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Evaluation of three commercial feeds for the farming of Japanese quail (*Coturnix japonica* Temminck y Schlegel)

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ABSTRACT

Objective: To evaluate, for the farming of Japanese quail (*Coturnix japonica*) three brands of feed, with different nutritional content, enzyme complexes, particle size and presentation, in the variables of production, weight and length of organs, height of intestinal villi and cost per quail.

Design/Methodology/Approach: 300 young birds of both sexes were used; three commercial starter feeds of different brands (A, B and C) were evaluated. The response variables evaluated were feed consumed (AC), total feed consumed (ACT), live weight (PV), weight gain (GP), total weight gain (GPT), feed conversion (CA), total feed conversion (CAT), carcass yield, length, and weight of organs, as well as the size of the intestinal villi and the cost of the quail (CC). An analysis of variance was performed using the SAS® GLM procedure.

Results: From week three the birds were classified by sex, and the lowest AC and best CA ($p<0.05$) was obtained with treatment A in both sexes. Carcass yield was not affected by treatments ($p>0.05$); the longest and heaviest proventriculus and gizzard ($p<0.05$) were for treatment B. Regarding the villi, it was found that the enzymes favored ($p<0.05$) their size.

Limitations/Implications: The study showed that the size of the intestinal villi is influenced by the type of enzymes that are used, as well as by their concentrations or combinations.

Findings/Conclusion: It is concluded that feed presentation influences the consumption of feed. Enzyme complexes improve the size of the intestinal villi.

Keywords: enzymes, granulometry, intestinal villi, carcass yield.

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INTRODUCTION

The Japanese Quail (*Coturnix japonica*) is an avian species that is used in order to obtain egg and meat. Within the advantages of farming these birds, they do not require large areas;

are resistant to diseases; their growth is fast and have low feed consumption. Currently, in Mexico there are different brands of commercial feeds for quail farming, which are made of various ingredients, nutrient content, particle size, the use or not use of enzyme complexes and type of feed presentation. There are tables with recommendations to satisfy the nutritional requirements of protein (PC) and metabolizable energy (EM) in quails. Leeson and Summers (2005) suggested 28% CP for 2900 kcal kg^{-1} EM and Rostagno (2017) recommended 25.12 to 22.23% PW for 2900 kcal kg^{-1} EM. In the formulation of commercial feeds, in addition to considering the nutritional requirements, the thermal processing technique is important to obtain the pelletizing since the size and physical shape affects some organs, the digestibility of the diet, and consequently the yield of birds (Netto *et al.*, 2019).

Regarding the use of additives, exogenous enzymes such as xylanase, amylase and protease have been used in poultry farming for decades. In Mexico diets are formulated based on corn, sorghum and soy paste, ingredients with non-starchy polysaccharides (PNA), and enzymes that decrease the viscosity of the digest and increases the digestibility of nutrients, also improving the size of intestinal villi (Zhu *et al.*, 2014; Sugiharto, 2016; Alagawany *et al.*, 2018). Therefore, the objective of the study was to evaluate three brands of feed with different particle size, presentation, nutritional content, with or without enzymatic complexes, during quail farming, for production variables, carcass yield, weight and length of organs, height of intestinal villi and cost per quail.

MATERIALS AND METHODS

The experiment was conducted at a quail farm located in Texcoco, State of Mexico, Mexico. For the proper handling of birds, the Regulation for the use and care of animals for research of the Colegio de Postgraduados (2016) was complied; 300 young birds of both sexes were used, with an initial age of 1 d and a final of 42 d; The birds were randomly assigned to three treatments, with five replicates of 20 birds each. The birds were housed in spaces with electric breeders of 30×55 cm, linear feeders and automatic drinkers. When the birds were three weeks old the heat source was removed, in addition, they were grouped by sex to obtain the productive variables. Three commercial starter feeds of different brands (A, B and C) indicated in Table 1 were evaluated, the water and feed were offered *ad libitum* and determined the size of the feed particle.

Production variables

The response variables evaluated weekly were feed consumed (AC, g d^{-1} per bird), total consumed feed (ACT), live weight (PV, g), weight gain (GP, g), total weight gain (GPT, g), feed conversion (CA, kg of feed/GP), and total feed conversion (CAT).

Histological study

At 42 d of age, three males by replicate were randomly selected, weighed, and subsequently fasted for 12 h; then sacrificed by cutting the section of the jugular vein and carotid artery following the recommendations of the Official Mexican Standard NOM-033-ZOO-1995. The intestinal samples were collected after bird death was confirmed, a

Table 1. Nutritional content of quail feed in the initiation-growth stage in three different brands.

Label content	A	B	C
CP (%)	27.00	28.00	28.5
CF (%)	2.50	3.00	3.00
CFB (%)	4.00	3.00	5.00
Ashes (%)	7.50	8.00	10.00
Humidity (%)	12.00	12.00	12.00
NFE (%)	47.00	46.00	43.50
Dehydrated enzymes	-	Phytase 500 FTU/kg	Phytase 500 FTU/kg
		Xylanase 1200 U/kg	β Xylanase 1100 U/kg
		β glucanase 200U/kg	β glucanase 100U/kg
		Cellulase 200/kg	Cellulase 200/kg
		Manase 1800U/kg	Xylanase 75 U/kg
			Protease 1000U/kg
Presentation	mash	pellet	pellet
Cost ($ kg^{-1})	10.70	11.67	12.95
Particle size			
GMD	791	958	767
GSD	2.19	1.49	1.65

PC, crude protein; GC, crude fat; FC, crude fiber; ELN, nitrogen-free extract; PGD, geometric average of diameter; DEG, geometric standard deviation.

sample per replicate was taken of duodenum (descending) and jejunum (proximate). Each intestinal segment was collected closed with a size of 2.0 cm in length, and after cutting the samples the intestinal lumen was washed with distilled water and 10% buffered formalin to eliminate intestinal content. All samples were placed in individually identified bottles containing 10% buffered formalin for processing and cutting (Gava *et al.*, 2015).

Later, the samples were then included in paraffin, cut into 4.0 μm thick sections (with an optical micrometer), rinsed in xylene, dehydrated at graduated alcohol concentrations, and stained with hematoxylin-eosin. Once the slides were obtained, 15 intestinal villi of each sample were measured. The measurements were made as follows: height of the villi (AVLL), from the crypt to the apex of the villi, micron scale was used in a light microscope with the 4X objective (Image J, Version 1.8.0).

Carcass yield, length, and weight of organs

Sequentially, with the males slaughtered from each replicate, variables were evaluated for carcass yield (RDC, %), viscera weight (PVISC), small intestine weight (PID), small intestine length (LID), large intestine weight (PIG), large intestine length (LIG), proventricular length (LPROV, mm), proventricular width (APROV, mm), proventricular weight (PPROV); gizzard length (LMOLL, mm), gizzard width (AMOLL, mm), gizzard plus digest (MOLLMD, g), gizzard without digest (MOLLSD, g), clean gizzard (MOLLLI, g), liver weight (PHIG, g) and length of the gastrointestinal tract (LTGI, cm). All measurements were done with a digital Vernier ruler (Steren®).

Feed cost per quail

The cost of quail (CC) was determined by multiplying the accumulated feed consumption by the cost of feed.

Statistical analysis

For the production variables, carcass yield, weight and size of organs, intestinal villi, feed cost per quail, a completely random experimental design (SAS® GLM procedure) was used. Mean differences per treatments were obtained with the Tukey test (SAS, 2011).

RESULTS AND DISCUSSION

When quails were housed in mixed sexes arrangement (Table 2), the birds that consumed the most feed ($p \leq 0.05$) were those of treatment B with a cumulative consumption of 297.03 g. The presentation of this feed was in pellet which increased the consumption capacity of the animals as reported by Massuquetto *et al.* (2019). However, the high consumption was not reflected in the PV; they are the birds that had the lowest weight, in addition this treatment had the largest particle size. The gizzard of young birds is not yet fully developed; therefore, it has a limited ability to grind coarse particles (Kheravii *et al.*, 2018). It is possible that the temperature of the pelletizing process affected the digestibility of the nutrients reflected in the low weight.

Table 2. Production variables initial (1 d) and per week (1 to 3 weeks) in mixed housing of Japanese quails.

Weeks	**1d**	**1**	**2**	**3**	
Treatment	**Weekly body weight (g)**				
A	9.56	37.64	79.49a	137.46a	
B	9.78	34.35	74.27b	128.51b	
C	9.43	33.7	73.71b	129.16b	
SE	0.06	1.17	0.68	1.00	
	Feed intake g/bird/d				**AFI (g)**
A		5.82b	12.14b	17.90b	252.32b
B		7.39a	13.70a	21.37a	297.43a
C		6.38b	12.48b	20.30a	272.78b
SE		0.19	0.24	0.49	5.79
	Weekly weight gain (g)				**TWG (g)**
A		24.85	37.64	58.00	127.93
B		24.51	34.35	54.24	118.73
C		24.26	33.70	55.45	119.73
SE		0.65	0.96	0.84	1.79
	Weekly feed conversion				**TFC**
A		1.19b	1.07c	0.92b	1.83c
B		1.50a	1.29a	1.16a	2.31a
C		1.33b	1.18b	1.09a	2.11b
SE		0.04	0.02	0.03	0.06

EEM, standard error of the mean. Means with different letters among columns are different ($p \leq 0.05$). ACA, accumulated feed consumed; GPT, total weight gain; CAT, total feed conversion.

The birds that were fed with the diets A and C had a lower intake ($p \leq 0.05$) (45.11 and 24.65 g respectively). In addition, those birds of treatment A that consumed less feed were the birds with higher PV and better CA ($p < 0.05$). GP was not affected ($p > 0.05$) although treatment A had 7% better gain (Table 2). This is related to the presentation of the A feed that was in flour, since when that is the case, the ingredients are ground and mixed homogeneously. Whereas, for the granulates, the feed undergoes a process that combines high temperature and humidity, which improves the physical quality of the granule, increases the consumption of feed but affects the digestibility of nutrients such as amino acids and energy (Loar *et al.*, 2014; dos Santos *et al.*, 2020).

Table 3 shows the results by sex from week 4 to week 6, it was observed that in males no differences were found among treatments. However, in females at the end of farming the PV was the highest ($p \leq 0.05$). The best PV was obtained with treatment B compared to C because at this age the gastrointestinal tract was already developed; the size of the feed 985 PGD favored the growth of the gizzard and consequently the digestibility of the

Table 3. Production variables from 4 to 6 weeks (Sem) in Japanese quails fed with different commercial feeds.

	Males				**Females**			
wk.	**3**	**4**	**5**	**6**	**3**	**4**	**5**	**6**
T	**Weekly body weight (g)**							
A	135.76a	179.03a	214.08	226.66	139.06	188.59	224.90ab	244.55ab
B	122.80b	169.49b	212.66	222.40	134.76	192.73	232.20a	249.05a
C	125.48b	166.42b	208.28	222.14	133.97	185.46	218.35b	236.72b
SE	1.3	1.24	0.10	0.10	1.29	1.35	1.42	1.51
	Feed intake g/bird/d							
wk.	**4**	**5**	**6**	**AFI (g)**	**4**	**5**	**6**	**AFI (g)**
A	23.73c	23.46b	19.27b	465.28c	24.36b	24.53b	25.12c	518.22c
B	28.81a	30.51a	25.78a	595.69a	30.66a	30.98a	31.65a	653.03a
C	26.42b	27.94a	23.66a	546.30b	26.84b	26.23b	27.49b	563.94b
SE	0.61	0.90	0.81	15.21	0.87	0.81	0.78	15.79
	Weekly weight gain (g)							
wk.	**4**	**5**	**6**	**TWG (g)**	**4**	**5**	**6**	**TWG (g)**
A	43.20ab	35.22b	12.54	90.96b	49.52b	36.31ab	19.54	105.39ab
B	46.53a	43.59a	10.13	100.26[a]	58.13a	39.54a	16.84	114.51a
C	41.57b	41.59a	11.45	94.61b	51.60b	31.93b	18.74	102.29b
SE	1.70	1.1	0.70	1.26	1.2	1.09	0.89	2.01
	Weekly feed conversion							
wk.	**4**	**5**	**6**	**TFC**	**4**	**5**	**6**	**TFC**
A	0.93c	0.66	0.59b	2.05c	0.90b	0.76b	0.72c	2.12c
B	1.19a	0.70	0.80a	2.66a	1.11a	0.93a	0.89a	2.62a
C	1.11b	0.67	0.74a	2.48b	1.00ab	0.84b	0.81b	2.38b
SE	0.03	0.08	0.02	0.05	0.03	0.02	0.01	0.07

EEM, standard error of the mean. Means with different letters among columns are different ($p \leq 0.05$). ACA, accumulated feed consumed; GPT, total weight gain; CAT, total feed conversion.

nutrients. Coarse particles are known to improve the bird yield, compared to fine ones (Lv *et al*., 2015). In addition, the feed presentation in pellets increased the CA and the weight of the birds (Massuwuetto *et al*., 2020). Treatment A, due to it was a flour had lower CA, but the nutrients were not compromised by high temperatures which in the end improved bird weight.

In ACA, both males and females consumption were higher ($p \leq 0.05$) with treatment B, followed by C; it is important to mention that the presentation of both feeds was in pellets, but they had different particle size. The one feed that had the lowest consumption was treatment A, which presentation was as flour; it is known that the physical form of the pellet increases feed consumption (Abdollahi and Ravindran, 2014).

In the GP variable in males and females it was recorded that the best gain was obtained by treatment B ($p \leq 0.05$) with 100.26 and 114.51 g respectively, which is related to high consumption and particle size of the feed. However, the best CA for both sexes was with treatment A ($p \leq 0.05$), followed by C and the worst was for B. The above is related to the presentation of the feed, since although treatment A had the lowest consumption because it was a flour, its nutrients were not affected by high temperatures. On the contrary, what happened with treatment B was that the consumption was so high that the CA was affected, which is related to the temperature of the pelletizing since it decreases the digestibility of nutrients (protein and energy) and it is known that birds eat to satisfy these requirements (Lesson and Summer, 2005; dos Santos *et al*., 2020).

In this research, the weight and size of the intestines was not modified ($p > 0.05$) due to the effect of enzymes or particle size. While Hussein *et al*. (2020) found that the length of the duodenum, ileum, and cecum increased with enzyme supplementation, as well as the weight of the duodenum. This increase in size of the gastrointestinal tract occurs as an adaptive mechanism to an increased demand for exogenous enzymes (Brenes *et al*., 1993).

Regarding the DRC, PVISC, PID, LID, PIG, LIG, LPROV, PHIG and LTGI, no differences were obtained among the treatments (Table 4). In the variables APROV and PPROV it was found that the widest and heaviest stomach was that fed on treatment B ($p < 0.05$) (Table 4). As the gizzard was significantly affected ($p \leq 0.05$) the LMOLL, AMOLL, MOLLMD, MOLLSD and MOLLLI, where the length, width and weight of the gizzard was greater in treatments B and C. Since these contained the largest particle size, which increased the crushing activity of the gizzard to grind the particles and consequently increased its development (Chewhin *et al*., 2012; Jacobs and Parsons, 2013). Whereas treatment A had the smallest particle size, and this tends to reduce the mechanical stimulation in the gizzard because flour is retained for less time than pelletized coarse particles; less time causes a reduced size of the organs (Mateos *et al*., 2012; Manyelo *et al*., 2019).

In week 7 the highest intestinal villi (VI) in duodenum and jejunum were obtained with treatment B ($p \leq 0.05$). This is attributed to the fact that this treatment had a complex of enzymes which favored growth with greater height. This is related to a larger absorption area (Bogustawska-Tryk *et al*., 2012). All of which coincides with Pérez *et al*. (2013) and Zhu *et al*. (2014) who found that the addition of enzyme complexes significantly increases the height of VIs during birds fattening. Treatment C also had a complex of enzymes,

Table 4. Carcass yield, length, and weight of internal organs at 42 d in male Japanese quails fed with different commercial feeds.

TRAT	A	B	C	SE
CPF (%)	80.60	79.44	78.80	0.38
VW (g)	14.50	15.55	13.80	0.51
SIW (g)	3.24	3.38	3.60	0.10
SIL (cm)	46.56	46.59	47.93	0.45
LIW (g)	2.17	2.51	2.45	0.10
LIG (cm)	13.16	14.36	14.50	0.43
PL (mm)	17.67	18.38	18.03	0.22
BP (mm)	9.18b	9.9a	9.24b	0.10
PW (g)	0.82b	1.02a	0.88b	0.02
GL (mm)	3.42b	4.17a	3.92a	0.29
WG (mm)	24.49b	26.41a	25.58ab	0.29
GPD (g)	4.50b	5.83a	5.0ab	0.17
GWD (g)	3.9b	4.7a	4.48a	0.10
CG (g)	3.42b	4.17a	3.92a	0.09
LW (g)	4.18	4.78	4.12	0.19
GITL (cm)	77.57	78.05	80.60	1.04

RDC, carcass yield; PVISC, viscera weight; PID, small intestine weight; LID, small intestine length; PIG, large intestine weight, LIG, large intestine length, LPROV, proventricular length; APROV, proventricular width; PPROV, proventricular weight; LMOLL, gizzard length; AMOLL, gizzard width; MOLLMD, gizzard plus digest; MOLLSD, gizzard without digest; MOLLLI, clean gizzard; PHIG, liver weight; LTGI, length of the gastrointestinal tract. EEM, standard error of the mean. Means with different letters in row are different (p≤0.05).

Table 5. Height of intestinal villi in six-week-old male Japanese quails.

Treatment	Duoenum (μm)	Jejunum (μm)
A	66.39b	32.49c
B	83.79a	76.70a
C	67.59b	61.88b
SE	2.64	1.66

EEM, standard error of the mean. Means with different letters in column are different (p≤0.05).

Table 6. Feed cost per quail for Japanese quail farming.

Treatment	Females USD$	Males USD$
A	0.4124b	0.384b
B	0.554a	0.521a
C	0.541a	0.530a
EEM	0.53	0.63

Feed cost for females and males (1 d to 6 weeks). EEM, standard error of the mean. Means with different letters in column are different (p≤0.05).

but it was different from that of B (Table 1), which could influence the villi size. Whereas treatment A was the one with the smallest VIs since this feed did not contain enzymes.

Treatment A had the lowest cost to produce a quail ($p \leq 0.05$) female and male (USD$0.41 and USD$0.38 respectively). This is related to the fact that the feed of this treatment was the least expensive, also to the fact that the accumulated consumption over the six weeks was the lowest ($p \leq 0.05$) (Table 3). Whereas, with treatments B and C the cost experienced an increase for females of USD$ 0.142 and USD$ 0.129 respectively, and in males increased USD$0.137 and USD$ 0.146 respectively. This cost increase occurred because these feeds are more expensive and greater consumption was recorded in both sexes ($p \leq 0.05$).

CONCLUSIONS

Pelletizing increased the feed consumption of quails, but nutrients are affected by the process which can reach minor feed conversions. The flour presentation is the best alternative for feeding during fattening for better feed conversion.

The particle size of the feed improves the size of the gizzard in quails. The enzymes used in these commercial feeds increase the size of the intestinal villi. Finally, the feed cost per quail depends on the feed conversion and the cost of balanced feeds.

REFERENCES

Abdollahi, M.R., and Ravindran, V. (2014). Influence of feed form on growth performance, ileal nutrient digestibility, and energy utilisation in broiler starters fed a sorghum-based diet. *Livestock Science*, 165, 80-86. https://doi.org/10.1016/j.livsci.2014.04.002

Alagawany, M., Elnesr, Sh. S., and Farag, M.R. (2018). The role of exogenous enzymes in promoting growth and improving nutrient digestibility in poultry. *Iranian Journal of Veterinary Research*, 19, 157-164.

https://www.researchgate.net/publication/328489334_The_role_of_exogenous_enzymes_in_promoting_growth_and_improving_nutrient_digestibility_in_poultry

Boguslawska, M.-Tryk, Piotrowska, A., and Burlikowska. K. (2012). Dietary fructans and their potential beneficial influence on health and performance parametrs in broiler chickens. *Journal Central Euroean Agricultutre*, 13, 272-291. https://hrcak.srce.hr/83284

Brenes, A., Smith, M., Guenter, W., and Marquardt. R. R. (1993). Effect of enzyme supplementation on the performance and digestive tract size of broiler chickens fed wheat- and barley-based diets. *Poultry Science*, 72,1731-1739. https://doi.org/10.3382/ps.0721731

Chewning, C. G., Stark, C. R., and Brake, J. (2012). Effects of particle size and feed form on broiler performance. *Journal of Applied Poultry Research, 21*(4), 830-837. https://doi.org/10.3382/japr.2012-00553

Colegio de Postgraduados. (2016). Reglamento para el uso y cuidado de animales destinados a la investigación en el Colegio de Postgraduados.

https://www.colpos.mx/wb_pdf/Investigacion/REGLAMENTO_USO_CUIDADO_ANIMALES%20DESTINADOS_INVESTIG_CP%20(1).pdf#:~:text=El%20presente%20Reglamento%20tiene%20como%20objetivo%20normar%20el,Colegio%20de%20Postgraduados.%201.2.%20Fundamento%20Legal%20ART%C3%8DCULO%202%C2%BA

dos Santos, R.O.F., Bassi, L.S., Schramm, V.G., da Rocha, C., Dahlke, F., Krabbe, E.L., and Maiorka, A. (2020). Effect of conditioning temperature and retention time on pellet quality, ileal digestibility, and growth performance of broiler chickens. *Livestock Science*, 240, 104110. https://doi.org/10.1016/j.livsci.2020.104110

Gava, M. S., Moraes, L.B., Carvalho, D., Chitolina, G.Z., Fallavena, L.C.B., Moraes, H.L.D.S. and Salle, C.T. (2015). Determining the best sectioning method and intestinal segment for morphometric analysis in broilers. *Brazilian Journal of Poultry Science*, 17, 145-149. http://dx.doi.org/10.1590/1516-635x1702145-150

Hussein, E. O. S., Suliman, G.M., Alowaimer, A.N., Ahmed, S.H., Adb El-Hack, M.D., Taha, A.E., and Swelum, A.A. (2020). Growth, carcass characteristics, and meat quality of broilers fed a low-energy diet supplemented with a multienzyme preparation. *Poultry Science*, 99, 1988-1994.https://doi.org/10.1016/j.psj.2019.09.007

Jacobs, C.; and Parsons, C.M. (2013). The effects of coarse ground corn, whole sorghum, and a prebiotic on growth performance, nutrient, digestibility, and cecal microbial populations in broilers fed diets with and without corn distiller drie grais with solubles. *Poultry Science, 92*(9), 2347-2357. http://dx.doi.org/10.3382/ps.2012-02928

Kheravii, S.K., Morgan, N.K., Swick, R.A., Choct, M., and Wu, S.B. (2018). Roles of dietary fibre and ingredient particle size in broiler nutrition. *World's Poultry Science Journal,* 74, 301-316. https://doi.org/10.1017/S0043933918000259.

Leeson, S., and Summers. J.D. (2005). Commercial Poultry Nutrition. 3 th ed. University Books, Guelph, Ontairo, Canadá. pp. 124–161. https://www.agropustaka.id/wp-content/uploads/2020/04/agropustaka.id_buku_ Commercial-Poultry-Nutrition-3rd-Edition-by-S.-Leeson-J.-D.-Summers.pdf

Loar, II, R.E., Wamsley, K. G. S., Evans, A., Moritz, J.S., and Corzo, A. (2014). Effects of varying conditioning temperature and mixer-added fat on feed manufacturing efficiency, 28-to 42-day broiler performance, early skeletal effect, and true amino acid digestibility. *Journal Applied Poultry Reserch*, 23, 444-455. https://doi.org/10.3382/japr.2013-00930

Lv, M., Yan, L., Wang, Z., AN, S., Wu, M., and Lv, Z. (2015). Effects of feed form and feed particle size on growth performance, carcass characteristics and digestive tract development of broilers. *Animal Nutrition*, 1, 252-256. https://doi.org/10.1016/j. aninu.2015.06.001.

Manyelo, T. G., Ng´Ambi, J. W., Norris, D., and Mabelebele, M. (2019). Substitution of *Zea mays* by *Sorghum bicolor* on Performance and Gut Histo-Morphology of Ross 308 Broiler Chickens Aged 1–42 d. *Journal of Applied Poultry Research*, 28, 647-657. https://doi.org/10.3382/japr/pfz015.

Mateos, G.G., Jimenez-Moreno, E., Serrano, M.P., and Lazaro, R.P. (2012). Poultry response to high levels of dietary fiber sources varying in physical and chemical characteristics. Journal Applied Poultry Reserch, 21, 156-74. https://doi.org/10.3382/japr.2011-00477

Massuquetto, A., Panisson, J. C., Marx, F. O., Surek, D., Krabbe, E.L., and Maiorka, A. (2019). Effect of pelleting and different feeding programs on growth performance, carcass yield, and nutrient digestibility in broiler chickens. Poultry Science, 98(11), 5497-5503.

https://doi.org/10.3382/ps/pez176

Massuquetto, A., Durau, J.F., Barrilli, L.N.E., Santos, R.O.F., Krabbe, E.L., and Maiorka, A. (2020). Thermal processing of corn and physical form of broiler diets. Poultry Science, 99, 3188-3195. https://doi.org/10.1016/j. psj.2020.01.027.

Netto, M.T., Massuquetto, A., Krabbe, E.L., Surek, D., Oliveira, S.G., and Maiorka, A. (2019). Effect of conditioning temperature on pellet quality, diet digestibility, and broiler performance. *Journal of Applied Poultry Research, 28*(4), 963-973. https://doi.org/10.3382/japr/pfz056

Pérez, C., Basilio,V., Colina, I., Machado, I., Rossini, M., y Arrieta D. (2013). Efecto de la adición de complejos enzimáticos en dietas a base de sorgo (*Sorghum bicolor*) sobre la integridad intestinal de pollos de engorde. *Revista científica*. *XXII* (1), 59-66. https://www.redalyc.org/pdf/959/95925465011.pdf

Rostagno, H.S., Teixeira, L., Donzele, J., Gomes, P., De Oliveira, R., Lopes, D., A. and Ferreira, A. (2017). Tablas brasileñas para aves y cerdos. Composición de alimentos y requerimientos nutricionales, 2. https://www.produccion-animal.com.ar/tablas_composicion_alimentos/126-tablas_brasileras_aves_cerdos.pdf

SAS (Statical Analysis System) (2011). Statistical Analysis Software (SAS/ STAT). Version 9.33 Ed. Cary, N.C. USA.

Sugiharto, S. (2016). Role of nutraceuticals in gut health and growth performance of poultry. *Journal of the Saudi Society of Agricultural Sciences,* 15(2), 99-111. https://doi.org/10.1016/j.jssas.2014.06.001

Zhu, H.L., Hu, L.L., Hou, Y.Q., Zhang, J., and Ding, B.Y. (2014). The effects of enzyme supplementation on performance and digestive parameters of broilers fed corn-soybean diets. *Poultry Science,* 93(7), 1704-1712. http://dx.doi.org/10.3382/ps.2013-0362