.16	0.13	0.13
L-Lysine	0.04	0.2	-	0.16	-	0.15	0.04	0.2	-	0.11	0.05	0.15	0.01	0.12	0.05	0.14
Coccidiostat[4]	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	-	-	-	-
Antibiotic[5]	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	-	-	-	-

[1]Starter diet fed Days 0-14d, Grower diet fed Days 15-29, Finisher diet fed Days 30-43, Withdrawal diet fed Days 44-54.
Veg = all-vegetable protein (only soybean meal)
Veg+Ani = vegetable plus animal protein (poultry by-product meal
[2]Vitamin premix supplies the following per kg of diet: vitamin A, 16,183 IU; vitamin D_3, 4,851 IU; vitamin E, 16.6 IU; vitamin B_{12}, 0.04 mg; riboflavin, 12 mg; biotin, 0.05mg; niacin, 80 mg, pantothenic acid, 29 mg; choline, 1,102 mg; menadione, 4.8 mg; folic acid, 1.1 mg; pyridoxine, 4.4 mg; thiamine, 22mg
[3]Supplies the following per kg of diet: manganese, 143 mg; zinc, 121 mg; iron, 13 mg; copper, 13 mg; iodine, 2.2 mg; selenium, 0.7 mg
[4]Monensin sodium premix, Coban 60 (Elanco Animal Health, Indianapolis, IN 46285).
[5]Starter and grower periods: Bacitracin Methyl Salicylate, BMD-50 (Alpharma Inc., Fort Lee, NJ 07024); Finisher period: Virginiamycin, Stafac-20 (Phibro Animal Health, Fairfield, NJ 07004).

Table 2. Inclusion rate of soybean meal and poultry-byproduct meal in experimental diets (%)

Diet	Soybean meal (48%CP)	Poultry by-product meal (55% CP)
Starter		
High Protein		
[1]Veg	39.3	–
[2]Veg+Ani	26.5	10
Low Protein		
Veg	34	–
Veg+Ani	21.2	10
Grower		
High Protein		
Veg	34.4	–
Veg+Ani	21.1	10
Low Protein		
Veg	29.2	–
Veg+Ani	15.9	10
Finisher		
High Protein		
Veg	28	–
Veg+Ani	18.7	7
Low Protein		
Veg	23.6	–
Veg+Ani	14.5	7
Withdrawal		
High Protein		
Veg	23.2	–
Veg+Ani	14.5	6.5
Low Protein		
Veg	19.3	–
Veg+Ani	12	6.5

[1]Veg = all-vegetable protein
[2]Veg+Ani = Vegetable plus animal protein

Table 3. Influence of protein level, protein source and gender on broiler performance

	1-14 d			1-29 d			1-43 d			1-54 d		
Treatment	Wt. (g)	FC[1]	Mort (%)	Wt. (g)	FC	Mort (%)	Wt. (g)	FC	Mort (%)	Wt. (g)	FC	Mort (%)
Protein Level (PL)	**	NS	NS	*	**	NS	**	NS	NS	NS	NS	NS
High	445^{a}	1.235	1.0	1452^{a}	1.486^{b}	1.2	2612^{a}	1.781	2.6	3523	1.962	3.6
Low	433^{b}	1.211	0.7	1410^{b}	1.543^{a}	1.0	2512^{b}	1.756	2.9	3541	1.967	3.4
Protein Source (PS)	NS	NS	NS	**	***	NS	***	***	NS	***	NS	NS
Veg	443	1.214	0.7	1458^{a}	1.467^{b}	1.2	2712^{a}	1.712^{b}	2.5	3625^{a}	1.953	3.5
Veg+Ani	436	1.242	0.9	1404^{b}	1.553^{a}	1.0	2421^{b}	1.834^{a}	3.0	3439^{b}	1.976	3.5
Sex (S)	***	NS	NS	***	*	NS	***	*	NS	***	***	NS
Female	429^{b}	1.221	0.4	1334^{b}	1.534^{a}	1.0	2348^{b}	1.790^{a}	2.2	3191^{b}	2.012^{a}	3.2
Male	449^{a}	1.226	0.3	1528^{a}	1.502^{b}	1.2	2786^{a}	1.744^{b}	3.3	3872^{a}	1.908^{b}	3.8
SEM[2]	5.0	0.5	0.7	25.0	0.02	0.7	41.2	0.03	1.3	52.4	0.03	1.3

NS=Not significant (p>0.05) *P<0.05 **P<0.01 ***P<0.001

[ab]Means within a treatment and column with different subscripts vary significantly.

[1]FC=Feed conversion adjusted for mortality

[2]SEM=Pooled standard error of mean

A significant PL*PS interaction was observed at 43d of age for Body wt and FC

A significant PS*S interaction was observed at 43 and 54d of age for Body wt

Table 4. Influence of protein level, protein source and gender on processing yields on Day 54

Treatment	WOG[1] (%)	Lean[2] (%)	Fat (%)
Protein Level	NS	NS	NS
High	75.9	73.5	2.4
Low	76.5	74.0	2.4
Protein source	NS	NS	*
Veg	76.1	73.8	2.3[b]
Veg+Ani	76.3	73.7	2.6[a]
Sex	NS	NS	***
Female	77.0	74.3	2.7[a]
Male	75.4	73.2	2.1[b]
SEM[3]	2.0	1.97	0.2

NS=Not Significant; *P<0.05; **P<0.01; ***P<0.001
[1]WOG =Carcass without giblets
[2]Lean =Whole carcass excluding abdominal fat
[3]SEM=Pooled standard error of mean
No interactions observed (P>0.05)

Table 5. Influence of protein level, protein source and gender on the incidence and severity of pododermatitis (%)

	29 d of age		43 d of age		54 d of age		
Treatment	None[1]	Mild[2]	None	Mild	None	Mild	Severe[3]
	NS	NS	NS	NS	***	NS	***
Protein Level (PL)	64	36	68	32	35^{b}	44	21^{a}
High	64	36	68	32	49^{a}	41	10^{b}
Low							
Protein Source (PS)	***	***	NS	NS	***	**	***
Veg	69^{a}	31^{b}	66	34	31^{b}	46^{a}	23^{a}
Veg+Ani	59^{b}	41^{a}	70	30	52^{a}	40^{b}	8^{b}
Sex (S)	NS	NS	NS	NS	NS	*	***
Female	65	35	68	32	45	45^{a}	10^{b}
Male	63	37	68	32	39	40^{b}	21^{a}
SEM[4]	3.9	3.9	3.1	3.1	4.8	2.6	4.1

NS=Not Significant; * P<0.05; ** P <0.01; *** P <0.001

[1]None=No lesion present; [2]Mild=Lesion< 1.5cm; [3]Severe=Lesion > 1.5cm

[4]SEM = Pooled standard error of mean

A significant PL*PS interaction was observed at 54d of age for mild footpad lesion

A significant PS*S interaction was observed at 54d of age for severe footpad lesions

Table 6. Litter nitrogen and ammonia-nitrogen analysis

	29 d of age		43 d of age		54 d of age	
	Nitrogen[1] (%)	NH_3-N[2] (ppm)	Nitrogen (%)	NH_3-N (ppm)	Nitrogen (%)	NH_3-N (ppm)
Treatment						
Protein Level (PL)	***	**	***	NS	NS	NS
High	2.3 [a]	1147[a]	3.1 [a]	2355	2.8	3063
Low	1.7 [b]	748[b]	2.6 [b]	2149	2.6	2805
Protein Source (PS)	NS	NS	**	NS	**	NS
Veg	2.1	1025	3.1 [a]	2173	2.9 [a]	3129
Veg+Ani	1.9	869	2.6 [b]	2332	2.5 [b]	2739
Sex	NS	NS	NS	NS	NS	NS
Female	2.0	889	2.9	2208	2.7	2998
Male	2.0	1005	2.8	2296	2.7	2870
SEM	0.18	181	0.19	186	0.16	289

NS=Not significant ($p>0.05$)

*$P<0.05$ **$P<0.01$ ***$P<0.001$

[1]Nitrogen (%) measured on dry-matter basis

[2]NH_3-N (ppm) = Ammonia nitrogen measured in parts per million measured on fresh matter basis

[3]SEM=Pooled standard error of mean

A significant PL*PS interaction was observed at 43 d of age for NH_3-N

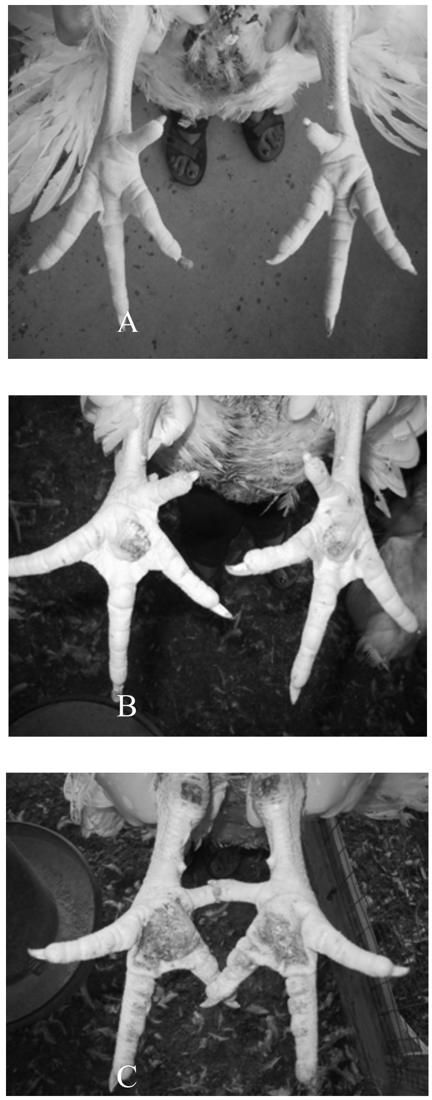


Figure1. Pododermatitis severity scores: Score 0 for no lesions (A), Score 1 for mild lesions of <1.5 cm (B) and Score 2 for severe lesions of >1.5 cm (C)

Figure 2. Protein level and source interaction for body weight on Day 43 (P<0.05)

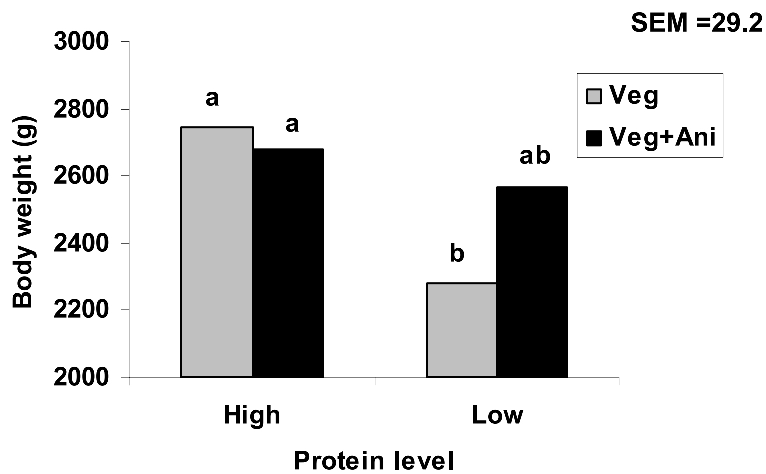


Figure 3. Protein source and sex interaction for body weight on Days 43
(SEM = 29.4)
and 54 (SEM = 36.1) at P<0.05

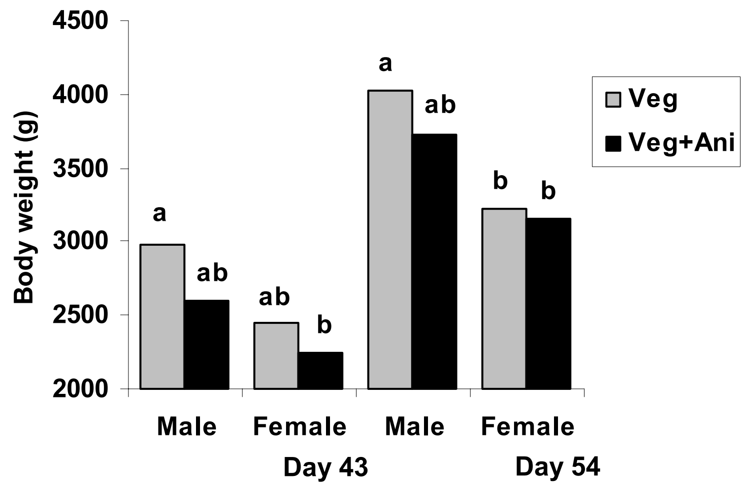


Figure 4. Protein level and source interaction for mild lesions at Day 54 ($P < 0.05$)

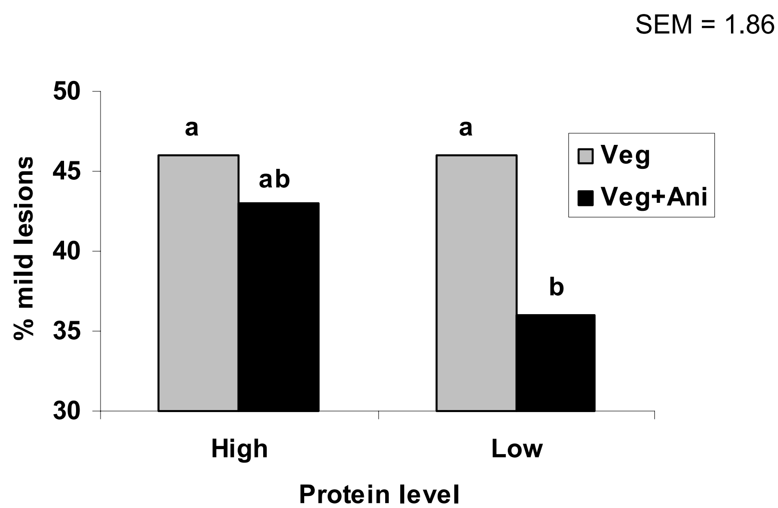


Figure 5. Protein source and sex interaction for severe lesions at Day 54 (P<0.05)

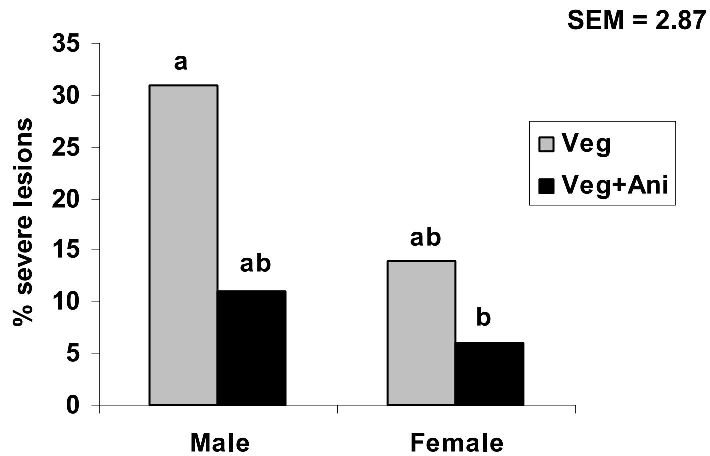
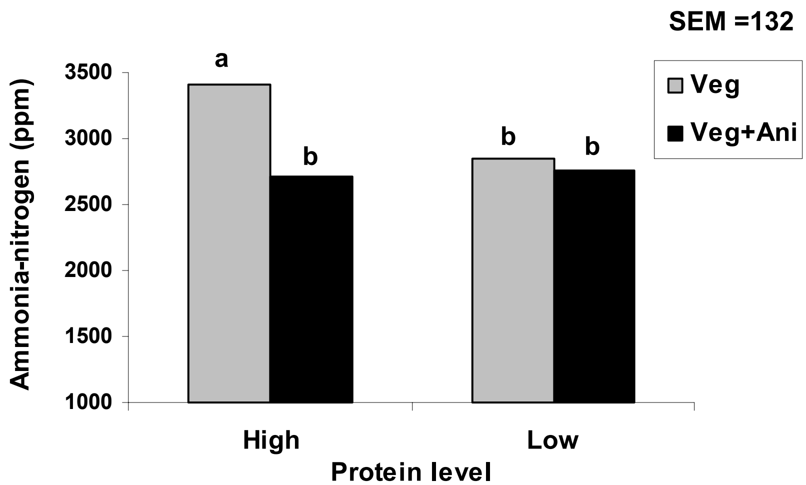


Figure 6. Protein level and source interaction for Ammonia-Nitrogen at Day 43 (P< 0.05)



IV. EVALUATION OF A FEED-GRADE ENZYME IN BROILER DIETS TO REDUCE PODODERMATITIS

SUMMARY

Nutritional and management interventions are needed to reduce the incidence of pododermatitis in poultry. In this study, enzyme (Allzyme Vegpro, Alltech, Nicholasville, KY) supplementation of corn-soybean based broiler diets was evaluated in an effort to reduce total and ammonia nitrogen excretion and its impact on pododermatitis in broiler chickens. A total of 1600 mixed sex chicks were raised on floor pens in a design involving 2x2x2 arrangement of protein level [High or Low], protein source [all vegetable (Veg) or vegetable plus animal (Veg+Ani)], and enzyme [with or without enzyme supplementation (0.06%)], on a four stage feeding program (four replicate pens per treatment; 50 birds per pen). In addition to live performance, the feet were scored for incidence of lesions on all birds on 28, 42, and 57 d of age and the severity was recorded as: none, mild, and severe. Pooled gut samples were collected at 57 d of age to determine viscosities of fore- and hind-gut contents. Pooled litter samples were analyzed for moisture, total and ammonia nitrogen at 14, 28, 42 and 57 d of age.

Live performance of birds did not vary among the treatments ($P > 0.05$). The incidence of pododermatitis was significantly affected by protein source at 42 d ($P < 0.05$), with birds fed all vegetable diets showing higher incidence and severity than those fed vegetable plus animal diets. At 57 d of age, birds reared on all vegetable diets with

enzyme supplementation showed a lower incidence of mild footpad lesions compared to other treatments.

Enzyme supplementation reduced viscosity of the gut contents irrespective of the protein level or protein source. Higher levels of litter ammonia nitrogen were observed with high protein diets (28 and 42 d), all vegetable diets (28 d) and with enzyme supplementation (28 and 42 d). In this study, enzyme supplementation had little effect on litter total and ammonia nitrogen levels, but reduced viscosity of the gut contents and severity of pododermatitis in older birds.

Key words: Broiler, footpad quality, pododermatitis, protein levels and source, enzyme

DESCRIPTION OF PROBLEM

Over the past decade, the poultry industry has benefited from growing domestic and international markets for chicken feet (paw) as a profitable commodity [1]. Insight into the causes downgrading are required to develop wholesome chicken feet [2, 3]. Pododermatitis, a type of contact dermatitis [4, 5, 6], is a common cause of condemnation and downgrading of chicken feet [7]. In addition, the incidence and severity of pododermatitis has been an animal welfare issue in recent years [8, 9, 10, 11]. Feed composition and programs have been implicated as an important factor in the etiology of pododermatitis. The use of high nutrient density diets [12, 13], high protein [14, 15] and high level of soybean meal inclusion [15, 16, 17] in broiler diets have been implicated to cause a higher incidence of pododermatitis. High protein diets lead to excessive nitrogen excretion and subsequently results in high ammonia levels in the broiler house. The non-starch polysaccharides (NSP) fraction of the soybean meal has poor digestibility which results in sticky and potentially irritant droppings and wet litter conditions. [16, 18].

These conditions could certainly predispose birds to contact dermatitis and other ulcerative lesions [16, 19, 20].

Peptic polysaccharides comprise the major fraction of NSP in soybean meal. These include 1-4 β-arabinogalactans, 1, 2-1, 4-β-rhamnogalacturonans and α-galactosides [21]. The dietary soluble NSP hinder the digestibility of lipids, protein and starch [22, 23] and also reduce nutrient absorption [24]. In young birds, limited amounts of endogenous enzymes [25, 26] limit digestibility of carbohydrate and vegetable protein diets [27]. Researchers have shown that use of exogenous enzymes can improve digestion [28] by breaking the polymers, inactivating the anti-nutritional factors, supplementing endogenous enzymes, manipulating gut micro-flora populations [29] and reducing the digesta viscosity [30].

Until recently, enzyme supplementation was assumed to have a limited value in corn-soybean meal rations. Now, many commercial exogenous enzymes are being marketed for use in corn-soy digest to further improve animal performance and meat yield. The common enzymes used are protease and carbohydrase [31], α-amylase [32], multi-enzyme preparations containing xylanase and β-glucanase, arabinofuranosidase, glucosidase, galactosidase, cellulose and polygalacturonase [33].

Previous research has shown that proportion and severity of pododermatitis can be induced by feeding broilers high protein and all vegetable diets [15]. It was our hypothesis in this study that the of use of a feed grade enzyme (Allzyme Vegpro) [34] designed to target the NSP fraction of soybean meal in broiler feeds [35] might help in reducing the incidence and severity of pododermatitis in broiler chickens.

MATERIALS AND METHODS

A total of 1600 day-old straight – run broiler chicks were randomly allotted to 32 different pens in a curtain sided, naturally ventilated, concrete floor house. The cement floored pens were bedded with 8 cm of new pine shavings as litter. All the pens were equipped with tube feeders and bell drinkers. There were 50 birds of mixed sex per pen and eight replicate pens per each treatment [36]. Experimental design included a 2x2x2 arrangement of protein level [high or low], protein source [all vegetable (Veg) or vegetable plus animal (Veg+Ani)], and enzyme [with or without enzyme supplementation (0.06%)]. The nutrient and ingredient composition of the experimental diets is shown in Tables 1 and 2. The level of poultry-by product meal was kept constant for each feed and the soybean meal levels were adjusted to attain the desired protein levels. The enzyme was supplemented at a recommended level of 0.06% [34]. The experimental diets were provided on a four stage feeding program consisting of crumbled starter (0-14 d of age), pelleted grower (15-28 d of age) finisher (29-42 d of age) and withdrawal (43-57 d of age) diets. Birds were reared on a 23:1h (Light: Dark) lighting program, in which they received feed and water continuously. All birds were weighed on a per pen basis at 14, 28, 42 and 57 d of age and average body weights (BW), feed conversion (FC) and mortality were determined.

On 57 d, eight birds were randomly sampled from each treatment for intestinal viscosity measurements. The birds were killed by carbon dioxide and fore gut (gizzard to

Meckel's diverticulum) and hind gut (Meckel's diverticulum to ileo-ceco-colic junction) segments of the intestine were collected. A small (1.5 g) sample of the intestinal contents was placed in a micro centrifuge tube and centrifuged [37]. The supernatant was collected and stored at 4 ^{o} C until further analysis. Viscosities were measured in centipoises using Brookfield DV-E viscometer [38] following the procedure described by Bedford and Classen [39].

The incidence and severity of pododermatitis were scored on 28, 42 and 57 d of age by a visual ranking system [40]. Litter samples were collected from each pen and pooled by each feeding program for litter moisture [41] total and ammonia nitrogen analysis on Days 14, 28, 42, 57 [42, 43]. The data were statistically analyzed by GLM procedure of SAS [44, 45, 46]. All percentage data was transformed to arcsine values prior to analysis and the significance level was set at $P < 0.05$.

RESULTS AND DISCUSSIONS

Total mortality at 57 d of age was higher than normal, but no differences ($P>0.05$) were detected in mortality between the treatments throughout the course of the study (Table 3). This could be attributed to the high environmental temperatures during the experimental period (July and August). Both protein level and source had a significant effect on body weight, but only at 14 d of age, where birds raised on high protein diets and vegetable diets had high body weights. High protein diets improved feed efficiency on 28 and 42 d of age. A significant ($P < 0.05$) protein level by protein source interaction at 28 and 42 d of age showed that birds reared on low protein and vegetable plus animal diets showed a depressed weight compared to other treatments (Figure 1). This was consistent with a previous study [15] but the effect was not seen at 57 d of age. Interestingly, the performance of birds fed with enzyme supplemented diets was similar to the birds that received diets without enzyme at 14, 28 and 42 d of age. This was in contrast to other researchers' findings, where they observed significantly better feed efficiency with enzyme supplementation [23, 24, 27]. This could be due to the variability in nutrient density and the corn-soy used to formulate the diets. It is also reported that certain extent of enzyme denaturation may occur due to the acidic pH of the stomach resulting in minimal improvements in live performance. Smiricky et al [47] concluded that there may be other anti-nutritional factors apart from oligosaccharides that potentially inhibit the efficient soy protein utilization in the gut even with enzyme supplementation. Given the array of commercial enzyme products available, further research is required to explore the ideal enzyme combination that targets the highly indigestible oligosaccharides and other anti-nutritional factors present in corn-soy diets. At 57 d of age, significant protein source and enzyme interaction was present for feed conversion ratio. It was observed that enzyme supplementation in all vegetable diets showed improved feed efficiency birds compared to other treatments (Figure 2). This finding suggests that the enzyme used in this study could help in improving live performance in older birds.

Gut viscosity was significantly affected by protein source and enzyme supplementation (Table 4). A significant protein level and source interaction was observed for gut viscosity where birds fed with high protein and all vegetable diets had higher gut viscosity as compared to other treatments (Figure 3). A significant protein level and enzyme supplementation interaction was present for hind gut viscosity. As compared to other treatments, birds on high protein diets with enzyme supplementation showed low viscosity of hind gut contents (Figure 4). In the hind gut, the interaction was due to the magnitude of differences between the high and low protein diets.

The incidence and severity of pododermatitis were significantly affected only by protein source at 28, 42 and 57 d of age in this study. Birds reared on all vegetable diets showed higher incidence and severity of lesions (Table 5). In contrast to previous study [15], no effect of protein level or gender was observed in this trial ($P > 0.05$). The absence of effect of protein level on incidence and severity of pododermatitis was unexpected. The explanation for this could be due to excessive wetting of litter due to excessive thirst in response to high environmental temperatures during the course of the study thus masking the effects of protein level on the footpad lesions. The effect of gender was consistent with the findings of Berg [48] where no conclusive association between gender and the incidence of pododermatitis was observed among different broiler chicken flocks.

A significant interaction between protein source and enzyme supplementation was detected for mild footpad lesions at 57 d of age. This interaction was due to a slight improvement in lesions with enzyme supplementation in birds reared on all vegetable diets (Figure 5). Jensen et al [16], Boling and Firman [18] and Nairn and Watson [49] suggested the complex carbohydrates of soybean meal that are not vulnerable to the endogenous enzymes were associated with footpad dermatitis in turkey poults. The reduction in the severity of lesions in the current experiment suggest that appropriate exogenous enzymes when added in commercial broiler diets formulated with soybean meal may help alleviate pododermatitis in broilers at an older age.

Litter quality also plays a significant role in the etiology of pododermatitis [20, 50, 51]. In this study, litter moisture varied little among the dietary treatments ($P > 0.05$) (Table 6). Litter total nitrogen and ammonia nitrogen was significantly affected by protein level and enzyme supplementation at 28 and 42d and by protein source at 28 d of age (Table 7), where analysis of litter samples from pens with high protein, all vegetable and enzyme supplemented diets showed higher percentage of total nitrogen and ammonia excretion. It is reported that use of enzymes in broiler feed improves utilization of protein. But the actual mechanism by which it enhances nutrient utilization is still unclear. The anti-nutritional factors in soybean meal may also interfere with digestibility of nutrients thus excreting nutrients directly into the litter. This could be a possible explanation for higher total and ammonia excretion by birds into the litter in enzyme supplemented diets.

It is clear from the results of this study that pododermatitis is a common problem seen in fast growing broiler chickens. The etiology is thought to be multifactorial. Our hypothesis that supplementation of exogenous enzymes in broiler diets may ameliorate this condition was not clearly proven although an improvement in footpad quality was seen at later stages of life. Further research is needed on other enzyme preparations that can be used in corn-soy diets that help improve feed utilization, reduce total and ammonia nitrogen excretion into litter and to reduce the incidence of pododermatitis in broilers.

CONCLUSIONS AND APPLICATIONS

1. Live performance of broilers was not affected by enzyme supplementation ($P > 0.05$).
2. Gut viscosity was reduced significantly by enzyme addition irrespective of protein level or source.
3. No protein level or gender effects on footpad lesions were observed in this experiment.
4. Enzyme supplementation in all vegetable diets reduced the incidence of mild lesions at 57 d of age.
5. Litter total and ammonia-nitrogen levels were affected by protein level (High>low), protein source (Veg >Veg+Ani) and by enzyme supplementation (With enzyme> No enzyme).

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40. The footpad lesions were assigned to one of three values: 0 = footpads with no lesions, dermal ridges intact within a central, with or without discoloration, 1 = footpads with mild lesions, dermal ridges not intact within a central, round to oval ulcer on the central plantar footpad surface, roughened lesion surface with small tag of crust < 1.5 cm in diameter and 2 = footpads with severe lesions, a brown >1.5 cm in diameter adhered to the central plantar footpad, sometimes extending up to the hock joint.
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44. The statistical model consisted of 2x2x2 factorial arrangement of protein level, protein source and sex. The data was analyzed for main effects, two-way and three-way interactions between the protein levels, sources and enzyme.
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Table 1: Nutrient Composition of Experimental Diets[1]

	Starter				Grower				Finisher				Withdrawal			
	High protein		Low Protein		High protein		Low Protein		High protein		Low Protein		High protein		Low Protein	
	Veg	Veg+Ani	Veg	Veg+Ani	Veg	Veg+Ani	Veg	Veg+Ani	Veg	Veg+Ani	Veg	Veg+Ani	Veg	Veg+Ani	Veg	Veg+Ani
Crude Protein (%)	24.7	25.5	21.8	22.3	22.4	20.4	20.2	19.9	20.2	18.4	16.4	17.2	19.6	17.4	18.6	16.6
ME (kcal/kg)	3096	3100	3093	3098	3117	3116	3117	3118	3149	3149	3151	3149	3186	3186	3190	3189
Ca (%)	1.08	1.11	1.05	1.22	1.06	1.41	1.08	1.39	0.92	1.0	1.04	0.93	0.7	0.94	0.76	1.01
Available P (%)	0.52	0.47	0.48	0.48	0.5	0.51	0.52	0.5	0.47	0.47	0.47	0.4	0.45	0.44	0.46	0.46
Lysine (%)	1.38	1.38	1.2	1.2	1.18	1.18	1.07	1.07	1.0	1.0	0.92	0.92	0.9	0.9	0.82	0.82
Methionine (%)	0.56	0.54	0.55	0.53	0.55	0.57	0.53	0.55	0.57	0.58	0.52	0.53	0.45	0.46	0.4	0.4
Methionine+ Cystine (%)	0.95	0.95	0.91	0.91	0.88	0.88	0.83	0.83	0.86	0.86	0.78	0.78	0.75	0.75	0.68	0.68
Potassium (%)	1.1	0.89	0.96	0.78	0.97	0.73	0.89	0.67	0.86	0.77	0.74	0.65	0.86	0.69	0.81	0.6
Sodium (%)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.23	0.23	0.23	0.23
Vitamin premix[2]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.1	0.1	0.1	0.1
Trace mineral	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.1	0.1	0.1	0.1
premix[3]	0.2	0.2	0.22	0.16	0.2	0.2	0.21	0.2	0.25	0.25	0.21	0.21	0.16	0.16	0.13	0.13
DL-methionine	0.04	0.2	-	0.16	-	0.15	0.04	0.2	-	0.11	0.05	0.15	0.01	0.12	0.05	0.14
L-Lysine	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	-	-	-	-
Coccidiostat[4]	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	-	-	-	-
Antibiotic[5]																

[1]Starter diet fed Days 0-14d, Grower diet fed Days 15-28, Finisher diet fed Days 29-42, Withdrawal diet fed Days 43-57.
Veg = all-vegetable protein (only soybean meal)
Veg+Ani = vegetable plus animal protein (poultry by-product meal)
[2]Vitamin premix supplies the following per kg of diet: vitamin A, 16,183 IU; vitamin D_3, 4,851 IU; vitamin E, 16.6 IU; vitamin B_{12}, 0.04 mg; riboflavin, 12mg; biotin, 0.05mg; niacin, 80 mg, pantothenic acid, 29 mg; choline, 1,102 mg; menadione, 4.8 mg; folic acid, 1.1 mg; pyridoxine, 4.4 mg; thiamine, 2.2 mg. [3]Supplies the following per kg of diet: manganese, 143 mg; zinc, 121 mg; iron, 13 mg; copper, 13 mg; iodine, 2.2 mg; selenium, 0.7 mg.
[4]Monensin sodium premix, Coban 60 (Elanco Animal Health, Indianapolis, IN 46285).
[5]Starter and grower periods: Bacitracin Methyl Salicylate, BMD-50 (Alpharma Inc., Fort Lee, NJ 07024); Finisher period: Virginiamycin, Stafac-20 (Phibro Animal Health, Fairfield, NJ 07004).

Table 2. Inclusion levels of soybean meal, poultry by-product meal and enzyme in the experimental diets (%)

Feed		SBM[1]	PBPM[2]	Enzyme[3]
Starter				
High Protein	Veg	39.3	-	-
	Veg+Ani	26.5	10	-
Low protein	Veg	34	-	-
	Veg+Ani	21.2	10	-
High Protein	Veg	39.3	-	0.06
	Veg+Ani	26.5	10	0.06
Low protein	Veg	34	-	0.06
	Veg+Ani	21.2	10	0.06
Grower				
High Protein	Veg	34.4	-	-
	Veg+Ani	21.1	10	-
Low protein	Veg	29.2	-	-
	Veg+Ani	15.9	10	-
High Protein	Veg	34.4	-	0.06
	Veg+Ani	21.1	10	0.06
Low protein	Veg	29.2	-	0.06
	Veg+Ani	15.9	10	0.06
Finisher				
High Protein	Veg	28	-	-
	Veg+Ani	18.7	7	-
Low protein	Veg	23.6	-	-
	Veg+Ani	14.5	7	-
High Protein	Veg	28	-	0.06
	Veg+Ani	18.7	7	0.06
Low protein	Veg	23.6	-	0.06
	Veg+Ani	14.5	7	0.06
Withdrawal				
High Protein	Veg	23.2	-	-
	Veg+Ani	14.5	6.5	-
Low protein	Veg	19.3	-	-
	Veg+Ani	12	6.5	-
High Protein	Veg	23.2	-	0.06
	Veg+Ani	14.5	6.5	0.06
Low protein	Veg	19.3	-	0.06
	Veg+Ani	12	6.5	0.06

[1]SBM – Soybean Meal (48% Crude Protein)
[2]PBPM – Poultry by-product Meal (55% Crude Protein)
[3]Allzyme Vegpro (0.06%)
Veg = all-vegetable protein (only soybean meal)
Veg+Ani = vegetable plus animal protein (poultry by-product meal)

Table 3. Influence of Protein level, protein source and enzyme on broiler performance

	1-14 d			1-28 d			1-42 d			1-57 d		
Treatment	Wt. (g)	FC[1]	Mort (%)	Wt. (g)	FC[1]	Mort (%)	Wt. (g)	FC[1]	Mort (%)	Wt. (g)	FC[1]	Mort (%)
Protein Level (PL)	*	NS	NS	**	***	NS	NS	**	NS	NS	NS	NS
High	383[a]	1.133	0.4	1262[a]	1.387[b]	1.1	2500	1.465[b]	8.0	4433	1.491	14.9
Low	371[b]	1.138	0.5	1198[b]	1.452[a]	1.1	2442	1.504[a]	7.0	4291	1.512	13.3
Protein Source (PS)	**	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Veg	384[a]	1.135	0.36	1251	1.428	1.1	2511	1.472	7.0	4387	1.484	12.3
Veg+Ani	369[b]	1.124	0.51	1209	1.431	1.1	2431	1.498	8.0	4336	1.503	15.9
Enzyme (E)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Present	377.	1.132	0.37	1243	1.393	1.1	2466	1.456	6.8	4351	1.492	11.7
Absent	376	1.138	0.5	1212	1.414	1.1	2476	1.483	8.1	4372	1.514	16.5
SEM	3.2	0.01	0.2	29.2	0.017	0.8	60.4	0.02	3.2	130.3	0.03	5.7

NS=Not significant ($P > 0.05$) *$P < 0.05$ **$P < 0.01$ ***$P < 0.001$

[ab]Means within a treatment and column with different subscripts vary significantly.

SEM=Pooled standard error of mean

[1]FC=Feed conversion adjusted for mortality

A significant PL*PS interaction was observed at 28 and 42d of age for body wt

A significant PS*E interaction at 57 d of age for feed conversion ratio

Table 4. Effect of enzyme supplementation on gut viscosity

Treatment	Fore gut	Hind gut
	----(centipoises)----	
Protein Level (PL)	NS	NS
High	1.66	2.33
Low	1.52	2.26
Protein Source (PS)	*	*
Veg	1.75^{a}	2.71^{a}
Veg+Ani	1.43^{b}	1.87^{b}
Enzyme (E)	**	***
Absent	1.76^{a}	2.55^{a}
Present	1.42^{b}	2.04^{b}
SEM	0.138	0.125

NS=Not significant (P > 0.05); *P < 0.05 **P < 0.01 ***P < 0.001

[ab]Means within a treatment and column with different subscripts vary significantly

SEM=Pooled standard error of mean

A significant PL*PS interaction was observed at 57d of age for gut viscosity

A significant PL*E interaction was observed at 57d of age for hind gut viscosity

Table 5. Influence of protein level, protein source and enzyme on the incidence of pododermatitis (%)

Treatment	28 d of age		42 d of age			57 d of age		
	None[1]	Mild[2]	None	Mild	Severe	None[1]	Mild[2]	Severe[3]
Protein Level (PL)	NS	NS	NS	NS	NS	NS	NS	NS
High	55	45	30	41	29	37	31	32
Low	57	43	37	39	24	37	31	32
Protein Source (PS)	NS	NS	*	NS	*	NS	NS	*
Veg	58	42	28[b]	41	32[a]	33	30	37[a]
Veg+Ani	54	46	39[a]	40	21[b]	41	31	28[b]
Enzyme (E)	NS	NS	NS	NS	NS	NS	NS	NS
Absent	55	45	33	40	27	36	31	33
Present	56	44	35	40	25	39	30	32
Sex(S)	-	-	-	-	-	NS	NS	NS
Female	-	-	-	-	-	36	32	32
Male	-	-	-	-		39	29	32
SEM	3.1	3.1	5.8	2.4	6.6	8.7	3.6	8.8

NS=Not Significant (P > 0.05); * P < 0.05; ** P < 0.01; *** P < 0.001
[ab]Means within a treatment and column with different subscripts vary significantly
SEM = Pooled standard error of mean
[1]None=No lesion present; [2]Mild=Lesion < 1.5cm; [3]Severe=Lesion > 1.5cm
A significant PS*E interaction was observed for mild lesions.

Table 6. Moisture levels of litter from different treatments

Treatment	Moisture (%)			
	1-14d of age	14-28d of age	28-42d of age	43-57d of age
Protein Level	NS	NS	NS	NS
High	24.0	44.6	50.3	42
Low	23.8	46.2	49.2	46
Protein Source	NS	NS	NS	NS
Veg	23.7	45.2	48.5	43.8
Veg+Ani	24.2	45.6	51.0	44.6
Enzyme	NS	NS	NS	NS
Present	22.5	46.3	48.4	42.1
Absent	25.4	44.5	51.1	46.3
SEM	5.582	2.902	3.506	3.408

NS=Not significant ($P > 0.05$)
SEM=Pooled standard error of mean
No interactions were significant

Table 7. Influence of protein level, source and enzyme on litter total and ammonia nitrogen concentration

	14 d		28 d		42 d		57 d	
Treatment	N (%)	NH_3-N (ppm)	N (%)	NH_3-N (ppm)	N (%)	NH_3-N (ppm)	N (%)	NH_3-N (ppm)
Protein Level (PL)	NS	NS	*	*	*	*	NS	NS
High	1.10	1191	1.74 [a]	1893[a]	1.89 [a]	2601 [a]	2.60	3614
Low	0.99	1151	1.59 [b]	1530[b]	1.68[b]	2298[b]	2.55	3552
Protein Source (PS)	NS	NS	*	*	NS	NS	NS	NS
Veg	1.10	1177	1.71 [a]	1881[a]	1.72	2524	2.58	3596
Veg+Ani	0.99	1066	1.61 [b]	1454[b]	1.75	2374	2.61	3570
Enzyme (E)	NS	NS	*	*	*	*	NS	NS
Present	1.06	1115	1.75[a]	1812 [a]	1.90[a]	2567 [a]	2.62	3671
Absent	1.04	1127	1.65[b]	1523 [b]	1.67[b]	2231 [b]	2.58	3494
SEM	0.17	198.23	0.13	207.12	0.13	385.35	0.22	424.24

[1]NH_3-N (ppm) = Ammonia nitrogen measured in parts per million on a fresh matter basis
NS=Not significant ($P > 0.05$); *$P < 0.05$ **$P < 0.01$ ***$P < 0.001$
SEM=Pooled standard error of mean
[ab]Means within a treatment and column with different subscripts vary significantly.

Figure 1. Protein level by source interaction for body weight ($P < 0.05$)

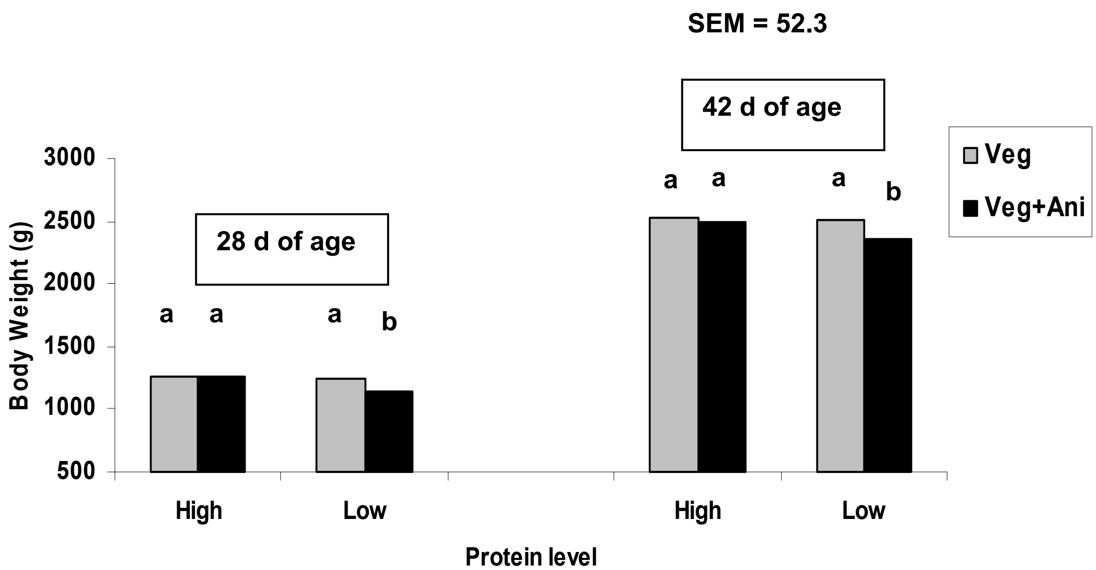


Figure 2. Protein source by enzyme interaction for feed efficiency at 57 d of age ($P < 0.05$)

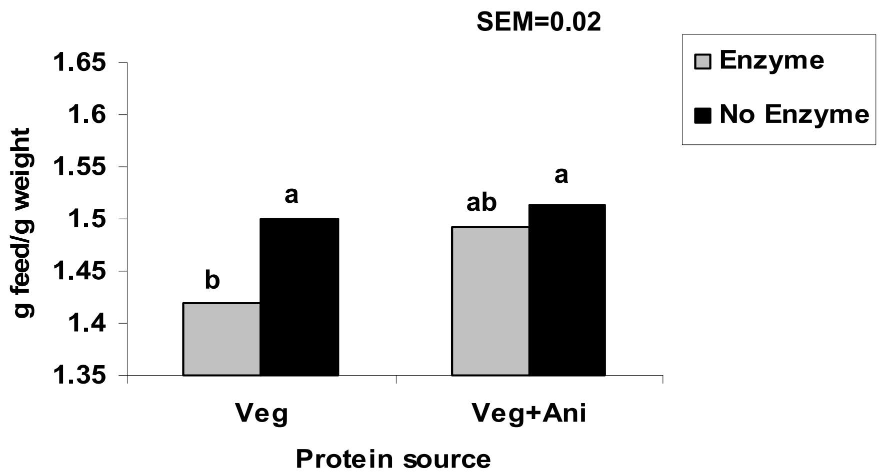


Figure 3. Protein level by source interaction for Gut Viscosity at Day 57 (P<0.05)

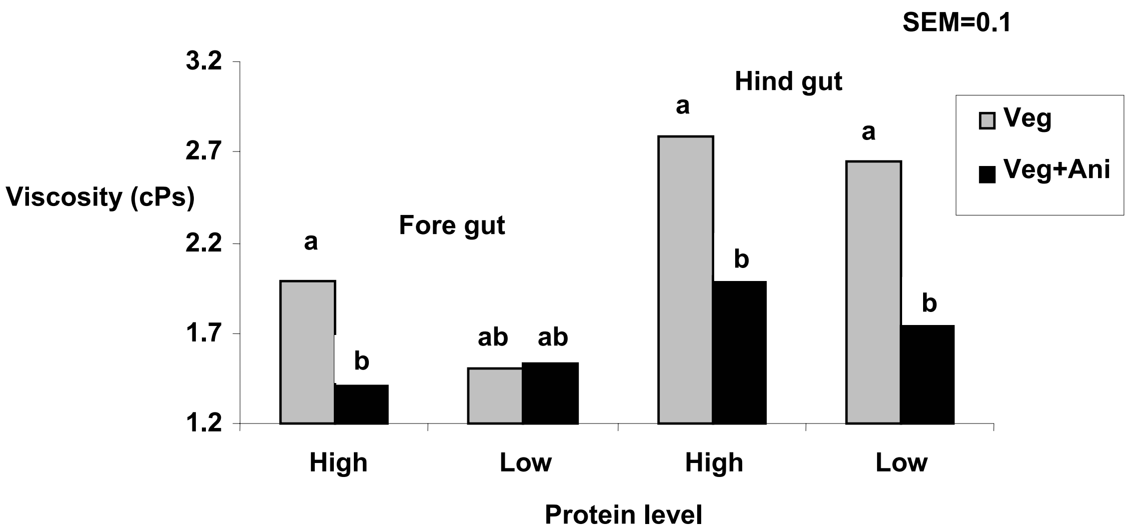


Figure 4. Protein level by enzyme interaction for Hind gut viscosity at Day 57 (P<0.05)

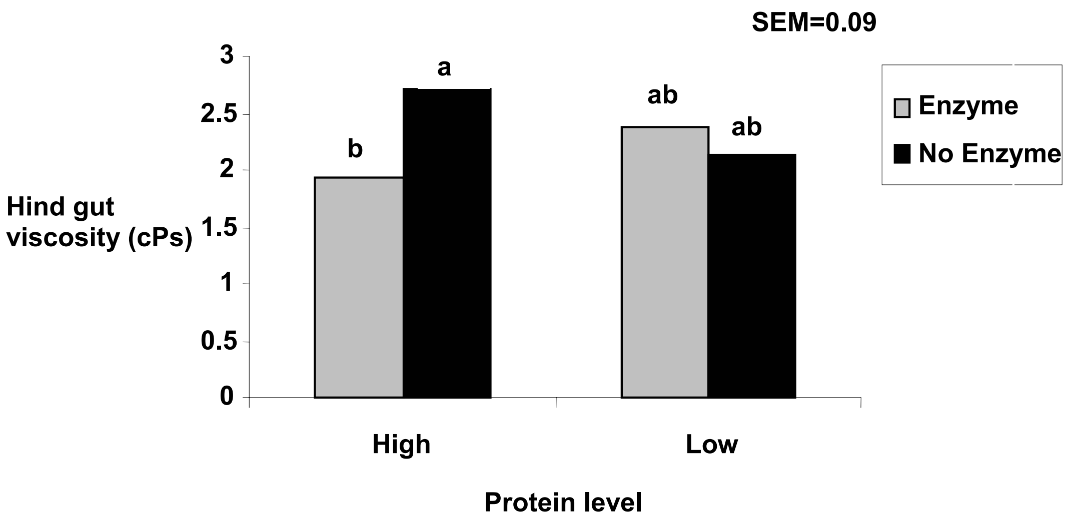
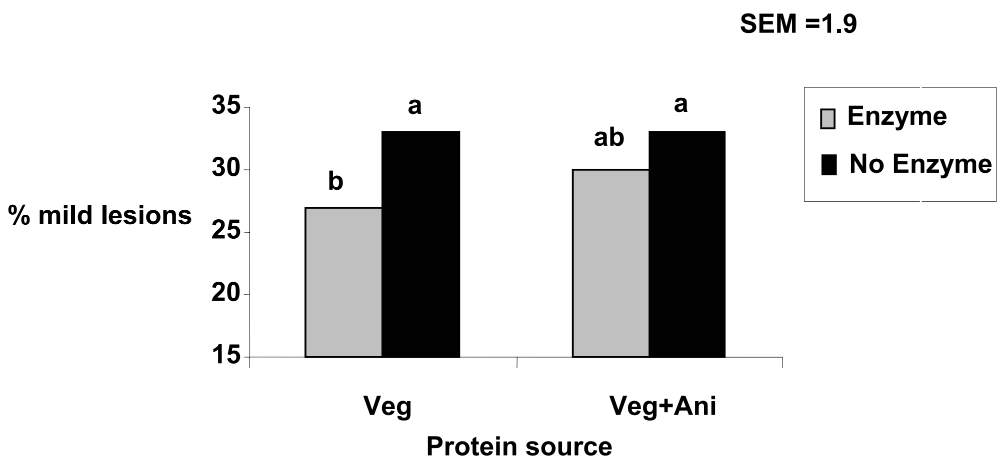


Figure 5. Protein source by enzyme interaction for mild lesions at 57d of age (P<0.05)



V. EFFICACY OF A LITTER AMENDMENT TO REDUCE PODODERMATTITIS IN BROILER CHICKENS

SUMMARY

Broiler house environment, especially volatile ammonia content, has a significant effect on pododermatitis in chickens. The efficacy of sodium bisulfate (SB) [Jones-Hamilton Co., Walbridge, OH] in reducing pododermatitis in broiler chickens was investigated in this study. 960 straight-run day old chicks were randomly assigned to 16 environmental chambers with four different levels of SB (4 chambers per treatment). The treatments(Trt) comprised of Trt 1 (control), Trt 2 with SB applied at 1x rate at the day of placement of chicks, Trt 3with SB applied at 2x rate at the day of placement of chicks and Trt 4 with SB applied at 1x rate at the day of placement of chicks and at 1x rate on 21 d. Birds were raised for a period of 49 d on a four stage feeding program of high protein and vegetable diets, which have been shown to induce high incidence of pododermatitis. At 35 d the litter was moistened artificially to see the effect of sodium bisulfate on ammonia volatilization. In addition to live performance, feet were scored on 42 and 49 d of age and the severity was recorded as none, mild, and severe. Ammonia concentration (ppm) in the chambers was measured prior to placement of chicks and on a weekly basis throughout the experiment.

No differences in live performance of the birds were observed throughout the study ($P > 0.05$). Sex had significant effect on incidence of pododermatitis ($P < 0.05$), with females showing higher incidence of pododermatitis than males. Sodium bisulfate had a significant effect on ammonia volatilization in the chambers ($P < 0.05$). NH3 concentration was significantly reduced in all treatments, except the control (Trt 1). Sodium bisulfate had no significant effect on ammonia levels after 35 d upon addition of moisture to the litter. Although not significant ($P > 0.05$), using SB as a litter amendment appeared to reduce the incidence and severity of pododermatitis.

INTRODUCTION

The economics dictate concentrated and confined broiler production systems with birds raised in large environmentally controlled houses under uniform management practices. The broiler house environment is a reflection of the overall efficiency of the grow-out operation. House design [1, 2] and environmental control [1, 3], ventilation [4] [5], feeder and drinker management [1, 6, 7], flock health [8, 9], stocking density [10] [11, 12], litter quality [7, 13] and husbandry are important factors in the maintenance of a good production environment. As birds spend most of their lifetime in close contact with the bedding material, litter quality has a major impact on bird's health and performance. It is a common practice to raise multiple flocks on used litter in the U.S. However, wet and sticky litter conditions, high pH and excessive ammonia production negatively affect litter quality. Poor drinker management practices, low air temperature and high relative humidity result in wet litter conditions [6, 14, 15].

Moisture levels in litter exceeding 35% have negative impacts on bird's health, often resulting in conditions such as pododermatitis [16, 17, 18, 19, 20], folliculitis and necrotic enteritis [21].

Moisture also increases the rate of production of ammonia and potentially other irritant substances [17, 22]. Ammonia is produced as a result of microbial activity on uric acid. Wet litter conditions and high pH acts like a catalyst in this process. The formed ammonia remains at an equilibrium between the uncharged ammonia (NH_3) and the charged ammonium ion (NH_4^+) at neutral pH. But as the litter pH increases (above 8) there is a shift in this equilibrium, resulting in production of higher levels of ammonia [23]. Levels of ammonia as low as 10 ppm can impair bird's performance [24] and immunity, and increase susceptibility to respiratory infections [24, 25, 26, 27]. Higher levels of ammonia released from litter cause severe irritation to birds' respiratory tract and skin resulting in pododermatitis, hock burns and breast blisters [28].

Hence, litter amendments are suggested to improve litter conditions and keep ammonia levels in check [23, 29, 30, 31]. Many litter additives such as propionic acid [32], monobasic calcium phosphate and phosphoric acid [33], ferrous sulfate [34, 35], aluminum chloride [35], potassium permanganate [35], alum [35, 36], clay [37] and sodium bisulfate (PLT®) [31, 38] have been used successfully to reduce litter pH, reduce ammonia volatilization and inhibit microbial activity.

Sodium bisulfate (Poultry Litter Treatment; PLT) a dry, anhydrous, crystalline acidifier, is used widely by the broiler industry to control ammonia [38]. It is readily soluble in water and a 5% aqueous solution has a $pH < 1$. Sodium bisulfate reduces ammonia volatilization through lowering the litter pH, interacting with uric acid and by limiting the growth of microbial populations that generate ammonia gas [39].

Research on the use of sodium bisulfate as litter amendment has shown better broiler performance [40], reduced pH and ammonia levels [39, 40] in the house and decreased microbial load in the litter [39, 41].

Previous research in our lab has shown that high protein and veg diets increase the incidence and severity of pododermatitis in broilers. This could be due to excessive nitrogen excretion and ammonia formation in the litter [42]. The objective of this current study was to evaluate the effect of sodium bisulfate as a litter amendment on the incidence and severity of pododermatitis in market age broilers fed a high protein and all vegetable diet.

MATERIALS AND METHODS

The experiment was conducted in 16 environmentally controlled chambers [43]. Sixty straight-run day old chicks were placed in each of 16 chambers. Each chamber was equipped with 8 cm of used pine shavings as litter, a tube feeder and 14 nipple drinkers. Prior to the placement of chicks, the ammonia levels in each chamber were measured using Dräger ammonia meters [44, 45]. There were four litter amendment treatments (Trt): Trt 1 was the control, with no litter amendment added; Trt 2 comprised of chambers hand sprinkled with sodium bisulfate at a recommended rate of 0.22 kg /m^2 at the day of placement of chicks; Trt 3 sodium bisulfate consisted of 2x recommended rate of 0.44kg /m^2 at the day of placement of chicks; Trt 4 consisted of sodium bisulfate applied at a rate of 0.22kg /m^2 at the day of placement of chicks and then again on 21 d.

Birds were raised for a period of 49 d on a four stage feeding program of high protein and all vegetable diets (Table 1), which have been previously shown to induce high incidence of pododermatitis [42]. Feed and water were provided for *ad libitum* consumption through the whole growing period. Ammonia concentration (parts per million) in each chamber was measured on a weekly basis using Dräger ammonia meters throughout the experiment [44, 45]. The litter used in this experiment was used for two flocks previously, and was dry and flaky at the time of chick placement. In order to facilitate the solubility of sodium bisulfate, at 35 d, the litter was artificially dampened to dissolve the sodium bisulfate and to increase ammonia generation [46]. Body weight, feed conversion and mortality were determined on 42 and 49 d of age. Feet were scored for pododermatitis on 42 and 49 d of age and the severity was recorded [47]. Litter samples were collected prior to placement of chicks and on 35, 42 and 49 d to assess moisture content [48]. Data were analyzed using GLM procedure of SAS [49, 50].

RESULTS AND DISCUSSION

No differences in live performance of the birds were observed throughout the study ($P > 0.05$) (Table 2). This was not consistent with the findings of other investigators who observed better live weight gain at 23 and 49 d of age with the use of sodium bisulfate [40, 50, 51]. The use of high nutrient density diets in this study may have masked the beneficial effects of sodium bisulfate on live performance. Table 3 summarizes the data on litter moisture for the study period. There were no significant ($P > 0.05$) differences in litter moisture content among the different treatments. Further, the low stocking density followed in this study and the use of nipple drinkers and effective ventilation for aeration of the chambers may have helped to maintain cleaner litter preventing the development of wet litter conditions. The lack of differences in ammonia levels in the chambers before placement of chicks resulted in maintenance of uniform litter conditions thus minimizing errors.

At the beginning of the experiment, the ammonia levels in the chambers were fairly low (3-8 ppm) on used litter (Table 4) and remained low through 35 d of age, with all the three sodium bisulfate treatments showing significantly ($P < 0.05$) lower ammonia levels than the control. Addition of moisture to the litter at 35 d caused ammonia levels to increase significantly (26-36 ppm). There were no differences in ammonia levels within different rates of sodium bisulfate application after 35 d. The depression in ammonia volatilization by sodium bisulfate depends on age and moisture of the litter material used. It is surmised that low levels of litter moisture also suppressed the hygroscopic effect of sodium bisulfate. Further, the variability in the ventilation rates could also have affected ammonia levels in the chambers. It is clear from this study that wet litter conditions hasten the process of ammonia release from litter. Further investigation is required about the solubility of sodium bisulfate and the amount of moisture needed for its dissolution to be effective in trapping volatile ammonia.

Table 5 summarizes the pododermatitis incidence at 42 and 49 d of age. There were no significant ($P > 0.05$) effects due to the sodium bisulfate treatments. However, there was a numerical trend of decreasing incidence and severity of pododermatitis with the use of sodium bisulfate. This finding suggests that other factors in the litter may also play a role in the etiology of pododermatitis apart from ammonia. Mayne *et al* [20] also reported no direct correlation between ammonia concentration in houses and the incidence of pododermatitis in turkeys and further suggested research into the role of unknown compounds in different litter materials in the causation of pododermatitis in broilers and turkeys. It is also possible that low levels of ammonia as observed in this study in contrast to commercial grow-out operations may not cause irritability to skin and cause lesions in the footpad. Although not severe, other effects of volatile ammonia like respiratory discomfort and labored breathing were observed in some birds by 42 d of age.

Sex had a significant effect on incidence of pododermatitis ($P < 0.05$), with females showing higher incidence of pododermatitis than males. This finding is in contrast to earlier research which indicated higher incidence of pododermatitis in males [42, 52, 53]. Higher incidence of lesions in female birds indicates that both the sexes may be equally susceptible to pododermatitis. Female broiler skin, having less skin protein and collagen matrix than male broilers has also been reported as a predisposing factor to skin injury and ulceration. However, males had higher proportion of severe lesions compared to females.

The reduction in ammonia levels in our study was comparable with other researcher's findings bearing the effectiveness of sodium bisulfate as a litter additive [39] [49]. Although not significant ($P > 0.05$), using sodium bisulfate as a litter amendment appeared to reduce the incidence and severity of pododermatitis. Small number of sampling units (i.e., 4 chambers per treatment) and possible influence of the variable ventilation rates and the use of nipple drinkers may have reduced the sensitivity of the study. Previous studies suggest a relationship between litter ammonia-nitrogen and the incidence of pododermatitis [42, 54]. Hence, a further study with large number of flocks is required to comprehend the association of pododermatitis, litter ammonia-nitrogen and volatile ammonia with a reference to wet litter conditions.

The extent of pododermatitis prevalence is used to assess the animal welfare conditions and may be used as an indicator of the overall litter quality as well [2, 55, 56, 57]. The above findings suggest that the incidence and severity of pododermatitis may be affected by factors other than feed ingredients, litter moisture and volatile ammonia. Further research is necessary to understand the interactions between those factors for the development of an effective control program for pododermatitis in broiler flocks.

CONCLUSIONS AND APPLICATIONS

1. Sodium bisulfate as a litter amendment had no significant effect on live performance of birds.
2. Wet litter conditions caused higher volatilization of ammonia from the litter.
3. Use of sodium bisulfate as a litter amendment significantly reduced volatile ammonia levels in the chambers.
4. Incidence and severity of pododermatitis appear to improve, although not substantially significant with use of sodium bisulfate.

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43. There were 60 birds of either sex per pen and four replicate chambers per each treatment. The environmentally controlled chambers were 8 X 8 ft in dimension (256 sq ft per treatment) with a final stocking density of 0.94 sq ft /bird. Each chamber was furnished with a force draft electric heater and the ventilation rate could be individually controlled.

44. Dräger CMS Analyzer and Chips for ammonia gas measurement, Dräger Safety AG & Co. KGaA, Revalstrasse 1, 23560 Luebeck, Germany.

45. The direct-reading Dräger Chip Measurement System (CMS) which uses chemical-specific chips and an electronic analyzer for precise measurements of ammonia gas and vapors and the reading appears on a LCD screen. The chips used in this experiment ranged from 0.2-5, 2-50 and 10-150 ppm, depending upon the ammonia concentrations in the chambers. The ammonia meter was hand held at about 1 foot from the litter in the center of the chamber for measuring ammonia.

46. 3.75 liters of water was evenly sprayed on the litter in each chamber at Day 35.

47. The scoring system followed was a three point score where the footpad lesions were assigned to one of three values: 0 = footpads with no lesions, dermal ridges intact within a central, with or without discoloration; 1 = footpads with mild lesions, dermal ridges not intact within a central, round to oval ulcer on the central plantar footpad surface, roughened lesion surface with small tag of crust < 1.5 cm

in diameter, and 2 = footpads with severe lesions, a brown >1.5 cm in diameter adhered to the central plantar footpad, sometimes extending up to the hock joint.

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Table 1. Composition of high protein and all vegetable diets[1]

	Feeding stage			
	Starter	Grower	Finisher	Withdrawal
Crude Protein (%)	24.7	22.4	20.2	19.6
ME (kcal/kg)	3096	3117	3149	3186
Ca (%)	1.08	1.06	0.92	0.7
Available P (%)	0.52	0.5	0.47	0.45
Lysine (%)	1.38	1.18	1	0.9
Methionine (%)	56	0.55	0.57	0.45
Methionine+Cystine (%)	0.95	0.88	0.86	0.75
Potassium (%)	1.1	0.97	0.86	0.86
Sodium (%)	0.2	0.2	0.2	0.23
Vitamin premix[2]	0.25	0.25	0.25	0.1
Trace mineral premix[3]	0.25	0.25	0.25	0.1
DL-methionine	0.2	0.2	0.25	0.16
L-Lysine	0.04	–	–	0.01
Coccidiostat[4]	0.08	0.08	0.08	–
Antibiotic[5]	0.05	0.05	0.05	–

[1]Starter diet placed: 0-17d; Grower diet placed: 18-30d; Finisher diet placed: 31-41d; Withdrawal diet placed: 42-48d

[2]Vitamin premix supplies the following per kg of diet: vitamin A, 16,183 IU; vitamin D_3, 4,851 IU; vitamin E, 16.6 IU; vitamin B_{12}, 0.04 mg; riboflavin, 12 mg; biotin, 0.05mg; niacin, 80 mg, pantothenic acid, 29 mg; choline, 1,102 mg; menadione, 4.8 mg; folic acid, 1.1 mg; pyridoxine, 4.4 mg; thiamine, 2.2 mg.

[3]Supplies the following per kg of diet: manganese, 143 mg; zinc, 121 mg; iron, 13 mg; copper, 13 mg; iodine, 2.2 mg; selenium, 0.7 mg.

[4]Monensin sodium premix, Coban 60 (Elanco Animal Health, Indianapolis, IN 46285).

[5]Starter and grower periods: Bacitracin Methyl Salicylate, BMD-50 (Alpharma Inc., Fort Lee, NJ 07024); Finisher period: Virginiamycin, Stafac-20 (Phibro Animal Health, Fairfield, NJ 07004).

Table 2. Influence of sodium bisulfate as a litter amendment on broiler performance

	42d of age			49d of age		
	Wt (g)	FC[1]	Mortality (%)	Wt (g)	FC[1]	Mortality (%)
Treatment	NS	NS	NS	NS	NS	NS
1	2260	1.713	3.03	2640	1.872	2.68
2	2310	1.708	3.9	2670	1.867	1.34
3	2270	1.705	3.51	2630	1.869	0.46
4	2280	1.723	3.51	2630	1.881	2.71
SEM	26.9	0.026	1.14	40.6	0.026	0.96

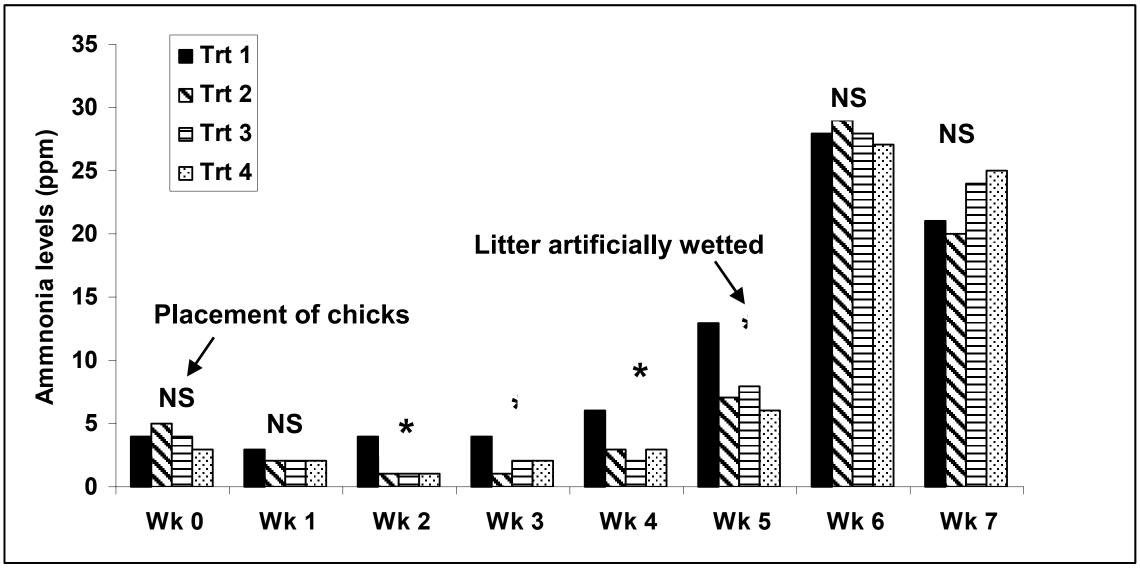
NS=Not significant ($P > 0.05$)
SEM=Pooled standard error of mean
[1]FC=Feed conversion adjusted for mortality
Trt 1 = control with no litter amendment
Trt 2 = litter amendment applied at a rate of 0.02 kg/sqft at the day of placement of chicks
Trt 3 = litter amendment applied at a rate of 0.04 kg/sqft at the day of placement of chicks
Trt 4 = litter amendment applied at a rate of 0.02 kg/sqft at the day of placement of chicks and again at 21 d.

Table 3. Moisture levels of litter from different treatments

	Moisture (%)			
	Before placement of chicks	35d	42d	49d
Treatment	NS	NS	NS	NS
1	10	11	18	14
2	9	10	16	13
3	8	12	17	13
4	10	11	14	12
SEM	1.4	1.5	1.8	1.7

NS=Not significant (P > 0.05)
SEM=Pooled standard error of mean
Trt 1 = control with no litter amendment
Trt 2 = litter amendment applied at a rate of 0.02 kg/sqft at the day of placement of chicks
Trt 3 = litter amendment applied at a rate of 0.04 kg/sqft at the day of placement of chicks
Trt 4 = litter amendment applied at a rate of 0.02 kg/sqft at the day of placement of chicks and again at 21 d.

Table 4. Influence of sodium bisulfate on ammonia levels (ppm) in chambers on a weekly basis



NS=Not significant (P > 0.05); * P < 0.05
SEM=Pooled standard error of mean
ppm = parts per million
Trt 1 = control with no litter amendment
Trt 2 = litter amendment applied at a rate of 0.02 kg/sqft at the day of placement of chicks
Trt 3 = litter amendment applied at a rate of 0.04 kg/sqft at the day of placement of chicks
Trt 4 = litter amendment applied at a rate of 0.02 kg/sqft at the day of placement of chicks and again at 21 d.

Table 5. Influence of sodium bisulfate on footpad lesions (%)

	42d of age			49d of age		
	None	Mild	Severe	None	Mild	Severe
Treatment	NS	NS	NS	NS	NS	NS
1	33	42	24	50	35	15
2	41	40	19	57	28	15
3	47	36	18	60	33	8
4	50	36	14	60	31	10
SEM	6.9	3.6	3.8	7.2	3.9	4.0
Sex (S)	*	**	NS	*	**	NS
Female	40	43	18	52	37	10
Male	46	34	20	61	26	13
SEM	2.1	2.0	1.4	2.3	2.0	1.6

NS=Not significant (p>0.05); *P < 0.05; **P < 0.01
SEM=Pooled standard error of mean
No Interactions were significant. P≤0.05
Trt 1 = control with no litter amendment
Trt 2 = litter amendment applied at a rate of 0.02 kg/sqft at the day of placement of chicks
Trt 3 = litter amendment applied at a rate of 0.04 kg/sqft at the day of placement of chicks
Trt 4 = litter amendment applied at a rate of 0.02 kg/sqft at the day of placement of chicks and again at 21 d.

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