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Effect of Litter Density, Organic Minerals (Availa Zn and Mn) and Microaid on the Incidence of Footpad Dermatitis in Broiler Chickens

Josafhat SR[1], Juan VHC[1], Juan MCC[1], Aleida SHC[1], Miguel ALV[1], Victor HBD[2], Osval AML[3] and Joel VV[1]*

[1]Colegio de Postgraduados Campus Córdoba, Km 348 Carretera Federal Córdoba-Veracruz, Ejido Manuel León, Amatlán de los Reyes Veracruz, México
[2]Synbios S.A de C.V. ciruelos, #137-112 Jurica 7, Querétaro, Qro, México
[3]Universidad de Colima. Av. Universidad No.333, Colima, México

Abstract

The effect of litter density, organic minerals and an extract of Yucca schidigera (MicroAid®) on the development of footpad dermatitis (FPD) in broiler chickens was evaluated. Four treatments were studied: Trt 1) traditional fattening program plus a litter density of 1 kg m^{-2}, Trt 2) traditional fattening program (Trt 1) plus a litter density of 2 kg m^{-2}, Trt 3) traditional fattening program plus a foot health program (40 ppm of Availa-Zn, 40 ppm of Availa-Mn and 125 ppm of MicroAid®) added to the diet, and Trt 4) combination of treatment 2 (Trt 2) and the foot health program implemented in treatment 3. Ross-line chickens were used. FPD was evaluated at day 45 of the fattening cycle using three scores (categories): 0=no lesions, 1=mild lesion and 2=severe lesion. Data were analysed using a generalized linear mixed model with multinomial response. Significant differences (P<0.05) among treatments were observed. The increase in litter density and the foot health program, on a separate basis, significantly reduced the percentage of chickens with a severe lesion to the footpad and increased the percentage of chickens with no lesions. The use of organic minerals (Availa-Zn and Availa-Mn at 40 ppm) and MicroAid® as supplements in the diet in conjunction with a litter density of 2 kg m^{-2} resulted in the greatest reduction in the incidence of FPD in broiler chickens (Trt 4).

Keywords: Litter density; Organic minerals; MicroAid®; Footpad dermatitis

Introduction

In recent years, poultry production has paid considerable attention to animal welfare, which has been associated with bird mortality, behaviour and health, among other aspects [1,2]. One of the diseases related to animal welfare is footpad dermatitis (FPD), since among many repercussions it affects the bird's ability to walk [3,4]. FPD is known as contact dermatitis or pododermatitis, and it is characterized by inflammation and necrotic lesions, ranging from superficial to deep on the plantar surface of the footpads and toes. Deep ulcers may lead to abscesses and thickening of underlying tissues and structures [5].

Chicken feet or paws are taking on great economic importance because of high demand in the foreign market, with the main market being Southeast Asia and China; however, diseases or disorders such as FPD lead to significant economic losses since feet with such a condition are unsuitable for human consumption and prices are downgraded in the market [6]. Due to this product's economic importance, research [7] has been conducted to determine what factors cause this disease and find strategies to reduce lesions on the foot in broilers.

One of the important factors in poultry farming is the litter as it has several functions, as thermal insulation, for moisture absorption, and as a protective barrier between the floor and the animal, among others [3].

The litter or bedding material most commonly used is pine shavings in the United States, but straw is frequently used in Europe. Rice and peanut hulls are also regularly used as litter material [8].

Other important aspects in fattening chickens are nutrition and feeding programs, which have significant effects on the performance and especially the health of the chicken. Feeding programs have considerable direct or indirect influence on the development of FPD [3]. Gordon et al. [9] identified that water consumption by poultry, due to the high level of protein in their diet, causes uric acid overload in the kidneys and therefore litter moisture increases and predisposes the birds to developing FPD.

The aim of this study was to evaluate the effect of litter density and organic minerals (Availa-Zn and Availa-Mn) with an extract of Yucca schidigera (MicroAid®), provided as supplements to a traditional fattening program, on the development of FPD in broilers.

Materials and Methods

The experiment was conducted from February to April 2015 in two commercial farms operated by a poultry company, located in the municipalities of Chocaman and Mariano Escobedo in the state of Veracruz with coordinates 19° 01´ NL, 97° 02´ WL, 18° 55'NL and 97° 08' WL and at elevations of 1360 and 1520 masl, respectively. The predominant climate of this region is temperate sub-humid with summer rains and average annual rainfall of 1722 mm.

The genetic material used in this experiment was mostly male Ross-line broilers. The experiment was performed following the criteria of the Mexican Official Norm on Technical specifications for the production, care and use of laboratory animals (Norma Official Mexicana sobre las especificaciones técnicas para la producción, cuidado y uso de los animales de laboratorio, NOM-062-ZOO-1999) and in accordance with the regulations for the use and care of animals for research, approved by the General Academic Council of the Colegio de Postgraduados, México. It is important to point out that the broilers used in this research were strictly used for the time period of the research last,

***Corresponding author:** Joel VV, Colegio de Postgraduados Campus Córdoba, Km 348 Carretera Federal Córdoba-Veracruz, Ejido Manuel León, Amatlán de los Reyes Veracruz, México, Tel: +52(271)-716 6000; E-mail: joel42ts@colpos.mx

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and no more studies were carried out. The 50-day traditional broiler fattening program carried out by the poultry farm consists of three phases: 1) initiation diet (1-18 days), 2) growth diet (19-35 days) and 3) completion diet (36-50 days). Rice hulls were used as litter material at a rate of 1 kg m^{-2}. In this study, a foot health program, additional to the traditional fattening program, was implemented, consisting of the addition of 125 ppm of MicroAid® (extract of Yucca schidigera), 40 ppm of Availa-Zn and 40 ppm of Availa-Mn to the fattening diet.

Based on the above information, the following four treatments applied on both farms were evaluated: Treatment 1 consisted of applying the company's traditional fattening program (Trt1): Treatment 2 consisted of the company's traditional fattening program plus an increase in litter density from 1 to 2 kg m^{-2} (Trt2); Treatment 3 consisted of the traditional fattening program plus the implementation of a foot health program during the entire fattening period (Trt3) and Treatment 4 consisted of the traditional fattening program, the foot health program and an increase in the litter density from 1 to 2 kg m^{-2} (Trt4). Table 1 details the treatments applied.

The degree of lesion on the foot (FPD) was evaluated at the end of the fattening period (50 days); for this, 1250 chickens per treatment were randomly selected. The degree of lesion on the foot was determined according to a visual guide for lesions in chickens based on the method of De Jong et al. [10]. This method consists of defining three scores; the 0 score is assigned to feet with no lesions, the 1 score is given if there are lesions on some footpad areas (<50%) and the 2 score is given if the foot has large lesions on footpad areas (50%-100%).

Statistical model

To compare the treatments under study we used two versions of the generalized linear mixed model (GLMM) for multinomial response. The cumulative logit model that is appropriate for ordered outcomes and the generalized logit model that is more appropriate for nominal categories where the outcomes are not ordered. Under both models with *C* categories are required *C*-1 equations (link functions) instead of one to fully specify a model relating the response probabilities ($\pi_1, \pi_2, \ldots \pi_c$) to the linear predictor [11]. The multinomial *C*-1logit equations contrast each of categories 1, 2, *C*-1.

Cumulative logit model

Linear predictor: The linear predictor for this data is $\eta_{cij} = \eta_c + \tau_I + b_j$, where η_{cij} is the cth link (c=0, 1) for the treatment *i* and block *j*, η_c is the intercept for *cth* link, τ_i is the *ith* fixed treatment effect, and b_j is the *jth* random block effect. Since there are three response categories, we have two link functions, one for each boundary. Distributions. The response has a multinomial distribution, that is, $y_{0ij}, y_{1ij}, y_{2ij} | b_j \sim Multinomial\left(N_{ij}, \pi_{0ij}, \pi_{1ij}, \pi_{2ij}\right)$ where y_{0ij}, y_{1ij}, y_{2ij} are the response in foot lesion of frequencies observed on each *C* category (none, mild, and severe) and each $b_j \sim N\left(0, \sigma_b^2\right)$. Link function. $\eta_{0ij} = log\left(\frac{\pi_{0ij}}{1-\pi_{0ij}}\right)$ and $\eta_{1ij} = log\left(\frac{\pi_{0ij}+\pi_{1ij}}{1-\pi_{0ij}-\pi_{1ij}}\right)$ and the inverse for each link are equal to: $\pi_{0ij} = \left(\frac{1}{1+e^{-\eta_{0ij}}}\right)$ and $\pi_{0ij} + \pi_{1ij} = \left(\frac{1}{1+e^{-\eta_{1ij}}}\right)$, respectively [11].

Generalized logit model

Linear predictor: The linear predictor in this case was $\eta_{cij} = \eta_c + \tau_{ci} + b_{cj}$, where η_{cij} and η_c are defined as in the cumulative logit model, τ_{ci} and b_{cj} denotes the *ith* fixed treatment effect and the *jth* random block effect under the *cth* link function, respectively. Also here two link functions are required since there are three response categories. Distributions: The response has a multinomial distribution, that is $y_{0ij}, y_{1ij}, y_{2ij} | b_j \sim Multinomial\left(N_{ij}, \pi_{0ij}, \pi_{1ij}, \pi_{2ij}\right)$ where y_{0ij}, y_{1ij}, y_{2ij} are the response in foot lesion of frequencies observed on each *C* category (none, mild, and severe) and each $b_{0j} \sim N\left(0, \sigma_{0b}^2\right)$ and $b_{1j} \sim N\left(0, \sigma_{1b}^2\right)$. Link function. $\eta_{0ij} = log\left(\frac{\pi_{0ij}}{\pi_{2ij}}\right)$ and $\eta_{1ij} = log\left(\frac{\pi_{1ij}}{\pi_{2ij}}\right)$.

Here the inverse link is equal to $\pi_{cij} = \frac{e^{\eta_{cij}}}{1+\sum_{c=0}^{C-1} e^{\eta_{cij}}}$ for *c*=0, 1 [11]. Both GLMM multinomial models were implemented using the GLIMMIX procedure of SAS version 9.3 (SAS Institute, Inc., Cary, NC).

Results

The results are presented for each type of multinomial model. First are given the results under the Cumulative logit model and then under the Generalized logit model.

Cumulative logit model

Results of the statistical analysis showed that the degree of foot lesion (FPD) in the tested treatments was significantly different (P<0.05). In the results in Table 2 we can see that the first estimated intercept, $\hat{\eta}_0 = 0.6144$ defines the boundary between the no and mild lesion scores, and that the second one, $\hat{\eta}_1 = 3.8787$ defines the boundary between the mild and severe lesion scores. The estimated effect of the treatments $\left(\hat{\tau}_i\right)$ shows that the boundaries move upwards and downwards when a certain treatment is applied. In this sense, all the estimated treatment have a negative effect (negative coefficients) with respect to treatment 4 (Table 2). This means that chickens under treatments 1 to 3 have a higher probability of developing a mild lesion and a severe lesion than treatment 4.

To calculate the odds that a chicken does not develop any degree of lesion (c=0) when it received treatment 1, that is, "C=0, trt=1", first we estimate the linear predictor $\hat{\eta}_{01} = \hat{\eta}_0 + \hat{\tau}_1 = 0.6144 + \left(-1.5034\right) = -0.889$ and taking the inverse of for this model we obtain $\hat{\pi}_{01} = 1 / 1+e^{-(-0.889)} = 0.29$. This value is the estimated probability that a chicken did not develop FPD when it received treatment 1. For "C=0, trt=1", $\hat{\eta}_{11} = \hat{\eta}_1 + \hat{\tau}_1 = 3.8787 + \left(-1.5034\right) = 2.3753$ whose inverse value is 0.915. This value is an estimate of $\hat{\pi}_{01} + \hat{\pi}_{11}$; from this value we can

Treatment	Characteristics
Trt1	Traditional program + 1 kg m^2 of rice hulls
Trt2	Traditional program + 2 kg m^2 of rice hulls
Trt3	Traditional program + Foot health program + 1 kg m^2 of rice hulls
Trt4	Traditional program + Foot health program + 2 kg m^2 of rice hulls

Table 1: Description of treatments.

Effect	Degree of lesion	Trt	Estimate	Standard Error
Intercept	None		0.6144	0.1799
Intercept	Mild		3.8787	0.2465
Trt		1	-1.5034	0.2086
Trt		2	-0.2509	0.2055
Trt		3	-1.0365	0.2036
Trt		4	0	.

Table 2: Solution for the fixed effects under a cummulative logit model.

obtain the probability that a chicken develops a mild lesion and a severe one. For a mild lesion $\hat{\pi}_{11} = 0.915 - \hat{\pi}_{01} = 0.915 - 0.29 = 0.624$, and for a severe lesion $\hat{\pi}_{21} = 1 - 0.915 = 0.085$. Similarly, the probabilities of the scores (C=0, 1, 2) for the rest of the treatments can be obtained and these probabilities are given in Figure 1.

Figure 1 shows that under the traditional feeding program with a litter density of 1 kg of rice hulls m^{-2} (Trt 1) there is a greater probability of obtaining feet with mild and severe lesions, $\hat{\pi}_{11} = 0.624$ and $\hat{\pi}_{21} = 0.085$ respectively. When the litter density was increased from 1 to 2 kg of rice hulls m^{-2} under the traditional fattening program (Trt 2), the probability of a mild and severe lesion developing in the chicken's footpad decreased significantly to $\hat{\pi}_{12} = 0.384$ and $\hat{\pi}_{22} = 0.026$, respectively, whereas the probability of not developing a foot lesion increased to $\hat{\pi}_{02} = 0.590(\text{Trt2})$ compared with $\hat{\pi}_{01} = 0.291(\text{Trt1})$. Regarding the implementation of the two foot health programs plus the litter density of 2 kg of rice hulls m^{-2}, an increase in the probability of not developing a foot lesion, $\hat{\pi}_{04} = 0.649$ (Trt4) compared with $\hat{\pi}_{03} = 0.396(\text{Trt3})$ can be seen, and the probability of developing a mild and severe lesion decreased to $\hat{\pi}_{14} = 0.331$ and $\hat{\pi}_{24} = 0.020(\text{Trt4})$ compared with $\hat{\pi}_{13} = 0.549$ and $\hat{\pi}_{23} = 0.055(\text{Trt3})$.

Generalised logit model

Results of the analysis of variance for the fixed effects in each of the degree of foot lesion scores are shown in Table 3. Following the same logic in the estimation of probabilities as in the above procedure, we can see the estimated intercepts: $\hat{\eta}_0 = 4.8525$ which defines the boundary between the no and mild lesion scores, and the second, $\hat{\eta}_1 = 4.2485$ which defines the boundary between the mild and severe lesion scores. The effect $(\hat{\tau}_i)$ of the treatments and the estimated odds of not developing a lesion or a mild lesion per treatment are shown in Table 3. The probability of not having a foot lesion when the individual received treatment 1 is $\hat{\pi}_{01} = 0.315$, whereas for a mild lesion it is $\hat{\pi}_{11} = 0.57$. From these values we can estimate the odds of having a severe lesion in each of the treatments. For example, the probability of having a severe foot lesion under treatment 1 is $\hat{\pi}_{21} = 1 - (0.315 + 0.57) = 0.115$; following the same logic, the scores of the other treatments are estimated.

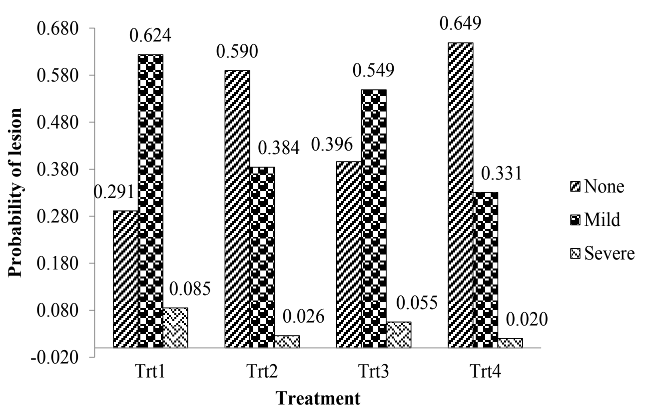

Figure 1: Estimated probabilities for the degree of foot lesion scores in each of the treatments tested using a cumulative logit model.

Effect	Degree of lesion	Trt	Estimate	Standard Error	$\hat{\eta}_{ci}$	$\hat{\pi}_{ci}$
Intercept	None		4.8525	1.0059		
Intercept	Middle		4.2485	1.0071		
Trt	None	1	-3.8447	1.0330	1.007	0.3150
Trt	Middle	1	-2.6478	1.0327	1.6007	0.5700
Trt	None	2	-1.1888	1.1618	3.6637	0.5850
Trt	Mild	2	-0.9651	1.1662	3.2834	0.4000
Trt	None	3	-2.7860	1.0585	2.0665	0.3929
Trt	Mild	3	-1.8326	1.0598	2.4159	0.5573
Trt	None	4	0	.	4.8525	0.6433
Trt	Mild	4	0	.	4.2485	0.3517

Table 3: Solution for the fixed effects under a generalized logit model.

In Figure 2 we can see that in treatments 2, 3, and 4 the estimated probabilities $(\hat{\pi}_{ci}; c = 0,1,2; y i = 1,2,3,4)$ of not developing FPD are 0.585, 0.393, and 0.643 compared with a probability of 0.315 in treatment 1, and the odds in these treatments of developing mild lesions are 0.40, 0.557, and 0.352 compared with a probability of 0.57 in the traditional fattening program (Trt 1), respectively. In addition, the likelihood of developing a severe lesion is greater in treatment 1 $(\hat{\pi}_{21} = 0.115)$ than in the estimated probabilities in treatments 2–4 $(\hat{\pi}_{21} = 0.115)(\hat{\pi}_{22} = 0.015,\ \hat{\pi}_{23} = 0.05, \text{and}\ \hat{\pi}_{24} = 0\ 005)$ respectively.

A common use of the odds ratio (OR) is to determine the size of the effect of a difference in two treatments. The OR results are shown in Table 4. Individuals (chickens) that received treatment 2 had 14.23 times more individuals without FPD and 5.38 times fewer individuals with mild FPD than chickens under treatment 1, while treatment 3 showed 2.88 times more individuals with no lesions and 2.26 times less with mild lesions than treatment 1. Finally, treatment 4 showed 46.74 times more chickens with no foot lesions and 14,123 times less with mild lesions than treatment l.

Discussion

Under both GLMM for multinomial response we arrived to the same conclusion but of course with small differences in the

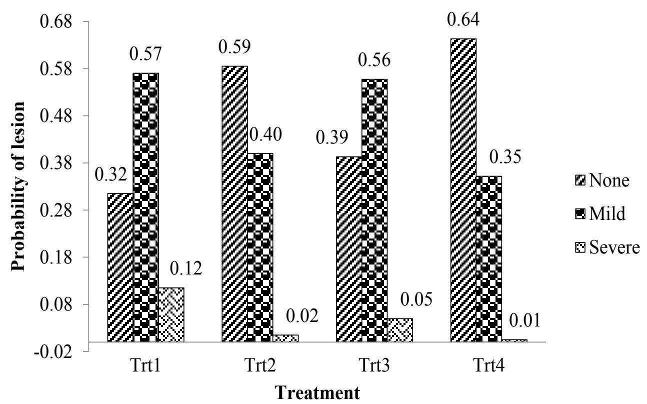

Figure 2: Estimated probabilities of developing foot lesion in each of the treatments using generalized logit model.

Comparison	Estimate	95% Confidence Limits	
None: trt 2 *vs.* 1	14.239	4.106	49.372
Mild: trt 2 *vs.* 1	5.38	1.559	18.564
None: trt 3 *vs.* 1	2.883	1.277	6.507
Mild: trt 3 *vs.* 1	2.26	1.028	4.969
None: trt 4 *vs.* 1	46.746	6.153	355.159
Mild: trt 4 *vs.* 1	14.123	1.86	107.234

Table 4: Odds ratio and cofidence limits for the degree of foot leison as a function of the treatment applied. Serve lesión reference score.

probabilities for each treatment category combination. In general, the inclusion of the two foot health programs in the chicken fattening program significantly reduced the development of FPD, and this effect is reduced even more when litter density was increased from 1 to 2 kg of rice hulls m^{-2}, observing a greater likelihood of obtaining feet with no lesions and lower odds of obtaining feet with mild and severe lesions. The percentage of chickens with mild and severe lesions at a litter density of 1 kg m^{-2} (Trt 1 and Tr 3) was higher than when a litter density of 2 kg m^{-2} (Trt2) was utilized. Results in this study are consistent with those obtained by García et al. [7] who found that the presence of lesions (scratches, bruises and lesions on the footpad) were influenced by the type of litter material evaluated (wood chips, rice hulls, cut elephant grass, and sugar cane bagasse). The chickens had higher plantar injuries and scratches when the bedding was based on sugarcane bagasse and chopped elephant grass, and combinations of 50% bagasse: 50% chips and 50% bagasse: 50% rice husks due to the high degree of litter compaction. The incidence of plantar lesions is closely related to the quality and quantity of bedding material. Furthermore, the use of small-sized bedding material particles results in a reduction in moisture content, higher density and lower litter height, minimizing the development of lesions on the tarsolmetatarsal joint and footpads. High litter moisture content leads to cycles of wetting and drying that compact the material causing burns and FPD [12]. Dowsland [13] also argues that the development of FPD depends on several factors, with the most important including the quality and type of bedding, the feed and the health of the chickens. The lesion on the chicken's footpad can appear at any stage of fattening and the main cause is poor litter quality due to high moisture content and hardness. Another important factor influencing the development of FPD, according to Arnold and Colin [14] and Bilgili et al. [12], is the quality of the nutrition and feeding programs which, if appropriate, improve feed digestibility and can thus reduce the incidence of PFD on a poultry farm. High concentrations of protein in the diet and the intake of high levels of minerals (sodium, potassium and magnesium) increase water consumption which, in turn, increases litter moisture. Moreover, carbohydrates such as non-starch polysaccharides of plant protein origin can cause an increase in the viscosity of the stool that adheres to the footpad, and rations formulated with soybean as the main source of protein cause the bird's feces to be stickier and the pH to increase, which can irritate the footpad. In addition, intestinal health is essential to maintain good-quality litter as any health problem or stress may affect the functioning of the intestine, increasing litter moisture and hardness and thus favouring the production and release of ammonia due to the very high proliferation of microorganisms [15]. Cabuk et al. [16] found that by supplementing the broiler diet with Yucca schidigera and natural zeolite significantly decreased the environmental ammonia concentration and fecal dry matter without affecting broiler performance. As can be seen, the treatments applied with the organic minerals Availa-Zn and Availa Mn at 40 ppm and MicroAid® at 125 ppm (foot health program) significantly reduced the risk (probability) of the birds developing a mild or severe lesion and increased the probability of not observing lesions in the footpad of the animal [17]. This may be because these supplements (organic minerals and MicroAid®) improve feed digestibility and the intestinal health of chickens, both determinants in the development of FPD in broilers.

Conclusion

The incidence of footpad dermatitis strongly depends on the characteristics of the bedding material, such as moisture, density and type of material used, as well as the quality of nutrition and health of the chickens. The use of organic minerals (Availa-Zn and Availa-Mn at 40 ppm) and MicroAid® in conjunction with a litter density of 2 kg m^{-2} significantly reduced the incidence of FPD in broilers. Taking into account the effect separately from organic minerals - MicroAid® and litter density, both significantly reduced the incidence of footpad dermatitis. For the above expressed we believe that the proposed treatments are a good alternative to reduce significantly the problems produced for the FDP disease.

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