Revista Brasileira de Zootecnia
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ISSN 1806-9290
www.sbz.org.br

R. Bras. Zootec., 45(3):107-112, 2016

Effect of substitution of corn for molasses in diet on growth performance, nutrient digestibility, blood characteristics, fecal noxious gas emission, and meat quality in finishing pigs

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ABSTRACT - The objective of this experiment was to evaluate the effect of molasses as a substitute for corn in diet on growth performance, nutrient digestibility, blood characteristics, fecal noxious gas emission, and meat quality in finishing pigs. A total of 120 [(Landrace × Yorkshire) × Duroc] pigs with an average initial body weight (BW) of 54.21±2.62 kg were used in this experiment. Pigs were randomly assigned to 1 of the 3 dietary treatments on the basis of BW and sex (10 replicate pens per treatment with four pigs per pen: two gilts and two barrows in each pen). The experiment was divided into two phases: 0-5 weeks and 6-10 weeks. Dietary treatments were as follows: control, basal diet; control + 2.5% cane molasses; and control + 5% cane molasses. No significant differences were observed in terms of growth performance, nutrient digestibility, red blood cells, and white blood cells in blood characteristics, fecal noxious gas emission, and meat quality in this study. However, blood lymphocytes were higher with control + 2.5% cane molasses than with control at the end of the 10th week. Molasses can be considered an alternative for corn at the level of 2.5% without any negative influence in finishing pigs.

Key Words: body weight, dietary treatments, finishing pig, lymphocyte

Introduction

Molasses, a mixture of sucrose, glucose, fructose, minerals, pantothenic acid, etc., is derived from sugar-rich crops (beet, cane, blackstrap, etc.) and could be considered an alternative for cereals (Bayley et al., 1983). Cane molasses, which was used in this study, usually contains sucrose, protein, non-protein amino acids, and fatty acids (Mee et al., 1979). It can reduce the cost of diets, because the price of molasses is much lower than that of cereals in livestock feedstuffs. Molasses can also reduce the dust during feed processing and this can improve the environment. However, adding a high level of molasses to the diet of pigs will cause poor growth performance (Brooks and Iwanaga, 1967). These adverse effects may be due to inefficient absorption and utilization of either energy component or fructose in the diet (Bayley et al., 1983). Feoli et al. (2007) reported that adding 5% molasses to diets containing 40% distillers dried grains with solubles (DDGS) did not decrease the growth performance in finishing pigs. Molasses or sucrose can be used to replace 50% or 100% lactose (100 g/kg) in diets for nursery pigs, and it does not have a detrimental influence on the growth performance of pigs (Mavromichalis et al., 2000). There were no detrimental consequences on growth performance in pigs when a proper amount of molasses was added to the diets (Brooks and Iwanaga, 1967). Previous studies assessing the effect of molasses on blood characteristics, fecal noxious gas emission, meat quality, etc. in finishing pigs were inadequate. Therefore, the aim of this experiment was to evaluate the effect of molasses as a substitute for corn on growth performance, nutrient digestibility, blood characteristics, fecal noxious gas emission, and meat quality in finishing pigs.

Material and Methods

The experimental protocols describing the management and care of animals were reviewed and approved by the Animal Care and Use Committee of Dankook University.

A total of 120 [(Landrace × Yorkshire) × Duroc] pigs with an average initial body weight (BW) of 54.21±2.62 kg were randomly assigned into three dietary treatments during this 10-week experiment. The three treatments were as follows: control, basal diet; control + 2.5% cane molasses; and control + 5.0% cane molasses. Cane molasses (NongHyup Inc., Seoul, and Republic of Korea) contained water (33%),

Received June 10, 2015 and accepted November 27, 2015.
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http://dx.doi.org/10.1590/S1806-92902016000300004

sucrose (33%), other saccharides (12%), crude protein (3%), minerals (5%), sugar-free organic matter (8%), and other ingredients (6%). Each treatment had 10 replications with four pigs (two gilts and two barrows) per replication. The experiment was divided into two phases: 0-5 weeks and 6-10 weeks. All diets were formulated to meet or exceed the nutrient requirements recommended by NRC (2012) (Table 1). Each pen was provided with a one-sided self-feeder and a nipple drinker that allowed for *ad libitum* access to feed and water throughout the experiment.

Body weight and feed intake were measured at the beginning of the experiment and at the end of the fifth week and the 10th week of the experiment to calculate average daily gain (ADG), average daily feed intake (ADFI), and gain:feed ratio (G:F). Chromium oxide (Cr_2O_3) was added to the diet at 0.20% as an indigestible marker at the beginning of the fifth week and the 10th week to calculate the digestibility coefficient. Fecal grab samples were then collected randomly from at least two pigs in each pen. Feed and fecal samples were dried for 72 h at 70 ºC, after which they were finely ground to be able to pass through a 1-mm screen and then frozen and stored in a refrigerator at −20 ºC until analysis. Dry matter and nitrogen (N) concentrations were analyzed according to AOAC (2000). Chromium levels were determined via ultraviolet absorption spectrophotometry (Shimadzu, UV-1201, Japan) and the apparent digestibility of DM and N was calculated using indirect-ratio methods. The gross energy (GE) was determined by measuring the heat of combustion in the samples using a Parr 6100 oxygen bomb calorimeter (Parr instrument Co., Moline, IL).

Table 1 - Feed compositions of control diet (as-fed basis)

	CON	M2.5	M5
Ingredient, %			
Corn	50.72	47.99	45.25
Wheat	15.00	15.00	15.00
Rice bran	4.31	4.47	4.62
Wheat bran	2.00	2.00	2.00
Soybean meal	15.29	15.42	15.55
DDGS	7.00	7.00	7.00
Limestone	0.78	0.73	0.68
Animal fat	3.00	3.00	3.00
Molasses	0.00	2.50	5.00
Salt	0.30	0.30	0.30
Choline chloride	0.02	0.01	0.01
L-lysine	0.21	0.21	0.21
DCP	0.99	0.99	1.00
Mineral premix[1]	0.25	0.25	0.25
Vitamin premix[2]	0.13	0.13	0.13
Total	100.00	100.00	100.00
Calculated composition, %			
ME, MJ/kg	14.51	14.41	14.31
Crude protein, %	15.50	15.50	15.50
Calcium	0.65	0.65	0.65
Phosphorus	0.60	0.60	0.60
Lysine	0.76	0.76	0.76

CON - basal diet; M2.5 - CON + 2.5% molasses; M5 - CON + 5.0% molasses. DDGS - distillers dried grains with solubles; DCP - dibasic calcium phosphate; ME - metabolizable energy.
[1] Provided per kg of complete diet: Cu (as $CuSO_4 \cdot 5H_2O$) - 15 mg; Fe (as $FeSO_4 \cdot 7H_2O$) - 70 mg; Zn (as $ZnSO_4$) - 50 mg; Mn (as MnO_2) - 50 mg; I (as KI) - 0.5 mg; Co (as $CoSO_4 \cdot 7H_2O$) - 0.3 mg; Se (as $Na_2SeO_3 \cdot 5H_2O$) - 0.2 mg.
[2] Provided per kg of complete diet: vitamin A - 9,000 IU; vitamin D_3 - 1,200 IU; vitamin E - 40 IU; vitamin K (menadione bisulfate complex) - 3.0 mg; vitamin B_2 - 5.2 mg; vitamin B_6 - 2.6 mg; vitamin B_{12} - 26 µg; niacin - 32 mg; d-pantothenic acid (as d-calcium pantothenate) - 20 mg.

At the beginning of the experiment and at the end of the 5th and 10th weeks, two pigs were randomly chosen from each pen and bled via jugular venipuncture to obtain blood samples. At each collection time, the blood samples (5 mL) were collected into a K_3EDTA vacuum tube (Becton, Dickinson and Co., Franklin Lakes, NJ, USA). All blood samples were centrifuged for 30 min at 2000 × g and 4 ºC to separate the serum, after which the white blood cells (WBC), red blood cells (RBC), and lymphocytes were assessed using an automatic biochemistry analyzer (HITACHI 747, Japan).

For analysis of the fecal ammonia and acetic acid concentration, fresh fecal samples were collected from at least two pigs in each pen on the first, third, fifth, and seventh days of the 5th and 10th weeks. The ammonia concentration was then determined using the method described by Chaney and Edward (1962). To determine the fecal acetic acid concentration, 300 g of fresh fecal samples were transferred to a sealed box and fermented for 30 h in an incubator (35 ºC). The fermented samples were then analyzed using a gas search probe (Gastec Corp., Kanagawa, Japan).

At the end of the experiment, all pigs were slaughtered at a local commercial slaughterhouse. After chilling at 2 ºC for at least 24 h, a piece of the right loin sample was removed between the 10th and 11th ribs. The meat samples were thawed at an ambient temperature. The lightness (L*), redness (a*), and yellowness (b*) values were measured at 3 locations on the surface of each sample using a Model CR-410 Chroma meter (Konica Minolta Sensing, Inc., Osaka, Japan). At the same time, duplicate potential of hydrogen (pH) values of each sample was directly measured using a pH meter (Pittsburgh, PA, USA). The *longissimus* muscle (LM) area was measured by tracing the LM surface at the 10th rib using a digitizing area-line sensor (MT-10S; M.T. Precision Co. Ltd., Tokyo, Japan). Cook loss was determined as described previously by Sullivan et al. (2007). Drip loss was measured using approximately 2 g of meat sample according to the plastic bag method described by Honikel (1998).

In the current study, all data were subjected to statistical analysis in a randomized complete block design using the

GLM procedures of SAS (Statistical Analysis System, version 7.0), with the pen serving as the experimental unit. Variability in the data was expressed as the pooled standard error and a P<0.05 was considered to be statistically significant.

Results

In both the earlier (0-5 weeks) and the later (6-10 weeks) periods, there was no significant effect of different molasses levels on BW, ADG, ADFI, and G:F (P>0.05; Table 2). Average daily gain, ADFI, and feed conversion parameters were not significantly different during the 5th wk. None of the contents was significantly affected by different levels of energy during the two periods separately. Average daily gain, ADFI, and feed conversion parameters were not significantly different during the 10th wk. None of the contents was significantly affected by different levels of energy during the two periods separately.

At the end of the 5th and 10th weeks, there was no significant influence of treatments on the digestibility of N, DM, and GE (P>0.05; Table 3). Dry matter, nitrogen, and energy were not significantly affected in finishing pigs during the 5th to 10th wk. Dry matter, nitrogen, and energy were not significantly affected by different levels of energy during one period separately; however, by 10 wk of age, the high-energy diet provided higher energy compared with the low-energy diet (P<0.05).

Table 2 - Effects of molasses supplementation on growth performance in finishing pigs

Item	CON	M2.5	M5	SE	P-value	
					Linear	Quadratic
BW, kg						
Initial	54.8	54.2	53.6	1.6	0.1983	0.5384
5 weeks	80.7	80.2	80.9	2.1	0.1972	0.6731
10 weeks	111.0	111.1	111.2	2.2	0.2365	0.7725
5 week						
ADG, g	739	744	781	26	0.1051	0.0739
ADFI, g	1,971	1,905	1,925	49	0.6738	0.6738
G:F	0.375	0.391	0.406	0.014	0.6306	0.8787
10 week						
ADG, g	867	884	865	31	0.4472	0.3687
ADFI, g	2,711	2,610	2,623	102	0.8310	0.5470
G:F	0.320	0.339	0.330	0.011	0.1300	0.3206
Overall						
ADG, g	803	814	823	13	0.2721	0.2066
ADFI, g	2,341	2,258	2,274	57	0.2365	0.0622
G:F	0.343	0.361	0.362	0.011	0.3542	0.195

CON - basal diet; M2.5 - CON + 2.5% molasses; M5 - CON + 5.0% molasses; SE - standard error.
BW - body weight; ADG - average daily gain; ADFI - average daily feed intake; G:F - gain:feed.

The obtained data showed that there were no influences on RBC and WBC when molasses was added to the diets at the beginning, in the fifth week, and at the end of the experiment (P>0.05; Table 4). Moreover, there was no difference in lymphocytes at the beginning and during the fifth week of the experiment (P>0.05). However, there was a significant increase in lymphocytes with control + 2.5% cane molasses compared with control in the 10th week (P<0.05).

There were no significant effects of dietary treatments on ammonia emission and acetic acid emission at the end of the 5th and 10th weeks (P>0.05; Table 5).

Pigs fed diets substituted with molasses showed no difference in meat color, and there was no influence of treatments on the pH, LM area, cooking loss, and drip loss (P>0.05; Table 6).

Table 3 - Effects of molasses supplementation on nutrient digestibility in finishing pigs

Item	CON	M2.5	M5	SE	P-value	
					Linear	Quadratic
5 weeks						
N	79.17	77.80	79.99	1.62	0.1768	0.5574
DM	79.40	78.55	78.96	1.88	0.1741	0.6148
GE	76.06	78.62	76.29	1.90	0.1523	0.7767
10 weeks						
N	73.37	74.24	74.64	1.80	0.1447	0.4928
DM	74.39	73.87	76.66	1.77	0.1512	0.5274
GE	73.28	73.70	73.53	1.98	0.1376	0.3842

CON - basal diet; M2.5 - CON + 2.5% molasses; M5 - CON + 5.0% molasses; SE - standard error.
N - nitrogen; DM - dry matter; GE - gross energy.

Table 4 - Effects of molasses supplementation on blood characteristics in finishing pigs

Item	CON	M2.5	M5	SE	P-value	
					Linear	Quadratic
RBC, $\times 10^6/\mu L$						
Initial	6.81	7.15	6.94	0.16	0.7417	0.3384
5 weeks	7.32	7.48	7.63	0.34	0.0556	0.9310
10 weeks	7.83	10.74	11.41	2.25	0.1006	0.3858
WBC, $\times 10^3/\mu L$						
Initial	17.43	18.37	18.14	1.38	0.0196	0.6153
5 weeks	25.97	25.96	26.22	0.47	0.8660	0.5674
10 weeks	24.17	27.50	28.54	2.04	0.0845	0.3005
Lymphocyte, %						
Initial	53.10	52.78	52.54	2.32	0.1658	0.0083
5 weeks	58.95	63.02	65.30	3.96	0.2305	0.7767
10 weeks	63.15b	69.78a	67.78ab	2.03	0.1658	0.0083

CON - basal diet; M2.5 - CON + 2.5% molasses; M5 - CON + 5.0% molasses; SE - standard error.
RBC - red blood cells; WBC - white blood cells.
a,b - means in the same row with different letters differ (P<0.05).

Table 5 - Effects of molasses supplementation on fecal noxious gas emission in finishing pigs

Item	CON	M2.5	M5	SE	P-value	
					Linear	Quadratic
			5 weeks			
Ammonia						
1 day	14.8	13.1	12.6	1.7	0.2098	0.9820
3 days	18.9	19.2	19.1	1.0	0.5230	0.7007
5 days	19.4	21.4	21.4	0.9	0.3195	0.1855
7 days	24.6	24.5	21.3	2.3	0.5973	0.5827
Acetic acid						
1 day	15.0	13.0	13.9	0.8	0.7869	0.4760
3 days	19.5	16.0	16.7	1.4	0.9069	0.3838
5 days	35.5	37.1	37.3	3.1	0.3882	0.1841
7 days	26.7	22.6	25.8	1.4	0.6138	0.5472
			10 weeks			
Ammonia						
1 day	13.3	12.5	11.1	2.1	0.3782	0.4275
3 days	16.5	15.9	15.6	0.6	0.9839	0.8844
5 days	19.0	19.5	18.7	0.7	0.1464	0.2796
7 days	18.4	17.6	16.8	1.9	0.5819	0.3453
Acetic acid						
1 day	15.2	14.6	15.6	1.2	0.5774	0.6306
3 days	17.9	17.5	17.7	0.5	0.5916	0.5597
5 days	27.1	26.8	25.5	0.8	0.3464	0.5855
7 days	21.6	20.6	20.3	0.5	0.5841	0.5627

CON - basal diet; M2.5 - CON + 2.5% molasses; M5 - CON + 5.0% molasses; SE - standard error.

Table 6 - Effects of molasses supplementation on meat quality in finishing pigs

Item	CON	M2.5	M5	SE	P-value	
					Linear	Quadratic
Meat color						
L*	57.76	55.36	55.77	1.70	0.1528	0.2265
a*	16.80	15.87	18.25	1.12	0.9189	0.7149
b*	9.68	8.02	8.94	0.58	0.2695	0.3862
pH	5.84	5.65	5.63	0.05	0.2186	0.5491
LM area, cm^2	48.27	48.58	50.31	1.90	0.3655	0.4582
Cooking loss, %	23.88	21.37	20.32	3.12	0.4892	0.6892
Drip loss, %						0.4357
1 day	5.11	3.45	3.85	1.47	0.3281	0.2956
3 day	5.86	5.94	5.79	1.42	0.5823	0.5643
5 day	6.61	8.91	8.44	1.59	0.1984	0.2846
7 day	9.02	12.01	9.77	1.71	0.2561	0.3184

CON - basal diet; M2.5 - CON + 2.5% molasses; M5 - CON + 5.0% molasses; SE - standard error.
pH - potential of hydrogen; LM - *longissimus* muscle.

Discussion

It has been reported that 5% molasses in the diet may have no effect on ADG in finishing pigs (George et al., 1949; Feoli et al., 2007), which was in agreement with results of the present study. The reason for this may be the nutrient digestibility, because there was no significant influence in nutrient digestibility in this study. There was no influence of treatments with 0, 5, and 10% invert cane molasses on BW, ADG, and G:F, respectively, in early weaned pigs (Diaz et al., 1956). Similar results were obtained, which showed that adding 20% molasses to the diet does not affect ADG (Brooks, 1967) and G:F (Brooks, 1972) in growing pigs compared with the treatments containing a lower level of molasses. There was no significant effect on BW and ADG in growing pigs fed 200, 400, 600, and 800 g/d of molasses, respectively (Xandé et al., 2010). However, there were some differences in the results. Addition of 49.8% molasses to growing swine diets can reduce the ADG and G:F compared with that in the corn basal group and 10% molasses group (Brooks and Iwanaga, 1967). It was observed that G:F was significantly decreased in pigs fed the diet containing 5% molasses. O'Grady et al. (1971) reported that the addition of 5% molasses significantly improved the daily gain and feed intake and increased the feed efficiency when BW was less than 25 kg, and after that, smaller effects or no effects on daily gain and feed intake were observed in pigs fed the diet containing 5% molasses. However, comparisons are complicated because of different stages of pigs, the level of added molasses, housing environment, etc.

Inclusion of molasses did not affect the N, DM, and GE digestibility in this study. Similar results were obtained, which showed that the apparent digestibility of DM and N was not influenced by the different levels of final molasses (23.5%, 39.5%, and 55.5%) in growing pigs (Velázquez et al., 1969). One of the trials in growing swine performed by Brooks (1967) demonstrated that DM digestibility was not influenced by 20% molasses treatment compared with the basal group (without molasses). However, digestibility was decreased with the highest level of condensed molasses solubles (of DM by 43%) in finishing pigs (Stemme et al., 2005). Compared with starch treatment, digestibilities of DM and energy were significantly reduced in the treatment containing 68.5% molasses in growing pigs (Bayley et al., 1983). Brooks (1967) reported that DM digestibility was much lower in growing pigs fed the diet containing 20% molasses compared with the basal group (without molasses). On the contrary, Brooks and Iwanaga (1967) reported that the high-level molasses treatment (49.8%) had a greater digestible energy than both the lower-molasses-level treatment (10%) and basal group (without molasses). According to the previous reports and this research, although not all studies showed similar results, a high level of molasses might reduce the N, DM, and energy digestibility in pigs and there was no adverse effect with a low level of molasses (less than 5%).

In this study, although there were no significant differences in RBC and WBC among groups, blood lymphocytes were significantly increased with control

+ 2.5% cane molasses compared with control in the 10th week. Lymphocytes are one of the main cells of the immune system. Low concentration of ammonia may lead to high immunity in livestock (Yan et al., 2011). There was no significant difference in fecal ammonia concentration, but ammonia concentration was lower in pigs fed control + 2.5% cane molasses compared with pigs fed control in the 10th week. This could be one of the reasons for the present result. Another reason may be the unidentified material in the molasses, whose function has not been proved. There is no report on this material; therefore, more evidence is required to prove this result.

Fecal noxious gas emission can indirectly indicate the health of the pigs and can directly affect the housing environment. Poor housing environment may cause health problems in pigs. In this study, there was no significant difference in fecal noxious gas emission among the treatments. There are no reports on the effect of molasses on fecal noxious gas emission, and there are only some studies assessing the effect of molasses on the DM in feces (Velázquez et al., 1969; Perez et al., 1983; Stemme et al., 2005). Therefore, it is difficult to explain the results of this study, and more studies on this aspect are needed. Higher amount of fecal noxious gas emission and worse housing environment were not observed; thus, according to this study, there was no adverse influence on housing environment in finishing pigs whose diet contained molasses.

There were no significant differences in meat quality among treatments. Studies also reported similar results, which suggests that molasses did not affect the meat quality of pigs compared with control diet (Karamitros, 1987; Xandé et al., 2010). The diet containing 20% molasses did not increase the loin eye area in weaning pigs (Brooks, 1967). However, Brooks and Iwanaga (1967) reported that the pigs fed the diet containing 37.4% molasses and 12.3% fat had a higher loin eye area and a lower dressing percentage compared with the pigs fed corn basal diets. These differences may be due to the amount of molasses, growth stage, etc.

According to the results, fecal noxious gas emission did not increase with control + 5.0% cane molasses; therefore, there was no harm to the housing environment in this study. Moreover, adding a low level of molasses (2.5%) to the diet can increase blood lymphocytes in pigs.

Conclusions

Molasses can be considered a replacement for corn in finishing pig diets at the level of 2.5% without any negative effects. It can improve growth performance, while improving meat marbling and firmness score.

Acknowledgments

We gratefully acknowledge the analysis supported by the laboratory members at Dankook University, Department of Animal Resource & Science, Cheonan, Choongnam, South Korea.

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