Effect of beak trimming at hatch and the inclusion of oat hulls in the diet on growth performance, feed preference, exploratory pecking behavior, and gastrointestinal tract traits of brown-egg pullets from hatch to 15 weeks of age

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ABSTRACT The influence of infrared beak trimming at hatch (**IRBT**) and the inclusion of oat hulls (**OH**) in the diet on growth performance, feed preference, exploratory pecking behavior, and gastrointestinal tract (**GIT**) development, was studied in brown-egg pullets from 0 to 15 wk of age. The experimental design was completely randomized with 4 treatments arranged as a 2 × 2 factorial with IRBT (sham vs. treated) and OH inclusion (0 vs. 3%) as main effects. Each treatment was replicated 20 times and the experimental unit was a cage with 10 pullets. Feed intake (**FI**), BW gain, feed conversion ratio (**FCR**), energy intake (**EI**, kcal AMEn/d), and energy conversion ratio (**ECR**, kcal AMEn/g of BW gain) were determined by feeding period (0 to 6, 7 to 10, and 11 to 15 wk of age) and cumulatively. Particle size preference was measured at 7 wk and exploratory pecking behavior of the pullets and at 8 to 14 wk of age. From 0 to 6 wk of age, beak trimming decreased FI ($P < 0.01$) and increased pullet mortality ($P < 0.001$) but did not affect BW gain. From 0 to 15 wk of age, OH inclusion improved BW uniformity ($P = 0.090$) but impaired FCR ($P < 0.05$) without showing any effect on BW gain or ECR. Preference for coarse particles was greater for the sham than for the treated pullets. Beak trimming and OH feeding reduced ($P < 0.05$) the exploratory pecking behavior of the pullets from 8 to 12 wk of age but not thereafter. Oat hulls increased the relative weights of the full gizzard and intestines at all ages ($P < 0.05$). In summary, beak trimming did not affect pullet performance at 15 wk of age or GIT development at any age. Oat hulls improved GIT development at all ages but did not affect BW or ECR. Both beak treatment and OH inclusion affected particle size preference and reduced the exploratory pecking behavior of the birds.

Key words: feed particle size, gastrointestinal tract, infrared beak treatment, oat hulls, pullet pecking behavior

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INTRODUCTION

The beak is a highly innerved organ used by the birds for food probing and preening, exploration of the environment, and social interaction. Beak trimming prevents feather pecking, cannibalism, and mortality (Gentle, 1986; Glatz, 2000) and improves feed efficiency and flock profitability (Breward and Gentle, 1985; Hughes and Gentle, 1995). However, because of animal welfare issues, beak treatment is under strict scrutiny in many parts of the world and thus, new strategies are needed to reduce aggressive behavior of the birds (Jung and Knierim, 2018; Nicol, 2018). Novel genetic programs and changes in management practices, have been proposed to prevent injurious pecking while maintaining productivity, with limited success, (Kjaer and Sorensen, 1997; Lambton et al., 2013). Prevention of cannibalism through nutrition, however, seems to be a feasible option (van Krimpen et al., 2008; Mens et al., 2020; Desbruslais et al., 2021). In this respect, Bearse et al. (1940) reported a decrease in aggressive behavior when the pullets were fed high crude fiber diets. In fact, Wahlstrom et al. (1998) reported less incidence of cannibalism and mortality in hens fed diets based on oats than in diets based on wheat. Similarly, Qaisrani et al. (2013) observed that feather pecking was reduced when the pullet diet was diluted with 15% oat hulls (**OH**). The information available suggests that insoluble fiber triggers a temporary satiety in the bird, reducing stress and injurious pecking (Hetland et al., 2004; Mateos et al., 2012). In addition, fiber increases the time that birds spend on exploratory and foraging behavior, with less time available for feather pecking and aggressive behavior (Huber-Eicher and Wechsler, 1998; Aerni et al., 2000; van Krimpen et al., 2009).

Research conducted in broilers (Jiménez-Moreno et al., 2013, 2019) and pullets (Guzmán et al., 2015;

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García et al., 2019) has shown that the inclusion of insoluble fiber in the diet stimulates the development of the gastrointestinal tract (**GIT**), resulting often in an improvement of growth performance. An excess of fiber, however, reduces feed acceptability, energy intake (**EI**), and nutrient digestibility in poultry (Jiménez-Moreno et al., 2011, 2016), and consequently, an excess of fiber should be avoided. The objective of this research was to investigate the effect of infrared beak treatment (**IRBT**) at hatch and the inclusion of 3% OH in the diet on growth performance, feed particle size preference, exploratory pecking behavior, and the development of the GIT of brown-egg pullets from 0 to 15 wk of age.

MATERIALS AND METHODS

Husbandry, Diets, and Experiment Design

The procedures used in this research were approved by the Animal Ethics Committee of the Universidad Politécnica de Madrid and were in compliance with the Spanish Guidelines for the Care and Use of Animals in Research (BOE, 2013). In total, 800 one-day-old Lohmann Brown Classic pullets, with an initial BW of 36.9 ± 2.58 g, were obtained from a commercial hatchery and vaccinated against main diseases (Infectious Bronchitis, Marek, and Infectious Bursal Disease) according to accepted commercial practices (Lohmann, 2020). Half of the pullets were trimmed at hatch by applying a high-intensity beam of an infrared energy source (Nova-Tech Engineering Inc., Willmar, MN) whereas the other half was handled similarly to treated pullets but without actual treatment. The process consists in exposing the tip of the bird to a non-contact, high intensity infrared light that penetrates in the rhamphotheca, damaging the keratin producing cells in the epidermis, hence preventing the growth of the treated beak tissue (Glatz, 2005). At arrival to the experimental station, the pullets were weighed individually and randomly allotted to 80 enriched cages (145 × 45 × 40 cm; Alternative Design, Siloam Springs, AR) in groups of 10. Each cage was provided with 2 low-pressure nipple drinkers and an open trough feeder. No access to first age drinkers or to extra feed placed on paper lining the cage floor were available to the pullets at the arrival to the experimental farm. From 0 to 3 d of age, the light period and light intensity were of 18 h and 25 lux, respectively. Afterward, the 18 h/d light program was maintained to d 6 of life, and then decreased gradually until reaching 9 h/d at 7 wk of age and kept constant to 15 wk of age (Lohmann, 2020). The temperature of the room was kept at 34 ± 2°C for the first 5 d of life, reduced gradually to reach 20°C at 6 wk of age, and maintained constant to 15 wk of age. Water and feed in mash form were available for ad libitum consumption throughout the experiment. The feeding program consisted of 3 periods: 0 to 6 wk, 7 to 10 wk, and 11 to 15 wk of age. The control diets were formulated according to FEDNA (2018) recommendations and were based on soybean meal, barley, and wheat, the ingredients most commonly used in pullet feeding in Spain. The experimental diets of the 3 feeding periods were obtained by diluting (wt:wt) the corresponding control diet with 3% OH. Before feed manufacturing, the batch of OH used as a source of insoluble fiber, was ground using a hammer mill provided with a 2-mm screen.

The experiment was conducted as a completely randomized design with 4 treatments arranged as a 2 × 2 factorial with IRBT at hatch (sham vs. treated) and level of OH in the diet (0 vs. 3%) as main effects. Each treatment was replicated 20 times and the experimental unit was a cage with 10 pullets.

Laboratory Analysis

Particle size distribution and mean particle size of OH and diets, expressed as geometric mean diameter ± geometric standard deviation (**GMD ± GSD**), were determined in 100 g samples using a Retsch shaker (Retsch, Stuttgart, Germany) provided with 8 sieves ranging in mesh from 5,000 to 40 μm, as outlined by the ASAE (2003). Oat hulls and diets were analyzed for moisture by oven-drying (method 930.15), total ash by muffle furnace (method 942.05), nitrogen by Dumas (method 968.06) using a LECO analyzer (model FP-528, LECO Corporation, St. Joseph, MI), and ether extract by Soxhlet after $3N$ HCl hydrolysis (method 920.39), as indicated by AOAC International (2019). Gross energy was determined using an isoperibol bomb calorimeter (model 356, Parr Instrument Company, Moline, IL). The starch content of the OH was measured by the α-amylase glucosidase method (method 996.11). Crude fiber was analyzed by sequential extraction with diluted acid and alkali (method 962.09) as indicated by AOAC International (2019) and neutral detergent fiber (**NDF**) as indicated by van Soest et al. (1991) and expressed on an ash-free basis. The physicochemical composition of OH and diets are shown in Tables 1 and 2, respectively.

Measurements

Feed disappearance and BW of the pullets were determined by replicate at the end of each feeding phase (6, 10, and 15 wk of age). Mortality was recorded and weighed as produced. The data were used to determine BW gain, feed intake (**FI**), and feed conversion ratio (**FCR**) by period and for the entire experiment. At 15 wk of age, pullets were weighed individually and the CV among BW by replicate was used as an indirect measurement of BW uniformity. The CV, expressed as a percentage (%), was calculated as the ratio of the standard deviation to the mean of the individual BW of the pullets within each replicate, as indicated by Peak et al. (2000). In addition, EI expressed as kcal of AMEn ingested per day and energy conversion ratio (**ECR**), expressed as kcal of AMEn ingested per g of BW gain, were determined at same ages.

At 10 and 15 wk of age, two birds per cage were randomly selected, weighed individually, and euthanized by

Table 1. Chemical analyses (% as fed basis) and physical properties of the oat hulls.

Determined analyses[1]	
Dry matter	89.7
Gross energy (kcal/kg)	3,950
Crude protein	4.6
Starch	2.7
Crude fiber	30.1
NDF	70.7
Total ash	4.9
Calculated analyses[2]	
AMEn, kcal/kg	400
Ether extract (with HCl hydrolysis)	1.4
Digestible amino acid	
Lys	0.04
Met + Cys	0.02
Thr	0.04
Calcium	0.09
Total phosphorus	0.14
Physical properties	
Sieve screen[3] (μm)	
2,500	1.6
1,250	14.7
630	31.0
315	30.7
160	17.3
80	4.8
GMD[4] ± GSD[4] (μm)	590 ± 2.16

[1]Analyzed in duplicate, except for mean particle size that were determined in triplicate.

[2]According to FEDNA (2021).

[3]The percentage of particles bigger than 5,000 μm or smaller than 80 μm was negligible.

[4]Geometric mean diameter ± geometric standard deviation.

CO_2 inhalation. The GIT (from the distal part of the esophagus to the cloaca, liver, spleen, and pancreas not included), was removed and the proventriculus, gizzard, and intestines (from the pyloric sphincter to the cloaca) were excised aseptically and weighed. The weights of all these organs, including their contents, are presented in absolute (g) and relative (**RW**, % BW) terms. In addition, gizzard pH was measured using a digital pH meter (Model 507, Crison Instruments S.A., Barcelona, Spain) as indicated by Jiménez Moreno et al. (2009). Briefly, the fine tip of the glass electrode was gently introduced into the gizzard and the pH was recorded twice. The mean value of the 2 birds per cage, was used for statistical evaluation. Then, the gizzard was emptied, cleaned from any digesta content, dried with desiccant paper, and weighed again. The fresh content of the organ was calculated by difference between the weight of the full and the empty gizzard and expressed in absolute (g) and relative (% of full gizzard weight) terms.

Feed preference behavior for coarse particles was determined at 7 wk of age by comparing the GMD and the GSD of the original diets supplied at 08.00 am (lights on) and of the refusals that remained in the feeders 24 h later. The amount of feed provided (900 g per replicate) ensured the correct evaluation of the particle size distribution of the feed residuals (approximately 400 g per replicate). Feed residuals were collected by replicate and the particle size distribution and the GMD ± GSD were determined. In addition, the exploratory pecking behavior of the birds was evaluated from 8 to 14 wk of age at 2 wk intervals, using 2 complementary procedures: 1) time elapsed from the introduction of a pecking stimulus (a ballpoint pen), at eye level, in the side panel of the cage, until a first pullet pecked it and 2) percentage of pullets within each cage, that pecked the ballpoint pen in less than 5 s after the offer.

Statistical Analysis

The normal distribution of the residuals and the homogeneity of the variance of the data were tested using the UNIVARIATE procedure and the Levene's Test, respectively (SAS Institute, 2004). Data were analyzed as a completely randomized design with IRBT of the pullets and OH inclusion in the diet as main effects, using the MIXED procedure of SAS (SAS Institute, 2004). The effects of age and the interaction between pullet age and IRBT and OH inclusion, on growth performance, exploratory pecking behavior, and GIT traits were tested as indicated by Littell et al. (1998). Data on mortality was not normally distributed and therefore the values were log-transformed before analysis. When significant differences among treatments were detected ($P \leq 0.05$), means were separated using the Tukey test. In addition, the effects of age on the variables studied, were partitioned into its linear (***L***) and quadratic (***Q***) components. Results in tables are reported as least square means.

RESULTS

The GMD ± GSD of the batch of OH used, were 590 ± 2.16 μm and contained by analyses 4.6% CP, 2.7% starch, and 70.7% NDF (Table 1). The GMD ± GSD of the control diets used for the 3 feeding periods of the experiment were 983 ± 1.93, 1,205 ± 2.39, and 1,147 ± 2.38 μm, respectively. The composition of the experimental diets was close to expected values, confirming that the feeds were manufactured correctly (Table 2). The proportion of barley in the diet was quite high (36.9 and 55.1%, depending on age). As a result, the crude fiber content was higher for the control than for the experimental feeds that were based on corn. No interactions between IRBT and OH inclusion in the diet were detected for any of the traits studied and therefore, only main effects are presented.

Growth Performance

Age affected all the performance traits studied, with significant interactions observed in some cases. In this respect, from 0 to 6 wk of age, FI and EI were greater for the sham birds ($P < 0.01$) than for the beak treated (**BT**) birds but an opposite effect ($P < 0.05$) was observed from 7 to 10 wk (Figures 1A and 1B). Also, OH inclusion reduced EI ($P < 0.05$) from 7 to 10 wk of age but not from 0 to 6 wk or from 11 to 15 wk (Figure 1C).

Table 2. Ingredient composition and physicochemical characteristics of the experimental diets (% as fed basis).

	0 to 6 wk		7 to 10 wk		11 to 15 wk	
Oat hulls	0%	3%	0%	3%	0%	3%
Ingredient						
Barley	-	-	36.9	35.8	55.1	53.4
Corn	66.3	64.3	38.2	37.1	-	-
Wheat	-	-	-	-	24.4	23.7
Soybean meal (47% CP)	29.2	28.3	19.9	19.3	8.82	8.56
Sunflower meal (34% CP)	-	-	1.15	1.12	8.24	7.99
Soy oil soapstocks	1.05	1.02	1.0	0.97	1.0	0.97
Oat hulls	-	3.00	-	3.00	-	3.00
Calcium carbonate	1.35	1.33	1.34	1.30	1.44	1.40
Dicalcium phosphate	0.95	0.93	0.61	0.59	0.38	0.37
Sodium chloride	0.33	0.32	0.35	0.34	0.35	0.34
DL-methionine (99%)	0.22	0.21	0.14	0.14	0.04	0.04
L-lysine·HCl (78%)	0.16	0.16	0.09	0.09	0.03	0.03
L-threonine (98%)	0.04	0.04	0.02	0.02	-	-
Vitamin and mineral premix[1]	0.40	0.39	0.30	0.29	0.20	0.19
Determined analyses[2]						
Dry matter	87.6	87.3	89.0	89.0	89.9	89.6
Gross energy (kcal/kg)	3,867	3,863	3,917	3,910	3,905	3,912
Crude protein	19.5	18.9	17.2	16.6	15.5	15.1
Crude fiber	3.2	4.0	3.7	4.4	5.5	6.2
NDF	8.7	10.5	12.4	14.0	16.4	18.0
Total ash	5.4	5.7	5.4	5.5	4.8	4.6
Calculated analyses[3]						
AMEn (kcal/kg)	2,960	2,885	2,860	2,785	2,732	2,658
Ether extract	4.0	3.92	3.24	3.18	2.52	2.49
Digestible amino acids						
Lys	0.98	0.95	0.77	0.75	0.55	0.54
Met + Cys	0.74	0.71	0.62	0.60	0.52	0.50
Thr	0.65	0.63	0.53	0.52	0.45	0.44
Trp	0.19	0.19	0.17	0.16	0.16	0.15
Calcium	0.90	0.88	0.85	0.83	0.85	0.83
Digestible phosphorus	0.42	0.41	0.35	0.34	0.33	0.32
Physical properties						
Sieve screen[4] (μm)						
2,500	4.6	4.6	23.1	23.0	21.5	22.0
1,250	34.8	33.3	31.0	30.4	29.2	29.1
630	35.6	37.8	23.3	23.0	24.1	23.1
315	20.9	20.1	12.4	12.7	17.1	17.2
160	4.03	4.15	9.4	10.0	8.29	8.6
Geometric mean diameter	983	977	1,205	1,183	1,147	1,154
Geometric standard deviation	± 1.93	± 1.92	± 2.39	± 2.42	± 2.38	± 2.37

[1]Provided the following (per kilogram of diet): vitamin A (trans-retinyl acetate), 10,000 IU; vitamin D_3, 2,600 IU; vitamin E (all-rac-tocopherol-acetate), 20 mg; vitamin B_1, 1.5 mg; vitamin B2, 5 mg; vitamin B_6, 2.3 mg; vitamin B_{12} (cyanocobalamin), 25 μg; vitamin K_3 (bisulphate menadione complex), 2.7 mg; choline (choline chloride), 250 mg; nicotinic acid, 30 mg; pantothenic acid (D-calcium pantothenate), 9 mg; folic acid, 0.6 mg; D-biotin, 0.15 mg; zinc (ZnO), 60 mg; manganese (MnO), 80 mg; iron ($FeCO_3$), 40 mg; copper ($CuSO_4$ $5H_2O$), 8 mg; iodine (KI), 0.6 mg; selenium (Na_2SeO_3), 0.3 mg, and 5,200 IU of endo-1,4-β-xylanase (EC 3.2.1.8)] supplied by DSM S.A., Madrid, and Natuphos 5000 [300 FTU/kg 6-phytase (EC 3.1.3.26), 60 mg, supplied by Basf Española S.A, Tarragona, Spain].

[2]Analyzed in duplicate, except for mean particle size that were determined in triplicate.

[3]According to FEDNA (Fundación Española Desarrollo Nutrición Animal, 2021).

[4]The percentage of particles bigger than 5,000 μm or smaller than 160 μm was negligible for all diets.

The effects of IRBT and of the inclusion of OH in the diet on pullet performance, are shown in Table 3.

Beak Treatment From 0 to 6 wk of age, BT pullets ate less feed (23.3 vs. 24.1 g/d; $P < 0.01$), had better FCR (2.33 vs. 2.36 g/g; $P < 0.05$), and higher mortality (2.5 vs. 0.5%; $P < 0.01$) than sham pullets, but BW gain was not affected. From 7 to 10 wk of age, BT pullets ate more feed (58.7 vs. 57.4 g/d; $P < 0.05$) and grew faster (17.8 vs. 17.3 g/d; $P < 0.05$) than sham pullets, but FCR was not affected. From 11 to 15 wk of age, IRBT did not affect pullet growth. As a result, from 0 to 15 wk of age the only variable affected by IRBT was mortality that was higher for the BT pullets than for the sham pullets ($P < 0.001$).

Oat Hulls Inclusion From 0 to 6 wk of age, OH inclusion had no effects on any of the growth performance traits studied except FCR that was impaired (2.37 vs. 2.33 g/g; $P < 0.05$). From 7 to 10 wk of age, OH inclusion reduced EI (161.7 vs. 166.5 Kcal AMEn/d; $P < 0.01$) and tended to improve ECR (9.24 vs. 9.41 Kcal AMEn/g of BW gain; $P = 0.063$) but no differences were observed from 11 to 15 wk of age. As a result, from 0 to 15 wk of age, the only traits affected by the inclusion of OH in the diet were FCR that was impaired (3.94 vs. 3.84 g/g; $P < 0.05$) and BW uniformity that tended to improve ($P = 0.090$).

Preference Behavior for Coarse Particles

The effects of IRBT and OH inclusion in the diet on particle size distribution of the original feeds and of the

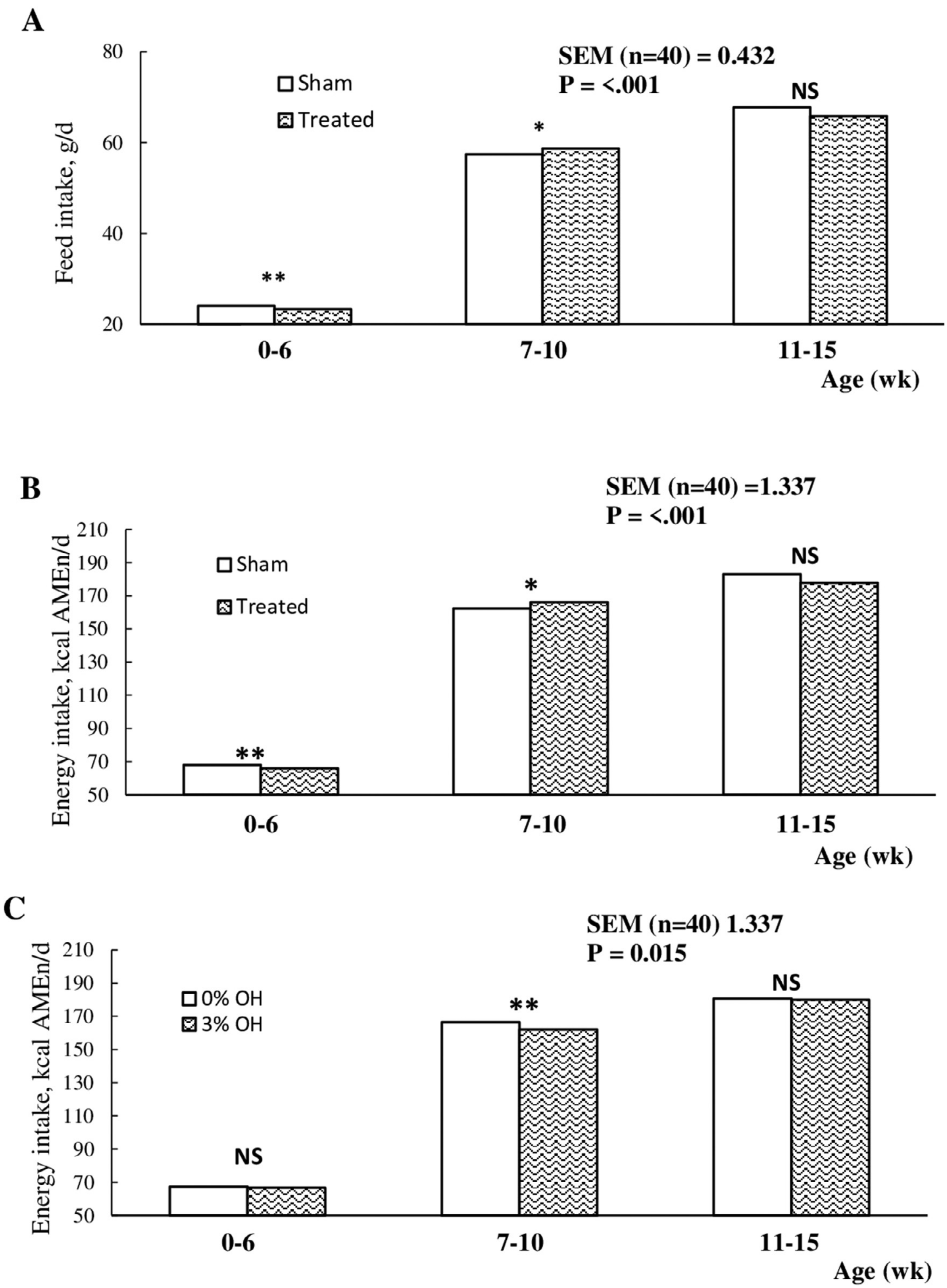

Figure 1. Interactions between age and infrared beak trimming on feed (A) and energy (B) intake and between age and oat hulls (OH) inclusion on energy intake (C). $0.001 < P < 0.01$ = **; $0.01 < P < 0.05$ = *; $P > 0.1$ = NS.

refusals at 7 wk of age, after 24 h of ad libitum consumption, are shown in Table 4.

Beak Treatment The GMD and the GSD were higher for the original diets than for the feed that remained in the feeders 24 h after feed provision ($P < 0.001$). Moreover, the GMD (1,018 vs. 923 μm; $P < 0.001$) and the GSD (2.31 vs. 2.25 μm; $P < 0.001$) of the residual feeds were higher for the BT than for the sham pullets. In fact, the percentage of coarse particles in the refusals, defined as particles with a GMD above 1,250 μm, was lower for the sham than for the BT birds (35.8 vs. 42.7%; $P < 0.001$) whereas the percentage of fine particles, defined as particles with a GMD under 315 μm was higher for the sham than for the BT birds (32.2 vs. 29.0%; $P < 0.001$).

Table 3. Effects of infrared beak treatment at hatch (IRBT) and the inclusion of oat hulls (OH) in the diet on growth performance of the pullets from 0 to 15 wk of age.

	IRBT		OH		SEM	*P*-value[3, 4]	
	Sham[1]	BT[2]	0%	3%	n = 40	IRBT	OH
0 to 6 wk							
BW gain (g/d)	10.16	10.04	10.12	10.08	0.124	0.362	0.740
Feed intake (g/d)	24.1	23.3	23.5	23.9	0.251	0.005	0.174
Feed conversion ratio (g/g)	2.36	2.33	2.33	2.37	0.019	0.016	0.041
Energy intake (kcal AMEn/d)	70.2	68.1	69.6	68.7	0.724	0.005	0.252
Energy conversion ratio[5]	6.91	6.78	6.87	6.82	0.056	0.013	0.233
Mortality[6] (%)	0.50	2.50	1.75	1.25	-	0.001	0.104
7 to 10 wk							
BW gain (g/d)	17.3	17.8	17.7	17.5	0.241	0.047	0.507
Feed intake (g/d)	57.4	58.7	58.1	58.0	0.522	0.011	0.752
Feed conversion ratio (g/g)	3.32	3.30	3.28	3.31	0.033	0.666	0.704
Energy intake (kcal AMEn/d)	162.3	165.9	166.5	161.7	1.499	0.019	0.002
Energy conversion ratio	9.38	9.32	9.41	9.24	0.096	0.775	0.063
11 to 15 wk							
BW gain (g/d)	12.3	12.2	12.2	12.3	0.182	0.510	0.775
Feed intake (g/d)	67.8	65.9	66.2	67.4	1.110	0.195	0.260
Feed conversion ratio (g/g)	5.51	5.40	5.43	5.48	0.090	0.442	0.380
Energy intake (kcal AMEn/d)	183.4	179.5	182.1	180.8	2.988	0.193	0.660
Energy conversion ratio	14.91	14.71	14.93	14.70	0.243	0.441	0.489
0 to 15 wk							
BW gain (g/d)	12.7	12.7	12.9	12.7	0.098	0.447	0.245
Feed intake (g/d)	49.9	49.6	49.5	50.0	0.484	0.568	0.294
Feed conversion ratio (g/g)	3.93	3.91	3.84	3.94	0.033	0.134	0.031
Energy intake (kcal AMEn/d)	138.68	137.94	139.40	137.23	1.324	0.578	0.106
Energy conversion ratio	10.92	10.86	10.81	10.81	0.091	0.130	0.403
Mortality (%)	0.50	2.50	1.75	1.25	-	0.001	0.104
BW uniformity[7]	7.63	6.68	7.68	6.63	0.615	0.127	0.090

[1]Intact beak.
[2]Beak trimmed.
[3]The interactions between main effects were not significant ($P > 0.05$).
[4]Significant interactions between age and IRBT ($P < 0.05$) and between age and OH inclusion for energy intake ($P < 0.05$) were detected (see Figure 1).
[5]Kcal AMEn:g BW gain.
[6]All the mortality occurred during the first week of age.
[7]BW uniformity was estimated as the coefficient of variation (%) of the individual BW of the birds within each replicate (Peak et al., 2000).

Oat Hulls Inclusion Oat hulls inclusion did not affect the GMD or the GSD of the residuals 24 h after feed provision. However, OH reduced the percentage of coarse particles (38.1 vs. 40.4%; $P < 0.05$) and tended to increase the percentage of fine particles (31.3 vs. 30.0%; $P = 0.067$) of the feed residuals.

Exploratory Pecking Behavior

The time needed for the first pullet to peck the ball-point pen used as stimulus, increased with age, with greater effects from 8 to 10 wk than from 12 to 14 wk of age (L, $P < 0.01$; Q, $P < 0.01$). Similarly, the percentage

Table 4. Effects of infrared beak treatment (IRBT) at hatch and the inclusion of oat hulls (OH) in the diet on preference behavior of the pullets for coarse particles at 7 weeks of age[1].

	IRBT		OH		SEM	*P*-value[4]		
	Sham[2]	BT[3]	0%	3%	n = 40	IRBT	OH	Time[5]
Original feed								
Geometric mean diameter (μm)	1,194	1,194	1,205	1,183	-	-	-	
Geometric standard deviation (μm)	2.41	2.41	2.39	2.42	-	-	-	
Particle size distribution (%)								
Coarse particles (≥1,250 μm)	53.8	53.8	54.2	53.4	-	-	-	
Fine particles (≤315 μm)	23.0	23.0	22.5	23.5	-	-	-	
Residual feed (24 h post-feeding)								
Geometric mean diameter (μm)	923	1,018	986	955	19.2	< 0.001	0.113	< 0.001
Geometric standard deviation (μm)	2.25	2.31	2.28	2.28	0.017	< 0.001	0.977	< 0.001
Particle size distribution (%)								
Coarse particles (≥1,250 μm)	35.8	42.7	40.4	38.1	1.184	< 0.001	0.049	
Fine particles (≤315 μm)	32.2	29.0	30.0	31.3	0.710	< 0.001	0.067	

[1]Feed preference for coarse particles was evaluated as the difference in GMD and GSD between the original feeds supplied at 08.00 am (lights on) and the residuals that remained in the feeders 24 hours after feed provision.
[2]Intact beak.
[3]Beak trimmed.
[4]The interactions between main effects were not significant ($P > 0.05$).
[5]Time effect was evaluated as the original feeds vs. the residuals.

Table 5. Effects of infrared beak trimming at hatch (IRBT) and the inclusion of oat hulls (OH) in the diet on the exploratory pecking behavior of the pullets from 8 to 14 wk of age.

	IRBT		OH		SEM	*P*-value[3]			
	Sham[1]	BT[2]	0%	3%	n = 40	IRBT	OH	Age	
Time to first peck[6] (s)								L[4]	Q[5]
8 wk	2.65	3.21	2.89	2.97	0.177	0.027	0.742		
10 wk	2.99	3.70	3.21	3.48	0.311	0.027	0.373		
12 wk	4.24	4.76	3.96	5.04	0.298	0.221	0.011		
14 wk	4.73	4.97	4.52	5.17	0.320	0.595	0.151		
Average	3.65	4.16	3.65	4.17	0.232	0.032	0.027	< 0.001	0.010
Percentage of pullets pecking[7]									
8 wk	72.3	62.1	72.3	62.1	1.918	< 0.001	< 0.001		
10 wk	65.4	56.4	65.5	56.3	2.705	0.021	0.016		
12 wk	60.3	51.6	59.1	52.8	3.643	0.096	0.217		
14 wk	61.9	61.0	62.8	60.1	3.401	0.856	0.586		
Average	64.9	57.8	64.9	57.8	2.940	0.018	0.018	0.221	0.823

[1]Intact beak.
[2]Beak trimmed.
[3]The interactions between main effects and between main effects and age were not significant ($P > 0.10$).
[4]Linear.
[5]Quadratic.
[6]Seconds elapsed from the introduction of a ballpoint pen in the side panel of the cage until a pullet pecked the stimulus for the first time.
[7]Percentage of pullets within the cage that pecked a ballpoint pen used as a pecking stimulus in less than 5 s.

of pullets that pecked the stimulus in less than 5 s after the offer, decreased with age but the effect was not significant. The effects of IRBT on the exploratory pecking behavior of the pullets are presented in Table 5.

Beak Treatment The time elapsed from the introduction of the pecking stimulus, in the side panel of the cage, at eye level, to the time at which the first pullet pecked it, was longer for the BT birds than for the sham birds (4.16 vs. 3.65 s; $P < 0.05$). Similarly, the percentage of pullets that pecked the ballpoint pen in less than 5 s after the offer of the stimulus, was lower for the BT than for the sham birds (57.8 vs. 64.9%; $P < 0.05$). In both cases, time to first peck and percentage of pullets pecking the stimulus, the effects were more pronounced for the first part of the experiment (8 to 10 wk).

Oat Hulls Inclusion The inclusion of OH in the diet increased the time elapsed between the introduction of the pecking stimulus in the side panel of the cage at eye level and the time at which the first pullet pecked it (4.17 vs. 3.65 s; $P < 0.05$). Also, the percentage of pullets that pecked the ballpoint pen in less than 5 s was lower for the pullets fed OH diet than for pullets fed the control diet (57.8 vs. 64.9%; $P < 0.05$). The inclusion of OH in the diet increased the time needed for the first pullet to peck the stimulus at all ages but the differences were significant only at 12 wk of age ($P < 0.05$). Similarly, the percentage of hens pecking the stimulus in less than 5 s, decreased with age, and the differences were significant at 8 and 10 wk of age but not thereafter (Table 5).

Gastrointestinal Tract Traits

Age affected the development of all the GIT traits studied (Table 6). In fact, the RW of all the organs, decreased with age ($P < 0.001$). Also, the RW of the gizzard content increased with age whereas gizzard pH decreased ($P < 0.001$).

Beak Treatment Beak treatment did not affect any of the GIT traits studied at any age.

Oat Hulls Inclusion In absolute terms, the inclusion of OH in the diet tended to increase ($P = 0.094$) gizzard weight at 10 wk of age but none of the other organs were affected. In relative terms, however, OH inclusion increased full gizzard and intestines weights at both ages ($P < 0.05$). The inclusion of OH in the diet increased gizzard contents with effects that, in absolute terms, were significant at 10 wk of age ($P < 0.01$) and in relative terms at 10 wk ($P < 0.01$) and 15 wk ($P = 0.071$) of age. The inclusion of OH reduced gizzard pH at both ages but the differences were not significant.

DISCUSSION

The batch of OH used had less starch and more NDF than the batches used in previous studies (Jiménez-Moreno et al., 2016; García et al., 2019; Berrocoso et al., 2020). The physicochemical characteristics of OH, a byproduct of the food industry, vary widely with type of seed, weather conditions, and dehulling process. Schmitz et al. (2020) reported that the starch and insoluble fiber (cellulose, hemicellulose, and lignin) contents of OH varied from 2.5 to 16.3% and from 62.6 to 83.9%, respectively.

Growth Performance

Beak Treatment Mortality was higher for the BT birds than for the sham birds. The BT pullets, probably because of beak damage, were reluctant to press the nipple of the drinkers for the first 3 to 5 d of life, and as a consequence, FI decreased. Probably, the beak damage caused by the IRBT, together with the reduced availability of water and feed for the first 3 d of life, had a greater negative impact on the BT pullets than in the

Table 6. Effect of infrared beak trimming (IRBT) at hatch and the inclusion of oat hulls (OH) in the diet on selected gastrointestinal tract traits of the pullets at 10 and 15 wk of age.

	IRBT		OH		SEM	*P*-value[3]		
	BT[1]	Sham[2]	0%	3%	n = 40	IRBT	OH	Age
Absolute weight, full organ (g)								
Proventriculus								< 0.001
10 wk	4.78	4.77	4.83	4.72	0.102	0.971	0.295	
15 wk	5.81	5.94	5.91	5.84	0.132	0.328	0.600	
Gizzard								< 0.001
10 wk	41.7	41.7	41.1	42.3	0.733	0.920	0.094	
15 wk	52.0	51.2	51.1	52.1	1.033	0.421	0.338	
Intestines[4]								< 0.001
10 wk	53.0	52.2	51.8	53.5	1.114	0.514	0.129	
15 wk	68.7	70.3	68.5	70.5	1.321	0.244	0.128	
Relative weight, full organ (% BW)								
Proventriculus								< 0.001
10 wk	0.50	0.51	0.51	0.50	0.010	0.862	0.312	
15 wk	0.42	0.43	0.42	0.42	0.009	0.298	0.846	
Gizzard								< 0.001
10 wk	4.40	4.40	4.34	4.47	0.069	0.958	0.048	
15 wk	3.71	3.66	3.63	3.76	0.065	0.375	0.049	
Intestines								< 0.001
10 wk	5.58	5.51	5.45	5.63	0.087	0.427	0.037	
15 wk	4.94	5.00	4.85	5.09	0.086	0.444	0.005	
Gizzard content								
Absolute, g								< 0.001
10 wk	9.21	9.68	8.95	9.94	0.366	0.199	0.008	
15 wk	14.5	14.4	14.1	14.8	0.575	0.972	0.281	
Relative (% gizzard weight)								< 0.001
10 wk	22.1	23.1	21.8	23.4	0.642	0.129	0.010	
15 wk	27.8	27.8	27.1	28.4	0.763	0.991	0.071	
Gizzard pH								< 0.001
10 wk	3.48	3.42	3.49	3.41	0.089	0.456	0.361	
15 wk	3.09	2.98	3.08	2.99	0.059	0.317	0.304	

[1]Intact beak.
[2]Beak trimmed.
[3]The interactions between main effects and between main effects and age were not significant ($P > 0.10$).
[4]From the pyloric sphincter to the cloaca, including the small and the large intestine. The weights of the liver, spleen, and pancreas were not included.

sham pullets. The BT birds recovered quickly and after the first wk of life, no mortality occurred in any of the treatments. The data reported herein, are in agreement with the results of Damme and Urselmans (2013) who found also a higher early mortality in BT pullets than in sham pullets.

From 0 to 6 wk of age, FI was lower for the BT pullets than for the sham pullets, but BW gain was not affected. In the current research, we did not determine feed wastage by replicate but we observed that at feeding time, the sham pullets were more choosy in selecting their feeds, by flicking their heads and pecking more on coarse particles than the BT pullets, which could account for greater feed wastage and reduced feed efficiency. As a consequence, FCR was better for the BT birds. It was visually observed that, compared to the sham pullets, the BT pullets had reduced capacity to pick up the feed particles which could have affected voluntary FI (Gentle et al., 1982, 1997). Glatz (1990), Lee and Craig (1990), and Marchant-Forde and Cheng (2010) reported that beak treatment reduced FI, a problem that persists from few days to several weeks, depending on the intensity of the procedure. In the current research, the BT pullets recovered quickly after the treatment and in fact, from 7 to 10 wk of age, BT pullets ate 2.2% more and grew 2.8% faster than sham pullets. From 11 to 15 wk of age, IRBT did not affect pullet growth and therefore, no differences in growth performance were observed at 15 wk of age between the 2 groups.

Oat Hulls Inclusion The information available on the effects of OH inclusion on growth performance of brown pullets is scarce. From 0 to 6 wk of age, the inclusion of OH in the diet did not affect EI, ECR, or BW gain but impaired FCR, in agreement with data of García et al. (2019) in BT pullets of similar age. Kimiaeitalab et al. (2018) reported that the inclusion of 3% sunflower hulls in a diet fed to BT pullets from 0 to 3 wk of age, did not affect pullet growth. In contrast, in broilers, the inclusion of 3% OH or other insoluble fiber sources in the prestarter diet, improved BW gain and FCR without affecting FI (González-Alvarado et al., 2007; Jiménez-Moreno et al., 2009, 2016; Tejeda and Kim, 2021). From 7 to 10 wk of age, the inclusion of OH in the diet did not affect BW gain but reduced EI, and consequently, ECR was improved. From 11 to 15 wk of age, OH inclusion increased FI and impaired FCR but the differences were not significant. The lack of significance of the effects of OH may reflect the high CF content of the control diets (Mateos et al., 2012). As a result, OH inclusion improved BW uniformity of the pullets at 15 wk of age but had no effect on BW or ECR.

Preference Behavior for Coarse Particles

Feed particle size was greater in the original diets than in the feed residuals that remained in the feeders 24 h after the offer, confirming that pullets have a preference for coarse particles, as shown in previous studies with broilers (Portella et al., 1988b; Xu et al., 2015) and laying hens (Portella et al., 1988a; Safaa et al., 2009; Herrera et al., 2018). The data reported herein, however, suggest that the preference response observed might be a combination of the predilection of the pullets for coarse particles and the rejection to consume fine particles. In fact, the percentage of coarse particles (average of the 4 treatments) decreased from 53.8% in the original feeds to 39.3% in the refusals, whereas the percentage of fine particles increased from 23.0% in the original feeds to 30.6% in the feed refusals, data that suggest that pullets might reject to consume fine particles, as suggested by Herrera et al. (2018) in laying hens. In this respect, Portella et al. (1988a) reported that hens discriminate against feed particles smaller than 850 μm.

Beak Treatment During the regular controls performed from 0 to 6 wk of age, it was observed that the feed remaining in the feeders before the allocation of new feed, was finer for the sham than for the BT pullets. This visual observation was confirmed at 7 wk of age, in which the particle size of the feeds remaining in the feeders 24 h after the pullets had free access to the feed, was 10% coarser for the BT pullets than for the sham pullets. In fact, the percentage of coarse particles of the residuals was lower and that of fine particles was higher for the sham than for the BT pullets. The results are consistent with data of Persyn et al. (2004) and Iqbal et al. (2019) who reported that layers with intact beaks, have a tendency to peck large particles directly, whereas BT layers, that caught the feed by scooping, consume, in relative terms, higher percentages of small particles.

Oat Hulls Inclusion The inclusion of OH in the diet did not affect the GMD or the GSD of the feed refusals 24 h post-feeding, probably because the GMD ± GSD of the original feeds (control and OH containing diet) were similar. Oat hulls, however, decreased significantly the percentage of coarse particles and increased that of fine particles of the residual feeds, although the differences were of limited practical interest.

Exploratory Pecking Behavior

Beak Treatment Beak treated pullets required 13% more time for the first peck and were less attracted by the ballpoint pen used as a stimulus, than sham pullets, suggesting a lower motivation for pecking. Gentle (1991) indicated that the changes in pecking behavior observed in BT birds, should be considered as a sign of guarding behavior, together with symptoms of pain and discomfort. The decrease in the motivation to peck the stimulus, observed in the BT pullets, could be a consequence of the dulling of the extreme part of the beak which caused a reduction in nerves sensitivity (Gentle et al., 1990; Kuenzel, 2007). Trimming of the terminal nerves, reduces beak sensibility, resulting in a lack of sensory rewards (Hughes and Gentle, 1995; Freire et al., 2011). In the current research, the effects of IRBT on the exploratory pecking behavior of the pullets decreased with time, and in fact, no differences were observed after 12 wk of age, confirming that the interest and motivation to peck the stimulus disappeared with time.

Oat Hulls Inclusion The inclusion of OH in the diet reduced the attention and the attraction of the pullets for the external stimulus offered, with an increase in the time needed to the first peck. The data suggest that insoluble fiber sources, such as OH, reduces the motivation of the pullets for pecking. Consequently, OH inclusion might help in the training of the birds, before the onset of egg production, redirecting the potential activities in the coming laying period toward foraging rather than feather pecking (Qaisrani et al., 2013; Mens et al., 2020).

Gastrointestinal Tract

Beak Treatment Beak trimming did not affect the development of any of the organs of the GIT. The authors have not found any published research on the potential effects of IRBT on the development of the GIT of sham vs. BT pullets to compare with the results reported herein.

Oat Hulls Inclusion The inclusion of OH in the diet increased the RW of the full gizzard and of the full intestines at 10 and 15 wk of age, consistent with data of Guzmán et al. (2015) who reported a 15% increase in gizzard weight in 10-wk-old pullets when 4% wheat straw was included in the diet. The information provided herein suggests that moderate amounts of insoluble fiber sources, such as OH, stimulates the growth and the development of the GIT tract of the birds, in agreement with data of Jiménez-Moreno et al. (2019) in broilers and García et al. (2019) in pullets. Consequently, the inclusion of moderate amounts of inert fiber in the diet might increase FI and BW gain in pullets at the onset of the egg production cycle (Guzmán et al., 2016).

In summary, beak treatment at hatch increased pullet mortality for the first wk of age and reduced FI from 0 to 6 wk of age but FCR was improved. From 7 to 10 wk of age, however, BT pullets recovered and ate more feed and grew faster than sham pullets. From 11 to 15 wk and cumulatively (0−15 wk of age), IRBT did not affect pullet performance. The inclusion of OH in the diet tended to improve BW uniformity at 15 wk of age but did not show any effect on BW or ECR. The preference for coarse particles, together with the discrimination against the consumption of fine particles, was greater for the sham than for the BT pullets. Beak treatment and OH inclusion decreased the attraction of the pullets to peck a ballpoint pen used as a stimulus. The inclusion of OH in the diet increased the RW of the gizzard and intestines at all ages. Oat hulls inclusion in the rearing period diets might be a sound nutritional strategy to improve the performance of sham pullets, as it improves GIT development while reducing at the same time, the undesirable aggressive pecking behavior at the onset of the egg cycle.

DISCLOSURES

The authors confirm that there are not conflicts of interest in this research.

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