

Italian Journal of Animal Science

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tjas20

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To cite this article: A. Kurul , Ö. Cengiz & A. Y. Pekel (2020) Live performance, digestive tract features, and ileal nutrient digestibility in broilers fed diets containing soy hulls, Italian Journal of Animal Science, 19:1, 1567-1572, DOI: 10.1080/1828051X.2020.1857312

To link to this article: https://doi.org/10.1080/1828051X.2020.1857312

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Published online: 26 Dec 2020.

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ITALIAN JOURNAL OF ANIMAL SCIENCE
2020, VOL. 19, NO. 1, 1577–1582
https://doi.org/10.1080/1828051X.2020.1857312

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BRIEF REPORT

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Live performance, digestive tract features, and ileal nutrient digestibility in broilers fed diets containing soy hulls

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ABSTRACT

This study aimed at determining the impact of dietary soy hulls (SH) addition on growth performance, digestive tract attributes, and apparent ileal digestibility of dry matter (DM), nitrogen, and phosphorus (P) in broiler chickens. Male broilers (Ross 308, $n = 224$) were assigned to one of four diets, including 0, 20, 40, or 60 g/kg SH, with eight replications per treatment from 0 to 21 d of age in a completely randomised design. Dietary chromic oxide was the indigestible marker for determining the apparent ileal digestibility. Data were subjected to orthogonal polynomial contrasts using the Proc GLM of SAS. Growth performance and small intestine weight and length, and gizzard content pH were not influenced ($p > .05$) by increasing levels of dietary SH. Increasing the dietary SH level resulted in a linear increase ($p < .01$) in absolute empty gizzard weight. Relative gizzard weight was greater ($p < .05$) in birds fed on 60 g/kg SH diet compared to birds fed on 40 g/kg SH diet. Apparent ileal digestibility of nitrogen was not affected ($p > .05$) by dietary SH inclusion. However, apparent ileal digestibility of DM and P increased linearly ($p < .01$) with increasing dietary SH levels. In conclusion, the addition of SH up to 60 g/kg improved the ileal digestibility of DM and P and increased gizzard weight without affecting the proportionate small intestine morphology and live performance of broiler chickens at 21 d of age.

HIGHLIGHTS

- Soy hulls did not have any effect on growth
- Soy hulls increased the digestibility of P
- Soy hulls increased gizzard weight

ARTICLE HISTORY
Received 24 September 2020
Revised 21 November 2020
Accepted 25 November 2020

KEYWORDS
Broiler; digestive traits; growth performance; ileal digestibility; soy hulls

Introduction

Depending on its solubility in water, dietary fibre is classified into soluble and insoluble fibre (Chakraborty et al. 2019). Poultry lacks the enzymes to digest fibre and does not ferment fibre polymers to a great extent in the caecum. However, increasing evidence emphasises how nutrient utilisation and growth performance is improved by a moderate amount of insoluble dietary fibre (Sklan et al. 2003). Contrarily, soluble fibre can be used by harmful hindgut microbiota, which results in the disruption of the balance between commensal and pathogenic bacteria. Other disadvantages of soluble fibre include nutrient encapsulation because of increased digesta viscosity.

Dietary incorporation of a moderate amount of different insoluble fibre sources has been reported to exert favourable effects on growth performance through improving the development of gastro-intestinal organs and gut health in broiler chickens (Mateos et al. 2012). Rice hulls, oat hulls, sunflower hulls, and soy hulls (SH) are insoluble fibre sources that have been shown to have the capacity to affect nutrient utilisation and live performance positively in broilers (González-Alvarado et al. 2010). Previous studies have found that dietary oat hulls at a level of 3% improve live performance and nutrient utilisation in broilers fed low fibre diets (González-Alvarado et al. 2010; Jiménez-Moreno et al. 2013, 2016).

Soybean hulls constitute approximately 8–10% of the bean weight and contain mainly cell wall polysaccharides (Mielenz et al. 2009). Cellulose, hemicellulose, and lignin content of SH were reported to be 48%,

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24%, and 6% on a dry matter (DM) basis, respectively (Flauzino-Neto et al. 2013). Earlier reports have demonstrated that dietary SH addition had positive effects on nutrient utilisation (Jiménez-Moreno et al. 2009). However, to the best of our knowledge, there is no report on the dietary SH addition on ileal nutrient digestibility in broiler chickens. Therefore, the purpose of the present study was to investigate the effects of dietary SH on growth performance and nutrient utilisation in broilers.

Materials and methods

Adnan Menderes University Local Animal Ethical Committee (Aydın, Turkey) approved the experiment protocol (64583101/2018/089).

Birds, housing, and experimental design

A total of 224, 1-d-old male broiler chicks (Ross 308; Aviagen Anadolu, 06810, Ankara, Turkey) were used in the current study. Birds were housed in electrically heated battery cages fitted with nipple drinkers and trough feeders which were kept in an environmentally controlled room. Upon arrival, broiler chicks were randomly allotted to 4 treatments with eight replicates; each replicates having seven birds in a completely randomised design. The temperature was kept at 32 °C throughout the first week and reduced steadily until a temperature of 21 °C was achieved on d 21. During the first week, a 23L:1D cycle was used, and then it is followed by a 16L:8D light schedule to the end of the experiment.

Experimental diets

The composition of test diets and SH are shown in Table 1. The dietary treatments consisted of 0, 20, 40, and 60 g/kg dietary SH, and broilers were given the experimental diets for 21 d. The trial diets were formulated following the reported nutrient requirements of the breeder company (Aviagen 2019). Soy hulls were added at the expense of sepiolite to make the SH the only source of variation in the nutrient content of the experimental diets. Soy hulls were milled to cross through a 2-mm screen using a hammer mill. Chromic oxide was added to diets at 5 g/kg (as-fed) as an exogenous indicator to facilitate the calculation of the digestibility of nutrients. Birds had ad libitum access to diets in mash form and water.

Growth performance, sample handling, and analyses

On day 21, broilers were weighed and feed intake per cage taken. Any mortality was recorded daily. All broilers were euthanized by cervical dislocation, and the gizzard and small intestines were removed immediately.

Gizzard content pH was measured in triplicate by the introduction of a pH electrode straight into the gut lumen post euthanasia (Morgan et al. 2014). The empty weight and length of duodenum, jejunum, ileum, and total small intestine were recorded. Relative digestive organ lengths (cm/kg body weight) and weights (g/100 g body weight) were calculated by expressing them in relation to body weight (BW) of broilers. Digestive organ unit weight (g/cm) was calculated by expressing the weight to its length. Ileal digesta was immediately taken from the distal ileum by flushing the intact ileum with deionised water into plastic cups and stored at −20 °C.

Pooled ileal digesta samples were allocated in a forced-air oven at 55 °C for 1 week. Diets and dried ileal digesta samples were milled to pass through a 0.5-mm screen using an ultracentrifugal mill. The DM content of diets and ileal digesta samples was measured by drying the samples in a drying oven at 105 °C for 24 h (AOAC International 2006). Ash content was analysed according to AOAC International (2006) in a muffle oven for approximately 10 h at 550 °C (AOAC International 2006). The Kjeldahl method was adopted to quantify the nitrogen content of the samples with a nitrogen analyser (AOAC International 2006). The ether extract concentration of the samples was determined by a Soxhlet apparatus.

The diets and ileal digesta samples were digested using nitric acid and perchloric acid before the chromium and P concentrations were determined (Fenton and Fenton 1979). Phosphorus and chromium concentrations were measured by UV spectrophotometry at wavelengths of 440 and 620 nm in a plate reader, respectively.

Calculations and statistical analysis

The apparent ileal digestibility (AID) of nutrients was calculated using the index method according to the following equation:

$$AID\ (\%)\ \ 100 - [(Cr_i/Cr_o)\ \times\ (N_o/N_i)]\ \times\ 100$$

where Cr_i is the chromium concentration of diet, Cr_o is the chromium concentration of ileal digesta, N_o is the

Table 1. Ingredient and nutrient composition of experimental diets and soy hulls (g/kg, as-fed basis).

	Diets			
	Soy hulls level, g/kg			
Ingredients	0	20	40	60
Corn	473.20	473.20	473.20	473.20
Soybean meal (440 g/kg crude protein)	221.00	221.00	221.00	221.00
Fish meal (620 g/kg crude protein)	80.00	80.00	80.00	80.00
Corn gluten meal (600 g/kg crude protein)	70.00	70.00	70.00	70.00
Sepiolite	60.00	40.00	20.00	0.00
Soy hulls	0.00	20.00	40.00	60.00
Vegetable oil	36.00	36.00	36.00	36.00
Limestone (380 g/kg Ca)	9.80	9.80	9.80	9.80
Dicalcium phosphate (220 g/kg Ca)	9.00	9.00	9.00	9.00
DL-Methionine	3.00	3.00	3.00	3.00
L-Lysine.HCl	4.00	4.00	4.00	4.00
Vitamin–mineral premix[a]	5.00	5.00	5.00	5.00
Salt	4.00	4.00	4.00	4.00
Cr_2O_3 premix[b]	25.00	25.00	25.00	25.00
Total	1.000	1.000	1.000	1.000
Calculated composition, g/kg (as-is)				
Crude protein	236	239	242	244
Metabolizable energy, kcal/kg	3003	3000	3017	3035
Ca	9.65	9.76	9.87	9.98
P	6.74	6.77	6.81	6.84
Ca:P	1.43	1.44	1.45	1.46
aP, g/kg	4.90	4.91	4.92	4.93
Crude fibre	22.5	28.8	35.1	41.4
NDF	74.3	84.7	95.1	105.6
ADF	27.5	35.0	42.5	50.0
Total amino acids, g/kg				
Arg	13.20	13.32	13.45	13.57
His	6.06	6.13	6.19	6.26
Ile	9.71	9.80	9.89	9.97
Leu	23.66	23.82	23.98	24.13
Lys	14.6	14.78	14.94	15.11
Met	7.66	7.68	7.71	7.74
Met + Cys	11.35	11.42	11.50	11.57
Phe	11.58	11.68	11.77	11.86
Phe + Tyr	20.98	21.17	21.37	21.56
Thr	8.96	9.05	9.14	9.23
Trp	2.77	2.79	2.81	2.83
Val	11.19	11.30	11.42	11.53
Analysed composition, g/kg (as-is)				
Dry matter	894.73	910.5	901.58	909.47
Crude protein	243.25	248.85	251.49	251.95
Crude ash	118.92	101.01	87.96	65.87
Ether extract	44.28	53.09	59.01	66.63
P, g/kg	6.84	6.30	6.68	6.96
Soy hulls nutrient content, g/kg (as-is)				
DM	903.25			
Crude protein	110.67			
Crude ash	41.67			
Ether extract	13.83			
P	1.60			

[a]Supplied the following per kilogram of diet: vitamin A, 12,000 IU; vitamin D_3, 1,500 IU; vitamin E, 30 mg; vitamin K_3, 5 mg; vitamin B_1, 3 mg; vitamin B_2, 6 mg; vitamin B_6, 5 mg; vitamin B_{12}, 0.03 mg; niacin, 40 mg; calcium D-pantothenate, 10 mg; folic acid, 0.75 mg; D-Biotin, 0.075 mg; choline chloride, 375 mg; Mn, 80 mg; Fe, 40 mg; Zn, 60 mg; Cu, 5 mg; I, 0.4 mg; Co, 0.1 mg; Se, 0.15 mg; and antioxidant, 10 mg.
[b]Prepared as 5 g of chromic oxide (Nanokar Kimyevi Maddeler San. Tic. Ltd. Sti, 34912 İstanbul, Turkey) mixed with 20 g of finely ground (0.5-mm screen) corn.

nutrient concentration of ileal digesta, and N_i is the nutrient concentration of the diet.

All data were analysed by the GLM procedure of SAS as a completely randomised block design (SAS Institute 2006). The experimental unit was pen for all traits. Kolmogorov–Smirnov test was used to confirm the normal distribution of data. Quadratic and linear contrasts using polynomial contrasts were used to identify the effects of SH levels. A *p*-value of less than .05 was considered significant.

Results and discussion

Growth performance

Broilers fed with increasing levels of dietary SH did not have a significant difference in feed intake, BW

gain, and gain to feed ratio (G:F) (Table 2; $p > .05$). Therefore, the dietary addition of increasing levels of SH did not affect the live performance of broilers at 21 d of age. In contrast, González-Alvarado et al. (2007) indicated that 30 g/kg SH inclusion increased BW gain and improved the feed conversion ratio of broilers without affecting feed intake. This contradiction, at least in part, may be attributed to the differences in the strain of birds (Ross 308 versus Cobb 500), sex (male versus straight run), and the dietary composition (soybean meal based versus soy protein concentrate) between studies.

Absolute and relative weight/length of gastrointestinal organs

Absolute gizzard weight linearly increased ($p < .01$) with the increasing levels of dietary SH (Table 3). There was no effect of dietary SH inclusion on absolute weights of duodenum, jejunum, ileum, and total small intestine. The gizzard content pH was not affected by dietary SH addition. It was hypothesised that dietary inclusion of SH as an insoluble fibre source would increase gizzard activity, thereby increase gastroduodenal reflux and the time feed remain in the gizzard. Therefore, the increased gizzard activity would also result in more digesta reflux to proventriculus, and this, in turn, might increase the HCl secretion and decreases the pH of the content. This hypothesis was partly supported by the present data that showed a linear rise in the gizzard weight of birds with the increasing dietary levels of SH. However, the hypothesis that the increase in the weight of the gizzard by SH inclusion would result in a decrease in the pH of gizzard content was not backed by the current data.

The relative weight of (% BW) gizzard was increased quadratically for the birds fed on SH diets (Table 4). However, the dietary SH level did not have any linear or quadratic effect on proportionate weights of duodenum, jejunum, ileum, and total small intestine. The dietary level of SH did not have any impact on absolute and relative length (cm/kg BW) small intestine, and digestive organ unit weight (g/cm) (Tables 5, 6, and 7). One hypothesis is that a decrease in intestine size might reflect a more energy partition towards growth and more efficient nutrient utilisation (Dibner and Richards 2005). Another one suggests a longer small intestine might allow for a greater absorptive area, and, therefore, this can help birds to have better growth performance (Sklan et al. 2003). Similar to current results, González-Alvarado et al. (2007) noted no effect of 30 g/kg SH inclusion on the relative length and weight of the small intestine of broilers at 21 d of age. Therefore, there is a possibility that the chicks might have adapted to increasing levels of SH by increasing the passage rate through the digestive tract rather than increasing the size. However, this speculation needs further investigation.

Apparent ileal digestibility

The apparent ileal digestibility of DM and P showed a linear increase with increasing inclusion levels of SH

Table 2. Effect of dietary soy hulls inclusion on growth performance of broilers at 21 d.

Item	Day 0 BW (g)	Day 21 BW (g)	BWG (g)	Feed Intake (g)	G:F (g:kg)
Soy hulls (g/kg)					
0	48.71	757.13	708.42	950.79	745.75
20	48.69	750.56	701.86	917.91	769.49
40	48.67	798.93	750.26	971.29	772.39
60	48.70	777.05	728.36	959.43	762.74
SEM	0.860	23.047	23.063	32.861	30.258
Linear	0.831	0.149	0.149	0.452	0.578
Quadratic	0.752	0.642	0.642	0.655	0.442

$n = 8$. BW: body weight; BWG: body weight gain; G:F: gain and feed ratio; SEM: Standard error of the mean.

Table 3. Gizzard pH and absolute digestive organ weights (g) of broiler chickens on d 21.

Soy hulls (g/kg)	Gizzard pH	Gizzard	Duodenum	Jejunum	Ileum	Total small intestine
0	2.49	19.75	8.22	15.35	10.87	34.44
20	2.46	19.78	8.45	15.26	10.64	34.35
40	2.42	20.48	8.50	15.63	10.82	34.95
60	2.50	21.26	8.16	15.34	11.03	34.53
SEM	0.130	0.507	0.457	0.743	0.580	1.540
Linear	0.998	0.003	0.934	0.890	0.720	0.859
Quadratic	0.577	0.304	0.382	0.852	0.607	0.875

$n = 8$. SEM: standard error of the mean.

Table 4. Relative digestive organ weights (g/100 g body weight) of broiler chickens on d 21.

Soy hulls (g/kg)	Gizzard	Duodenum	Jejunum	Ileum	Total small intestine
0	2.61	1.09	2.04	1.45	4.58
20	2.64	1.13	2.03	1.42	4.57
40	2.57	1.07	1.96	1.36	4.38
60	2.74	1.05	1.98	1.42	4.45
SEM	0.063	0.065	0.099	0.082	0.218
Linear	0.119	0.395	0.425	0.561	0.404
Quadratic	0.099	0.588	0.855	0.427	0.822

$n = 8$. SEM: standard error of the mean.

Table 5. Absolute digestive organ lengths (cm) of broiler chickens on d 21.

Soy hulls (g/kg)	Duodenum	Jejunum	Ileum	Total small intestine
0	27.72	68.39	57.65	153.76
20	26.97	68.09	59.19	154.25
40	28.31	68.86	68.51	155.67
60	28.35	67.48	59.17	155.00
SEM	0.770	1.555	2.084	3.938
Linear	0.197	0.693	0.563	0.684
Quadratic	0.472	0.626	0.769	0.836

$n = 8$. SEM: standard error of the mean.

Table 6. Relative digestive organ lengths (cm/kg body weight) of broiler chickens on day 21.

Soy hulls (g/kg)	Duodenum	Jejunum	Ileum	Total small intestine
0	36.81	90.88	76.84	204.53
20	35.97	90.80	78.79	205.56
40	35.50	86.38	73.42	195.30
60	36.55	87.04	76.35	199.94
SEM	1.314	3.083	3.596	7.579
Linear	0.769	0.113	0.553	0.325
Quadratic	0.318	0.867	0.849	0.739

$n = 8$. SEM: standard error of the mean.

Table 7. Digestive organ unit weight (g/cm) of broiler chickens on day 21.

Soy hulls (g/kg)	Duodenum	Jejunum	Ileum	Total small intestine
0	0.296	0.225	0.188	0.224
20	0.313	0.224	0.180	0.223
40	0.300	0.227	0.185	0.224
60	0.288	0.227	0.186	0.222
SEM	0.0116	0.0095	0.0055	0.0062
Linear	0.292	0.728	0.911	0.897
Quadratic	0.090	0.988	0.243	0.916

$n = 8$. SEM: standard error of the mean.

Table 8. Apparent ileal dry matter (DM), nitrogen (N) and phosphorus (P) digestibility (%) of experimental diets on day 21.

Soy hulls (g/kg)	DM Digestibility	N Digestibility	P Digestibility
0	76.85	82.83	61.73
20	81.07	85.12	70.25
40	87.12	89.94	78.88
60	85.28	84.00	77.07
SEM	2.903	4.504	5.180
Linear	0.002	0.56	0.002
Quadratic	0.151	0.21	0.17

$n = 8$.
SEM: Standard error of the mean.

such that the DM digestibility was higher for 40 and 60 g/kg SH inclusion levels compared to no SH inclusion (Table 8; $p < .01$). However, the level of SH inclusion did not have any influence on the apparent ileal digestibility of nitrogen. The lack of significance for the small intestine weight and length with SH inclusion in the current study suggest that increase in the digestibility of DM and P was not through an alteration in the morphometry of the small intestine. Since the gizzard weight increased by SH, improvements in the ileal digestibility of DM and P might be in respect to the increased development and activity of the upper digestive canal, rather than a lower gastrointestinal tract development (Mtei et al. 2019). Moreover, dietary fibre has been shown to balance the absorption of minerals from the upper digestive tract (Metzler and Mosenthin 2008). A possible longer retention time in the gizzard, since dietary SH increased gizzard weight, might have increased the release of non-phytate phosphorus from ingredients in the current study. González-Alvarado et al. (2007) suggested that passage of the chime through gizzard to small intestines was slower when dietary SH included since SH had greater water holding capacity which resulted in bulkier chime. Therefore, physical pressure by bulkier chime created by SH might have resulted in a larger gizzard and help chime have more contact with the enzymes, which in turn enhances nutrient utilisation (Hetland et al. 2004). Furthermore, an increase in digesta backflow between the gizzard and duodenum by dietary SH as an insoluble fibre might also have played a role in the increased digestibility of DM and phosphorus (P) in the current study as shown by other authors (Hetland et al. 2004; Sacranie et al. 2012). Moreover, since the inclusion of SH did not affect the pH of the gizzard digesta, suggesting that the hydrochloric acid secretion was not increased, therefore, which might indicate the less likelihood of an increase in protein digestion by higher pepsinogen activation in the current study. Although it is challenging to compare ileal digestibility to total tract retention, González-Alvarado et al. (2007) showed that dietary SH at 30 g/kg level did not have a significant effect on total tract apparent retention of nitrogen in broilers at 18 d of age.

Conclusions

In conclusion, the use of dietary SH up to 60 g/kg had no detrimental effect on the growth performance of broilers. Moreover, dietary SH improved apparent ileal digestibility of DM and P, which can be partially

attributed to the ability of SH to increase gizzard weight. However, dietary SH addition did not influence the gizzard digesta pH, small intestine weight and length, and apparent ileal digestibility of nitrogen. The overall data suggest that the increase in the DM and P digestibility was not associated with a change in the size and weight of the small intestine. The mechanism behind the increase in P digestibility by SH warrants further investigations.

Disclosure statement

The authors declare that they have no conflict of interest.

Ethical approval

The experimental protocol was approved by the Adnan Menderes University Local Animal Ethical Committee.

Funding

The current experiment was funded by the Scientific Research Projects Coordination Unit of Istanbul University – Cerrahpasa. Project number: TDK-2019-32842. The authors gratefully acknowledge the Istanbul University – Cerrahpasa for granting the fund.

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