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Effects of α-Galactosidase Supplementation on Performance and Energy Metabolism for Broilers Fed Corn-non-dehulled Soybean Meal Diets*

Bo Zhang, Yunhe Cao, Yiqun Chen, Yihang Li, Shiyan Qiao and Yongxi Ma**

State Key Laboratory of Animal Nutrition, China Agricultural University,
No. 2 Yuanmingyuan West Road, Beijing 100193, China

ABSTRACT : To study the effects of α-galactosidase (α-Gal) supplementation on performance and energy metabolism, 216 Arbor Acres male broilers were placed in 36 cages of 6 birds each and allotted to 4 diets for 42 d, with 0-21 d as starter period and 22-42 d as grower period. The 4 diets were based on corn non-dehulled soybean meal in a 2×2 factorial arrangement, with 2 levels of α-Gal (0 vs. 60 U/kg feed) and 2 levels of ME (normal metabolizable energy (NME) and low metabolizable energy (LME)). Bird performance was obtained at 21 and 42 d of age with samples of feces collected for nutrient digestibility from 19-21 d and 40-42 d. At 21 and 42 d, 1 bird from 6 cages of each treatment was killed to determine liver weight, intestinal pH and chyme viscosity. With the addition of α-Gal the 42 d body weight (BW) and 0-42 d average daily gain (ADG) were significantly improved ($p<0.05$). Average daily feed intake (ADFI) of birds fed the LME diet was significantly increased compared to those fed the NME diet during starter ($p<0.01$) and grower ($p<0.05$) periods and overall ($p<0.01$). There was an interaction of α-Gal×ME on 0-21 d ADFI ($p<0.01$). Supplementation of α-Gal significantly improved ($p<0.01$) feed efficiency during the grower period and overall. Feed efficiency of birds fed the LME diet was significantly decreased ($p<0.05$) compared to those fed the NME diet during the starter period and overall. With the addition of α-Gal apparent metabolizable energy (AME) was improved ($p<0.01$) by 2.1% and 1.8% during starter and grower periods, respectively. There was a main effect ($p<0.05$) of α-Gal on the digestion of neutral detergent fiber (NDF) during the starter period and crude protein (CP), NDF and acid detergent fiber (ADF) during the grower period. With the addition of α-Gal, the relative weight of liver was reduced ($p<0.01$) during the two phases. The duodenal and jejunal pH were significantly decreased ($p<0.01$) with the supplementation of α-Gal at the two phases. α-Gal addition reduced ($p<0.01$) chyme viscosity of the ileum during the starter and grower periods. Overall, α-Gal showed a major effect on nutrient efficiency, improved ADG and feed efficiency, whereas LME decreased feed efficiency. The incorporation of α-Gal into a LME diet could at least partially offset ME deficiency of non-dehulled soybean meal. (**Key Words :** α-Galactosidase, Metabolizable Energy, Broilers Performance, Non-dehulled Soybean Meal)

INTRODUCTION

Soybean meal (SBM) is used extensively as a protein source in animal feed in view of particular merits, such as the desirable amino acid content, relative availability, high consistency, and low cost. However, SBM contains a lot of oligosaccharides (Bach Knudsen and Li, 1991; Parsons et al., 2000; Grieshop et al., 2003; Jankowski et al., 2009), which is essentially non-digestible and can not be eliminated easily by processing (Saunders and Wiggins, 1981; Leske et al., 1991). Most mammals do not express pancreatic α-galactosidase, and the raffinose series (raffinose, stachyose and verbascose) are just digested by microbial enzymes in the lower gut, release gases associated with flatulence in non-ruminant animals and man (Fleming, 1981; Nowak and Steinkraues, 1988; Zhang et al., 2001). The poor digestibility of the raffinose can also lead to potential energy loss. SBM and dehulled SBM contain 5 to 6% more gross energy than corn but 42 to 54% less metabolizable energy, respectively (Hill et al., 1960; Sibbald and Slinger, 1962).

α-Galactosidases (α-Gal, E.C.3.2.1.22) are generally involved in metabolic utilization of a variety of oligosaccharides, such as raffinose, stachyose, melibiose,

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** Corresponding Author: Yongxi Ma. Tel: +86-010-62733589, Fax: +86-010-62733588, E-mail: mayx@mafic.ac.cn

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and galactomannan (Brouns et al., 2006). α-Gal had been used *in vitro* to remove the raffinose family sugars from soybean flour and soymilk (Shivanna et al., 1989; Mulimani and Ramalingam, 1995; Mulimani et al., 1997; Kotwal et al., 1998), but with inconsistent results by *in vivo* studies (Irish et al., 1995; Kidd et al., 2001a; Waldroup et al., 2006).

Based on previous studies (Knap et al., 1996; Ghazi et al., 1997; and Waldroup et al., 2006), we premised the metabolizable energy (ME) of SBM was improved by 10% with α-Gal addition. Because most raffinose exists in the soybean hulls, non-dehulled SBM was used in this experiment. Birds may be more adversely affected by α-galactoside because of the high dietary SBM, especially during early growth stage. To test this hypothesis, we designed a growth trial and metabolic trial to determine the effects of α-Gal on the performance, energy metabolism and digestive parameters of broilers fed corn-non-dehulled SBM diets.

MATERIALS AND MATHODS

Enzyme and activity

The enzyme used in this study was prepared by submerged fermentation, which was cloned from *Penicillium janczewskii Zaleski* in our lab, with the activity of 300 U/g. The fermentation broth was suspended and the supernate was absorbed with the rice chaff. One unit of α-galactosidase activity was defined as the amount of enzyme liberating 1 μmol ρ-nitrophenol per min under assay conditions at 40°C and pH 4.8.

Growth trial

Two hundred-sixteen Arbor Acres male broiler chickens (45.28±0.33 g, 0 d of age) were randomly assigned into 4 treatments with 9 replicates of 6 broilers for each in a 2×2 factorial arrangement. The four treatments were composed of two basal diets containing normal metabolizable energy (NME) recommended by Feeding Standard of Chicken in China (ZB B 43005-86) or lower metabolizable energy (LME) based on the premise that the addition of α-Gal would improve the energy value of the non de-hulled SBM by 10% with or without 60 U/kg α-Gal (Table 1). All diets were antibiotic-free and provided in mash form. The experiment lasted two phases: starter (0 to 21 d) and grower (22 to 42 d).

Feed and water were supplied *ad libitum*. The initial

Table 1. Ingredients (%) and analyzed chemical composition of the basal diets

Ingredient	Starter (0-21 d)		Grower (22-42 d)	
	NME[1]	LME[2]	NME[1]	LME[2]
Corn (7.5% CP)	52.85	54.95	57.50	59.00
Hulled SBM (43.0% CP)	40.00	40.00	36.50	36.50
Fish meal (CP 62%)	1.90	1.00	0.00	0.00
Soybean oil	1.20	0.00	2.00	0.50
Dicalcium phosphate	1.00	1.00	1.00	1.00
Limestone	1.50	1.50	1.50	1.50
Premix[3]	1.00	1.00	1.00	1.00
DL-methionine (98%)	0.30	0.30	0.20	0.20
NaCl	0.25	0.25	0.30	0.30
Total	100.00	100.00	100.00	100.00
Nutrient content*				
Dry matter (%)	87.50	87.55	87.50	87.50
CP (%)	21.19	21.35	19.20	19.38
ME (kcal/g)	2.94	2.83	2.99	2.90
Methionine (%)	0.56	0.57	0.46	0.46
Lysine (%)	1.50	1.48	1.14	1.10
Cystine (%)	0.41	0.43	0.42	0.45
Calcium (%)	1.06	1.07	1.04	1.03
Phosphorus (%)	0.61	0.61	0.57	0.57

[1] NME = Normal metabolizable energy.

[2] LME = Lower metabolizable energy. The assigned ME value of the SBM was 2.587 kcal/g, and the adjusted ME value of SBM was 2.846 kcal/g adding α-Gal.

[3] Provided the following per kilogram of diet: vitamin A (as retinyl acetate), 12,000 IU; vitamin D_3, 2,500 IU; vitamin E (as DL-α-tocopheryl acetate), 20 IU; vitamin K_3 (as menadione sodium bisulfite), 1.5 mg; D-pantothenic acid, 10 mg; Niacin, 20 mg; vitamin B_{12}, 0.02 mg; riboflavin, 5.5 mg; choline chloride, 500 mg; Mn, 75 mg; Zn, 75 mg; Cu, 9 mg; Fe, 80 mg; Se, 0.3 mg; I, 0. 5mg.

* All values were analyzed except for ME.

house temperature (33°C) was gradually decreased to the ambient outside temperature (26-30°C). All chicks were continuously provided with uniform light for 24 h. The birds were raised in three-tiered battery cages (61.2×41.5×35.3 cm).

On d 21 and 42, all birds were weighed, and feed consumption was recorded. The performance data were analyzed on a cage basis. Mortality was recorded on a daily basis. Birds that were removed or died during the experiment were weighed and used to adjust the feed intake and feed:gain.

Metabolism tests

The objective of this study was to determine AME and apparent nutrient digestion. At the 17 d of the growth trail, 24 male birds were selected and allocated into individual cages for 4 dietary treatments with 6 replicates for each treatment. Each dietary treatment was provided with the same corresponding experimental diets as the growth trail (Table 1). The metabolism trial included a 3-d preliminary period at 17 to 19 d of age and 38 to 40 d of age followed by 2 d of total excreta collection. Feed was provided *ad libitum* or 80% of the *ad libitum* amount during the preliminary period or the collection period, respectively. The collected excreta were then dried at 65°C, grounded and stored until analysis.

Sample collection and analysis

On d 21 and 42, one broiler from each replicate was randomly selected, weighed, and killed by cervical dislocation. Liver was separated and weighed to calculate the liver relative weight (LRW) (g/100 g body weight). Duodenum, jejunum, and ileum were separated for analysis pH value using portable pH meter (pH Star, SFK Inc, Denmark). To determine chyme viscosity, intestinal contents from Meckel's diverticulum to the cecal junction were gently expressed and centrifuged at the speed with 3,000 rpm for 3 min at room temperature. The viscosity of a 0.5 ml aliquot of the supernatant from the centrifuged digesta samples was determined using a Brookfield viscometer (Model DV-1) with a CP40 cone. Measurements were performed at 25°C and at shear rates from 22.5 to 450/s, with the values expressed in centipoise (cps).

Chemical analyses of the diets and fecal samples were performed according to the Association of Official Analytical Chemists (AOAC, 2005), including dry matter (DM), crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), and gross energy. Feed samples from all feed batches were also analyzed for enzyme activity. From the calculated AME content of the diets, calorie conversion rations (CCR) were calculated by the following formula: $CCR_{(kcal/g)} = AME_{(kcal/g)}$/Gain:feed ratio.

Statistical analyses

The experiment was conducted using completely randomized design with factorial structure, with pen as experimental unit. Effects of enzyme (with and without) and energy (normal and lower) was analyzed as 2×2 factorial arrangement using ANOVA of SAS (8.0) software. Statistical significance was determined at α level of 0.05. The differences among means were compared by Duncan's multiple-range test (Duncan, 1955).

RESULTS

Enzyme and activity

The results (data were not shown) indicated that all diets supplemented with enzyme contained a minimum of 58 U of α-Gal/kg feed. The enzyme activity for diet 2 and 4 was 62.03±5.45 and 60.72±6.21 at starter, and 58.98±4.12 and 59.48±4.20 at grower, respectively. For diets 1 and 3, enzyme was undetectable (<1 U of α-Gal/kg feed) for the whole phase.

Bird performance

Birds were in good health throughout the experimental period. The effects of addition of α-Gal and ME level on bird performance were shown in Table 2. With the addition of α-Gal the 42 d BW and 0-42 d ADG were significantly improved ($p<0.05$). ADFI of birds fed LME diet was significantly increased than those fed NME diet at starter ($p<0.01$), grower ($p<0.05$) and overall ($p<0.01$). There was an interaction of α-Gal×ME on 0-21 d ADFI ($p<0.01$). Supplementation of α-Gal significantly improved ($p<0.01$) feed efficiency at grower and overall period. Feed efficiency fed LME diet was significantly decreased ($p<0.05$) than those fed NEM diet at starter and overall.

Nutrient digestion

The results of nutrient digestibilities were summarized in Table 3. The addition of α-Gal significantly improved ($p<0.05$) the digestibility of NDF at starter and the digestibilities of CP, NDF and ADF at grower, regardless of the energy level. There were no significant effects of ME level on the nutrient digestibility observed overall the whole experiment periods.

AME, calorie conversion ratio (CCR)

Birds supplemented with α-Gal had higher AME, which was improved ($p<0.01$) by 2.1 and 1.8% at starter and grower, respectively (Table 4). CCR of birds fed LME was significantly decreased ($p<0.05$) than those fed NME at starter and grower, respectively.

Table 2. Effects of α-galactosidase supplementation on growth performance of broilers

Item	α-Gal (without)		α-Gal (with)		SEM	p-value		
	NME*	LME**	NME	LME		α-Gal	ME	α-Gal×ME
BW (g)								
Initial	45.31	45.52	44.84	45.51	0.26	0.11	0.36	0.39
21 d	669	679	680	680	5.98	0.14	0.44	0.48
42 d	1,894	1,908	1,944	1,937	16	<0.05	0.82	0.49
ADG (g/d)								
Starter[1]	29.7	30.1	30.2	30.2	0.3	0.13	0.50	0.46
Grower[2]	58.3	58.6	60.2	59.8	1.0	0.07	0.98	0.68
Overall	44.0	44.4	45.2	45.0	0.4	<0.05	0.82	0.49
ADFI (g)								
Starter[1]	44.7	48.9	45.5	47.3	0.5	0.33	<0.01	<0.01
Grower[2]	143.6	152.0	146.0	148.5	2.1	0.79	<0.05	0.17
Overall	98.6	105.3	100.1	102.7	1.1	0.61	<0.01	0.07
F/G (g/g)								
Starter[1]	1.51	1.62	1.51	1.56	0.02	0.13	<0.01	0.14
Grower[2]	2.46	2.59	2.42	2.48	0.04	<0.01	0.06	0.68
Overall	2.24	2.38	2.20	2.28	0.02	<0.01	<0.05	0.55

[1] Data were means of 9 replicates, and each pen included 6 birds at starter. [2] Data were means of 9 replicates, and each pen included 5 birds at grower.
NME = Normal metabolizable energy. LME = Low metabolizable energy. F/G = Feed/gain.

Table 3. Effects of α-galactosidase supplementation on nutrient digestibility (%) of broilers[1]

Item	α-Gal (without)		α-Gal (with)		SEM	p-value		
	NME	LME	NME	LME		α-Gal	ME	α-Gal×ME
Starter								
CP	48.36	48.55	52.50	51.11	2.05	0.12	0.77	0.70
NDF	36.60	37.83	39.97	39.82	0.59	<0.01	0.37	0.26
ADF	22.95	23.73	24.29	23.88	1.56	0.63	0.40	0.19
Grower								
CP	46.35	45.61	48.37	47.14	0.74	0.03	0.20	0.74
NDF	43.55	43.13	45.27	44.86	0.75	0.03	0.58	0.99
ADF	30.27	27.46	31.37	30.72	0.97	0.04	0.09	0.28

[1] Data were means of 6 replicate. NME = Normal metabolizable energy. LME = Low metabolizable energy.

Table 4. Effects of α-galactosidase supplementation on AME and energy efficiency of broilers[1]

Item	α-Gal (without)		α-Gal (with)		SEM	p-value		
	NME	LME	NME	LME		α-Gal	ME	α-Gal×ME
Starter								
AME (kcal/g)	2.90	2.89	2.96	2.95	0.10	<0.01	0.76	0.99
CCR (kcal/g)	4.38	4.72	4.36	4.63	0.06	0.36	<0.01	0.52
Grower								
AME (kcal/g)	2.91	2.92	2.97	2.96	0.01	<0.01	0.92	0.59
CCR (kcal/g)	8.73	8.92	8.71	9.24	0.18	0.40	0.05	0.36

[1] Data were means of 6 replicates.
NME = Normal metabolizable energy. LME = Low metabolizable energy. CCR = Calorie conversion rations.

Intestinal pH value, liver relative weight and chyme viscosity

Results of intestinal pH value, liver relative weight (LRW) (g/100 g body weight) and chyme viscosity were summarized in Table 5. There was a significant effect of α-Gal on duodenal and jejunal pH at the two phases, which was decreased ($p<0.01$) compared with those without α-Gal.

LRW was decreased ($p<0.01$) by α-Gal addition during the whole experiment. There was no effect of ME on LRW observed during the two phases.

The addition of α-Gal significantly reduced ($p<0.01$) the chyme viscosity of ileum in the whole experiment. Enzyme addition significantly reduced digesta viscosity (3.4 and 2.9 cps as an average at starter and grower, respectively) as compared with no addition (4.5 and 4.1 cps as an average at starter and grower, respectively). No effect of ME level on the chyme viscosity was observed throughout the whole experiment.

DISCUSSION

Fungal and microbial enzymes are used to overcome the negative effects of oligosaccharides in the diet of animals, especially for mono-gastric animals. With the development of DNA recombinant technology, it is possible to obtain the genes of the enzymes and produce highly purified enzymes. In our lab, the α-Gal gene has been cloned from *Penicillium-janczewskii Zaleski* Strains and successfully expressed in the *P. pastrois* (not published).

The addition of α-Gal can hydrolysis those raffinose existed in non-dehulled SBM, releasing galactose and sucrose, weakening the antinutritional effects to birds, which can be reflected from the final BW and feed efficiency at grower and overall observed in this experiment. The effect of α-Gal on bird performance and feed efficiency was varied. Knap et al. (1996) reported that supplement α-Gal to corn (58%) and SBM (36%) diets from 1 to 21 d of age could improve the BW gain and feed conversion for Arbor Acres broilers. Kidd et al. (2001a, 2001b) found adding α-Gal to corn and SBM diets could improve feed efficiency under warm or thermoneutral circumstance, but no effect on live performance. No improvement on 21 d BW was observed in this experiment, which was due in part to the increased weight of the internal organs, possibly by a greater weight for the liver, which can be reflected from the LWR of 21 d in the experiment. Wang et al. (2005) reported the relative intestine weight decreased significantly at 250 mg/kg α-Gal. The great amount of raffinose series oligosaccharies existed in SBM, the ingestion of viscous polysaccharides may produce hyperplasia and hypertrophia of digestive organs and increase pancreatic juice secretion (Ikegami et al., 1990), which increases energy demand in the gut, inversely, the birds had a worse performance. Brenes et al. (1993a) reported that α-Gal at a low rate (1.0 g/kg) added to lupin-based broiler chicken diets failed to improve feed utilization or body weight gain, but was effective at 3.0 g/kg. The reason might be the dosage (1.0 g/kg) of the enzyme was too low. In the current study, the feed efficiency was improved with the addition of α-Gal at grower and overall, but it didn't reach significant level at starter. It is not difficult to speculate that the digestive enzyme in the gastrointestinal tract is not completely developed at starter; therefore, the poorer feed efficiency occurred.

Birds fed LME diets had more ADFI than those fed NME diets in the current study. Birds are particular animals which can ingest feed almost the whole day, especially when the dietary energy concentration is not high to meet

Table 5. Effects of α-galactosidase supplementation on intestinal pH value, liver relative weight (LRW) and chyme viscosity[1]

Item	α-Gal (without)		α-Gal (with)		SEM	p-value		
	NME	LME	NME	LME		α-Gal	ME	α-Gal×ME
Starter								
Duodenal pH	6.36	6.30	6.14	6.18	0.06	<0.01	0.88	0.42
Jejunal pH	6.39	6.08	6.14	6.35	0.07	<0.01	0.92	0.41
Ileal pH	6.21	6.11	6.33	6.34	0.11	0.13	0.66	0.63
LRW	1.69	1.90	1.50	1.50	0.85	<0.01	0.23	0.23
Viscosity	4.37	4.57	3.23	3.63	0.21	<0.01	0.17	0.63
Grower								
Duodenal pH	6.03	5.89	5.39	5.38	0.07	<0.01	0.27	0.35
Jejunal pH	5.69	5.73	5.31	5.16	0.13	<0.01	0.67	0.48
Ileal pH	5.90	5.60	5.49	5.57	0.21	0.31	0.60	0.37
LRW	2.23	2.65	2.04	2.04	0.13	<0.01	0.26	0.31
Viscosity	4.02	4.14	2.87	2.90	0.20	<0.01	0.73	0.82

[1] Data were means of 6 replicates.

NME = Normal metabolizable energy. LME = Low metabolizable energy. LRW = Liver relative weight.

the nutrients need. Therefore, ADFI fed LME diets were higher than that fed NME diets during the whole experiment. Higher feed intake observed in this experiment also indicated that birds can regulate their energy intake by feed consumption (Noy and Sklan, 2004). There was an interaction of ME×α-Gal for ADFI at grower, which indicated that supplement of α-Gal to the diets might compensate the energy deficiency in non-dehulled SBM.

Previous studies have shown the effect of α-Gal on poultry, most of which focused on the dosage of the cocktail enzyme (Kidd et al., 2001a, 2001b; Wang et al., 2005; Waldroup et al., 2006), but the relationship between ME and enzyme is rarely studied. In the present study, the interaction effect of ME level and addition of α-Gal on broilers was investigated. The dietary ME decreased 0.11 and 0.09 kcal/g at starter and grower, which was an average of 3.74 and 3% reduction in ME for the 2 periods, respectively. The effect of α-Gal on energy utilization was studied. Ghazi et al. (1997) proved α-Gal increased nitrogen retention and true metabolizable energy (TME) of SBM. Wang et al. (2005) found that α-Gal increased nitrogen-corrected true metabolisable energy (TMEn) and true digestibilities of methionine and cystine. In the present study, α-Gal addition increased dietary energy value (AME) by 2.08 and 1.79% in the two periods, respectively ($p<0.01$). This increase could be due to the hydrolysis of α-Gal, allowing digestive enzymes access to substrates such as protein and starch with a consequent improvement in the digestibility of nutrients (Salih et al., 1991), and in the nitrogen-corrected apparent metabolisable energy (AME_n, Fuente et al., 1995). Another reason maybe the poorly digested oligosaccharides were replaced by sucrose, the utilization of energy increased (Parsons et al., 2000). This finding might help to explain in part the greater ME observed for the diets based on the supplement of α-Gal in this study. Also, the variations in food intake might contribute to the differences observed in AME by altering the relative contribution of exogenous material to the total digesta (Kadim and Moughan, 1997). However, it was noted the poor energy utilization from SBM (toasted-defatted soy flakes) by poultry is not related exclusively to the presence of the oligosaccharides, raffinose and stachyose (Angel et al., 1988).

The digestibility of CP was significantly improved by supplementing α-Gal at grower, which was in agreement with Ghazi et al. (1997). Stachyose and raffinose existed in SBM can absorb digestive enzymes in the lumen (Coon et al., 1990), and raffinose decreased protein efficiency of SBM (Leske et al., 1991, 1995). The α-Gal can cleave the α-linked galactose units present in the non-dehulled SBM, alleviate the harm to the gut of birds, thus more digestive enzymes enter the gastrointestinal gut, indirectly improve the digestibility of CP.

NDF content can be used to predict the amino acids digestibility (Gdala et al., 1997), and the protein of the SBM might be associated with the NDF portion of the meal in a form that results in low digestibility (De Coca-Sinova et al., 2008). In our trail, the enzyme significantly improved the digestibility of NDF and CP (22-42 d), which can be attributed to the cleavage of the α-galactosides linkage and release of sucrose and galactose by adding Gal to the diets. The released galactose and sucrose improved the AME. The effect was consistent with the improved AME observed in our experiment.

The pH value was affected with the addition of α-Gal, speculated that the addition of α-Gal catalyzes the hydrolysis of the indigestible oligosaccharides, thus reduce its fermentation in the hindgut, which can promote favorable microflora, and these beneficial bacteria function by controlling the pH of the intestine through release of lactic and acetic acids (Modler et al., 1990). Digesta pH value can affect digestible enzyme activities and nutrient digestion. Low pH may favor the development of beneficial bacteria and/or inhibit the development of harmful bacteria (Fuller, 1977), improve the solubility and absorption of mineral salts (Guinotte et al., 1995) and favored pepsin activity. This was consistent with the improvement of the CP efficiency. In the present research, although the duodenal and jejunal pH were significantly decreased at starter with the addition of α-Gal, a slight improvement on the growth performance was observed, yet it didn't reach to a significant level. The reason may be the type of bird, the methodology applied to estimate pH, and differed among authors. In addition, differences in diet composition, especially those related to the fibre fraction, might explain part of the discrepancies.

Field observations indicate that when animals are fed diets with increased viscosity of intestinal contents, the weight of their digestive tract and organs also increase. The similar effect was observed in this experiment. Liver is an important organ, which takes part in the metabolism of protein, fatty acid and energy, as well as to be easy influenced by the exoteric impact. Birds ingested too much oligosaccharides and those oligosaccharides would prolong accumulation of undigested materials in the gut could cause distension of the gastrointestinal tract and an increase in relative length of the small intestine as a response to increased work of the bowel to move the contents (Rubio et al., 1990; Viveros et al., 1994). The addition of a commercial enzyme, derived from *T. viridae* (Roxazyme G), to a barley-based diet has been found to reduce the relative weights of liver by 8% (Brenes et al., 1993b). In our lab, Wang et al. (2005) showed the relative intestinal length and gizzard weight were reduced by the addition of α-Gal.

Usually, ileal viscosity was more sensitive and susceptible to the diet composition than other segments of the small intestine. In the present study, ileal chyme viscosity was significantly reduced when the dietary supplemented with α-Gal, which was consistent with that observed for AME. Rotter et al. (1990) have proved that reduction viscosity in the gut is the most important factor in the performance improvement in broilers fed high viscosity cereals, and that enzyme effectiveness is related to its capacity to decrease chyme viscosity. Significant increases in intestinal viscosity decrease body weight gain in broiler chickens (Almirall et al., 1995; Choct et al., 1995). Also, increased viscosity of digesta results in a longer transit time in the small intestinal due to reduced intestinal contractions (Turnbull et al., 2005). This leads to a reduced mixing of dietary components with endogenous enzymes, resulting eventually in lower nutrient digestibility. The addition of α-Gal alleviated the adverse effects of oligosaccharides existed in non de-hulled SBM, decreased the ileal chyme viscosity, improved the feed efficiency and enhanced the nutritional value.

In summary, α-Gal showed a major effect on the nutrient efficiency, improved ADG and feed efficiency; whereas LME decreased the feed efficiency. The incorporation of α-Gal and LME could offset at least part ME deficiency of non-dehulled SBM.

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