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≪Research Note≫

Effect of High Moisture Ear Corn and High Moisture Shelled Corn Feeds on Laying Hen Performance

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The aim of the study was to test the effect of high moisture ear corn (HMEC) and high moisture shelled corn (HMSC) feeds on laying hen performance. A total of 108 Rhode Island Red laying hens were divided by body weight and performance into 12 blocks (9 in each). Each block was assigned to one of three dietary treatments. The hens were fed one of three experimental diets containing 48.0% commercial laying hen diet (CON), 55.7% HMEC (EC) or 48.5% HMSC (SC) on a dry matter (DM) basis. All diets were isocaloric (2.80 mega calorie (Mcal) of (metabolizable energy (ME)/kg of DM) and isonitrogenous (15.5% CP of DM). DM Feed intake (139 to 148 g DM/d per hen), egg production rate (79 to 85%), egg mass (47.6 to 51.2 g/d per hen) and feed utilization (2.7 to 3.1 g of feed DM/g of egg) were not affected by diet. Body weight for the SC diet was significantly less than that for the CON diet ($P<0.05$). This was possibly due to the low feed intake during weeks 1 and 2 because of the short adaptation period to the experimental diet. The body weight loss of hens fed the SC diet may not have occurred when there had been a sufficient adaptation period. Eggshell strength (3.27 to 3.52 kg/cm^2) and Haugh unit (80.0 to 83.6) were not affected by diet. In conclusion, HMEC and HMSC diets do not significantly affect laying hen performance and can be used as a main ingredient of the laying hen diet.

Key words: high moisture ear corn, high moisture shelled corn, laying hen, laying hen performance

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Introduction

A main ingredient of poultry feed is corn, which is mostly dependent on import. When the price of imported corn soared in 2008, Japanese poultry farms encountered a severe management crisis (Japan Poultry Association, 2008). The price of corn has fallen somewhat since, but as demand from developing countries and biofuel industries increases, it cannot be expected that the high price of corn will continue to fall (FAO, 2011). For poultry farming to continue in a stable manner, the use of readily available domestic corn will be necessary. To this end, researchers at the NARO Hokkaido Agricultural Research Center (Sapporo City) now have studies examining the cultivation and harvest of high moisture corn (HMC) in Hokkaido that point to the possibility of domestically producing low cost corn rather than importing it (Oshita, 2015).

The harvesting and feeding of HMC is a popular practice among beef and dairy producers in the USA today (DuPont Pioneer, 2014). HMC is feed in which only the ear of corn is harvested for silage. It is expected to have similar nutritive value as dry corn (NRC, 2001). HMC is a perishable product, but because it does not have to be dried, it could be produced at low cost even in Hokkaido. There are two types of HMC, which differ depending on the method of harvest. When removing only the husk of an ear in harvest, it is called high moisture ear corn (HMEC). When removing the corn cob along with the husk, and preparing it only as kernel, it is called high moisture shelled corn (HMSC) (University of. Wisconsin, 2015). HMSC containing only the kernel is similar in chemical composition to dry corn. On the other hand, HMEC containing approximately 13% corn cob (Basalan *et al*., 1995) is 13 percentage points lower in starch and 9 percentage points higher in neutral detergent fiber (NDF) than HMSC and dry corn (Cornell University and the Cornell Research Foundation, 2015).

The nutritional value of HMEC or HMSC for lactating cows (Chandler *et al*., 1975; Ferraretto *et al*., 2013), beef cattle (Utley and McCormick, 1975; Stock *et al*., 1991), swine (Engelke *et al*., 1984; Asche *et al*., 1986) and broilers (Garlich, 1976; Cruz-Polycarpo *et al*., 2014) has been discussed in several reports. Those reports indicate that HMEC and HMSC are available to such livestock as energy feed. However, to our knowledge, little information is available regarding the influence of feeding laying hens HMEC and

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HMSC on their performance.

The aim of the present study was to test the effect of feeding laying hens HMEC and HMSC on their performance and egg characteristics and to elucidate whether HMEC and HMSC should be fed to laying hens.

Materials and Methods

All the animal procedures were approved by the Hokkaido Research Organization, Animal Research Center Care and Use Committee.

Silage Preparation

Corn hybrid (39K56, 85-d maturity, Pioneer Ecoscience Co., Ltd., Tokyo, Japan) was grown at the commercial field in Biei, the center of Hokkaido. HMEC and HMSC were harvested at black line stage on October 5 2014 using a wheat combine (M200, Laverda S.A.S., Breganze, Italy) equipped with a 6 row corn head (SL966, Dominoni S.N.C., Camisano, Italy). The forages were transported from the field to the storage area, ground through a 10-mm screen using a hammer mill (700 Universal, Peruzzo S.R.L, Curtarolo, Italy), and ensiled in 1-m^3 flexible container bags. After a minimum of 7 months, silages were opened and used for the feeding trial. The geometric mean particle sizes (MPS) of HMEC and HMSC, determined following the procedure described by Lammers *et al*. (1996), were 0.80 and 0.67 mm, respectively.

The silage fermentation quality is presented in Table 1. HMEC and HMSC were extracted with distilled water. The pH of the water extract was determined. After centrifuging a portion of the water extract, supernatant fractions were analyzed for volatile basic nitrogen (VBN) by steam distillation technique and for acetic acid, propionic acid, butyric acid and lactic acid by high pressure liquid chromatography (GC-17A, Shimazu Co.,Ltd., Tokyo, Japan). Because the pH was less than 4.2, VBN/total-nitrogen were as low as 3, and butyric acid was not detected in both silages, the fermentative qualities of HMSC and HMEC were deemed to be good.

Experimental Diets

The composition of feed ingredients is presented in Table 2, and the composition of experimental diets is presented in Table 3. Three experimental diets were fed to the hens: 1) a control diet (CON) based on a commercial laying hen diet (grains: 60%, oil seed meal: 27%, animal by-product feed: 1%, vegetable by-product feed: 1%, others: 11%; CP: ≥16.5 %, ME: ≥2.85 Mcal/kg on a fresh matter basis), 2) an HMEC diet (EC) based on HMEC and 3) an HMSC diet (SC) based on HMSC. The diets were formulated to be isocaloric and isonitrogenous using soy bean meal, wheat bran, cracked

Table 1. **The values of pH, total and individual fermentative fatty acids, and volatile basic nitrogen of high moisture ear corn and high moisture shelled corn**

	High moisture ear corn	High moisture shelled corn
pH	4.06	4.12
Volatile basic nitrogen, % of total N	2.7	2.5
Total fermentative fatty acids	1.82	1.75
Lactic acid, % of fresh matter	1.36	1.43
Acetic acid	0.43	0.27
Propionic acid	0.03	0.05
Butyric acid	0.00	0.00

Table 2. **The composition of feed ingredients**

	DM[1]	Crude protein	Ether extract	NDF[2]	Calcium	Non-phytate phosphorous	ME[3]
	%	----------	----------	% of DM	----------	----------	Mcal/kgDM
Commercial laying hen diet	87.9	18.0	4.4	11.0	3.00	0.60	3.09
High moisture ear corn	63.4	9.0	3.6	16.3	0.03	0.09	3.61
High moisture shelled corn	67.3	9.0	4.0	7.0	0.03	0.09	3.84
Soybean meal	87.9	51.1	2.2	15.5	0.37	0.34	2.72
Wheat bran	86.3	20.0	4.9	42.7	0.12	0.24	2.23
Cracked corn[4]	86.3	8.8	4.4	3.6	0.03	0.09	3.83
Calcium carbonate	99.6	0	0	0	38.73	0.01	0
Dicalcium phosphate	96.0	0	0	0	23.19	18.40	0
Sodium chloride	98.5	0	0	0	0	0	0
Vitamin mineral mix	100.0..	0	0	0	0	0	0

[1] Dry matter, [2] Neutral detergent fiber, [3] Metabolizable energy. [4] Mean particle size: 1.41 mm.

Table 3. **The composition of experimental diet fed to hens**

	Diets					
	CON[1]		EC[2]		SC[3]	
Commercial laying hen diet	48.00*	(47.90)†	—	—	—	—
High moisture ear corn	—	—	55.70	(62.46)	—	—
High moisture shelled corn	—	—	—	—	48.50	(56.81)
Soybean meal	—	—	11.00	(9.45)	8.40	(7.10)
Wheat bran	25.30	(25.72)	24.20	(21.17)	34.00	(29.27)
Cracked corn	21.00	(21.35)	—	—	—	—
Calcium carbonate	5.46	(4.81)	7.80	(5.91)	7.80	(5.82)
Dicalcium phosphate	—	—	0.80	(0.63)	0.80	(0.62)
Sodium chloride	0.12	(0.11)	0.25	(0.19)	0.25	(0.19)
Vitamin mineral mix	0.12	(0.11)	0.25	(0.19)	0.25	(0.19)

[1] Control diet based on commercial laying hen diet. [2] Diet based on high moisture ear corn. [3] Diet based on high moisture shelled corn.
* % on a dry matter basis. † % on a fresh matter basis.

corn and vitamin minerals mix. The concentrations of ME (2.80 Mcal/kg on a DM basis) and CP (15.5% on a DM basis) in the diets were determined to supply 110% of energy requirements (Japanese Feeding Standard for Poultry, 2011) based on body weight, feed intake and egg production in the pre-trial period, and not to greatly exceed energy requirements at the predicted ad libitum intake. Calcium and non-phytate phosphorus concentrate in diets were 3.3% and 0.3% on a DM basis, respectively. The percentage of commercial laying hen diet, HMEC and HMSC in each experimental diet was 48.0, 55.7 and 48.5% on a DM basis, respectively. DM percentage and pH of the CON diet were 87.2 and 6.00, respectively, whereas those of the EC diet and SC diets were 72.3% and 5.26, and 74.7% and 5.38, respectively.

Birds and Housing

A total of 108 Rhode Island Red laying hens, 53 weeks of age and kept in our research center, were used in this study. Hens were housed at 1 bird per cage (25×40 cm) with an individual feed trough and common water trough in 1 row in a conventional poultry house. The 108 cages in the row were divided into 12 blocks with 9 consecutive cages per block. An empty cage was kept between blocks to eliminate cross feeding. Based on the weight and performance of hens, which were fed a commercial laying hen diet 2 weeks before the start of the experiment (pre-trial period), 12 blocks were divided into 3 experimental groups so that 3 groups had similar average body weight and performance. The hens in each block were fed one of three diets (CON diet, EC diet and SC diet), for 6 weeks. For adapting the hens to the experimental diets, hens were fed a commercial laying hen diet mixed with the experimental diet in a 1:1 ratio on the first day of the trial period. Hens were fed for ad libitum intake (target of 10% orts) once daily in each block at 9:00 h. The diets were mixed using a tub mixer every 2 weeks, packed in polyethylene bags for every ration for every block, stored in a freezer, and thawed before feeding. The photoperiod was natural without artificial lighting. The present study was carried out in June and July.

Data Collection

HMEC and HMSC were collected from the container bags every 2 weeks and dried in a forced-air oven at 105℃ for 18 h for DM determination. Experimental diets were adjusted for changes in the DM content of HMEC and HMSC. The amount of diet fed to hens in each block, including their orts, was weighed every day. The orts of each block were composited every week and dried for DM content. Experimental diets were dried for DM content when they were prepared. The DM feed intake in each block was determined using the amount of diet offered and refused, and their DM content every week. Body weight was measured on the 4th and 6th week in the trial period. All laid eggs were collected daily and the number of eggs was recorded per hen. Three eggs per hen were sampled on the 6th week in the trial period. Sampling consisted of weighing and measuring the Haugh unit (HU) and yolk color. Egg production rate was calculated by the number of eggs produced from day 36 to day 42 in the trial period divided by 7. Egg mass was calculated by multiplying egg production rate by averaged egg weight divided by 100. Feed conversion was calculated by dividing DM feed intake by egg mass. HU was calculated from the height of the albumen and the egg weight using a HU formula modified (Eisen *et al*., 1962) by substituting for the constant and simplifying ($HU=100 \log (H-17W^{0.37}+7.57)$, where H is the height of the inner albumen thickness in millimeters and W is the weight of the egg in grams). Eggshell strength was evaluated using H.TESTER (INTESCO Co., Ltd., Chiba, Japan). Egg yolk color was determined instrumentally by Minolta Chroma-meter (CR-410, Konica Minolta, Osaka, Japan) in the CIE L* a* b* space. The L* value indicates the lightness, representing dark to light (0 to 100). The a* (redness) value gives the degree of the red to green color, with a higher positive a* value indicating more red color. The b* (yellowness) value indicates the degree of the yellow to blue color, with a higher positive b* value indicating more yellow color.

Table 4. **Effects of high moisture ear corn and high moisture shelled corn on feed intake, body weight, egg production, energy balance and feed utilization in hens on the 6th week in the trial period**

Item	Diets			SEM	P-value
	CON[1]	EC[2]	SC[3]		
Feed intake (gFM[4]/hen per d)	163[b]	205[a]	187[a]	5.55	0.01
Feed intake (gDM[5]/hen per d)	142	148	139	1.88	0.15
Body weight (kg)	3.47[a]	3.33[ab]	3.12[b]	0.05	0.01
Egg production rate (%)	79	80	85	2.41	0.57
Egg weight (g/egg)	60.5	60.5	60.0	0.76	0.96
Egg mass (g/d)	47.6	48.7	51.2	1.51	0.47
Energy balance[6] (%)	106	112	107	0.02	0.47
Feed utilization (gDM of feed /g of egg mass)	3.1	3.1	2.7	0.11	0.47

[1] Control diet based on commercial laying hen diet. [2] Diet based on high moisture ear corn. [3] Diet based on high moisture shelled corn. [4] Fresh matter, [5] Dry matter. [6] Metabolizable energy (ME) intake/ ME requirement × 100.
[a, b] Within a row, means without a common superscript differ ($P<0.05$).

Chemical Analysis

Commercial laying hen diet, HMEC and HMSC were analyzed for DM (135℃ for 2 h), crude protein (nitrogen (Kjeldahl method) × 6.25), ether extract (solvent extract), neutral detergent fiber (procedure of Mertens (2002)) and crude ash (600℃ for 2 h). ME content of commercial laying hen diet, HMEC and HMSC were determined by trial using 4 hens before the feeding trial. These values of another ingredients and another composition were used the tabulated composition data (Standard Tables of Feed Composition in Japan, 2009).

Statistical Analysis

Four hens which did not lay during week 6 in the trial period were removed from analysis. The experiment was a completely randomized design, and data were analyzed by the GLM procedure of SAS, with average values of each block used as the experimental unit. Differences were considered significant at $P<0.05$; treatment means were compared using Tukey's test.

Results

Effects of HMEC and HMSC on feed intake, body weight, egg production, energy balance and feed utilization in hens on the 6th week in the trial period are presented in Table 4. Feed intakes on a fresh matter (FM) basis of hens fed the EC diet and SC diet were significantly ($P<0.05$) higher than that for the CON diet (205 and 187 vs 163 g FM/d per hen, respectively), however, feed intakes on a DM basis were not affected by either diet (139 to 148 g DM/d per hen). Egg production rate (79 to 85%), egg weight (60.0 to 60.5 g), egg mass (47.6 to 51.2 g/d), energy balance (106 to 112%) and feed utilization (2.7 to 3.1 g of feed DM/g of egg) were not affected by either diet. Body weight for the SC diet was less than that for the CON diet ($P<0.05$). Changes in DM feed intake and body weight during the pre-trial period and the trial period are presented in Fig. 1. During the first 2 weeks of the trial period, hens fed the SC diet had significantly ($P<0.05$) lower feed intakes than hens fed the CON and EC diets. During first 4 weeks of the trial period, the body weights of hens fed the SC diet decreased significantly ($P<0.05$) more than the body weights of hens fed either the CON diet or the EC diet (−0.31 vs −0.05 and −0.14 g/hen/d, respectively).

Effects of HMEC and HMSC on eggshell strength, Haugh unit and yolk color in hens egg quality of hens on the 6th week in the trial period are presented in Table 5. Eggshell strength (3.27 to 3.52 kg/cm^2) and Haugh unit (80.0 to 83.6) were not affected by either diet. Spectrophotometric measurements of yolk color, redness (a*) and yellowness (b*) were lower and the lightness (L*) value was higher in the hens fed the EC diet and SC diet compared with the CON diet ($P<0.05$). Yellowness (b*) for the SC diet was significantly ($P<0.05$) lower than that for the EC diet.

Discussion

On the 6th week in the trial period, DM feed intakes did not differ among diets, however, the body weights of hens fed the SC diet were lower than those of hens fed the CON diet ($P<0.05$). The lower Body weights for the SC on the 6th week in the trial period might be attributed to their body weights loss during first 4 weeks of the trial period, resulting from their lower feed intakes during the first 2 weeks of the trial period, because there were no difference in feed intake among diets after the third week in the trial period (Fig. 1). This lower feed intake for the SC diet during the first 2 weeks might have been caused by the abrupt change from the commercial diet to the SC diet containing HMSC. HMSC had smaller particle sizes compared with cracked corn and HMEC (0.67 vs. 1.41 and 0.89 mm, respectively). It has been shown that decreasing particle grain size contributes to higher digestibility of starch in the digestive tract (Péron *et al*., 2005) and, consequently, starch overload in the intestine soon after the transition to the experimental diet, which may cause depression of feed intake. In addition, a review of feed particle size in poultry (Amerah *et al*., 2007) indicates that poultry have a preference for larger feed particles. Furthermore, Amornthewaphat *et al*. (2011) indicate that the feed intake of layer hens fed smaller particle size of corn was lower compared with coarse particles. Therefore, the lower

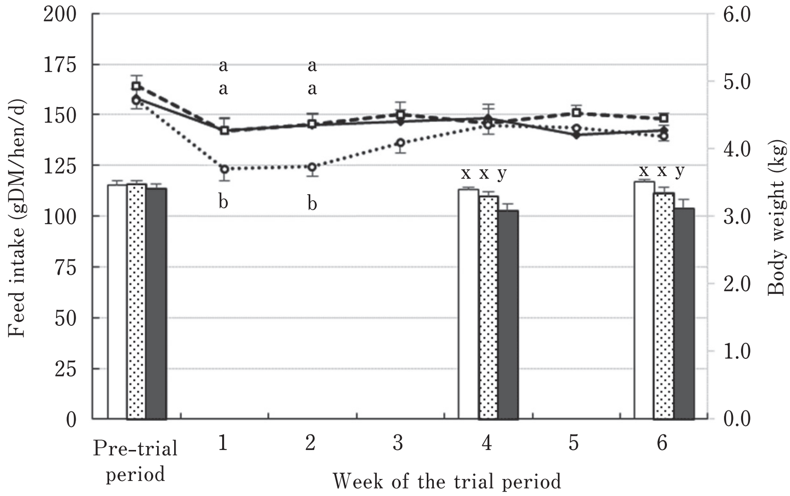

Fig. 1. **Changes in dry matter feed intake and body weight of hens fed diets containing 48.0% commercial laying hen diet (solid line and □), 55.7% high moisture ear corn (dashed line and ▒) or 48.5% high moisture shelled corn (dotted line and ■).** Line chart presents feed intake (left Y-axis) and Bar chart presents body weight (right Y-axis) Values are means±SEM. [a, b x, y] Means without a common superscript differ ($P<0.05$).

Table 5. **Effects of high moisture ear corn and high moisture shelled corn on eggshell strength, Haugh unit and yolk color in hens egg quality on the 6th week in the trial period**

Item			Diets			SEM	*P*-value
			CON[1]	EC[2]	SC[3]		
Eggshell strength		kg/cm^2	3.52	3.42	3.27	0.11	0.67
Haugh unit			80.0	83.6	83.5	0.82	0.11
Yolk color†	L*		50.3^b	51.9^{ab}	52.6^a	0.35	0.01
	a*		1.3^a	−4.1^b	−4.8^b	0.83	0.01
	b*		42.4^a	39.1^b	34.1^c	1.06	0.01

[1] Control diet based on commercial laying hen diet. [2] Diet based on high moisture ear corn. [3] Diet based on high moisture shelled corn. † Lab color space (L*: lightness, a*: redness, b*: yellowness).
[a, b] Within a row, means without a common superscript differ ($P<0.05$).

feed intake of hens fed the SC diet might relate to the adaptation for smaller particle size of corn.

Kelly and Holmes (1971) report no difference in the feed intake of laying hens (47 weeks old) when 70% of dry corn was replaced with reconstituted HMSC (as a % of diet DM). Cruz-Polycarpo *et al*. (2014) also reported no difference in the feed intake of broilers (7 weeks old) when 60% of dry corn was replaced with HMSC (as a % of diet DM). Furthermore, in a separate trial, which we ran at the same time as this trial, domestic meat-type chickens (90 birds) were fed the CON diet (53.5% commercial diet, on a DM basis), EC diet (61.9% HMEC) or SC diet (71.5% HMSC) from 4 to 17 weeks of age. We found that chickens fed the SC diet tended to have higher feed intake and significantly ($P<0.05$) heavier body weights on the 10th week of age compared with the CON diet (unpublished data). These findings demonstrate that HMSC might be highly palatable to hens. In this study, based on the fact that there were no differences in feed intake among the diets (148, 146 and 145 g DM/hen/d for the CON diet, EC diet and SC diet, respectively) on the 4th week of trial period, it seems likely that a decrease in feed intake and the associated body weight loss might not occur if the adaptation period were increased to several days.

The color of egg yolk was determined by the hen's diet. In the USA, the preferred yolk coloration ranges from 7 to 10 in the Roche yolk color fan; whereas in Asia, the preferred values are higher (10 to 14) (Galobart *et al*., 2004). To achieve the desired intense color of egg yolk, a laying hen's diet in Japan is generally enriched with carotenoid pigments. Paprika was added to the commercial laying hen diet in the current trial to provide these carotenoid pigments. Therefore, the difference in yolk color between CON and, EC or

SC may be contributed by commercial laying hen diet containing pigment. The yellowness (b*) of egg yolk for the SC diet was significantly ($P<0.05$) lower than that for the EC diet. It is known that the yellowness (b*) of egg yolk is determined by the amount of xanthophyll in a laying hen's diet (Japanese feeding standard for poultry, 2011). The SC diet did not contain corn cob, which makes up 13% of HMEC on a DM basis. Instead, the SC diet contained 8% more wheat bran compared with the EC diet (Table 3). Xanthophyll content is reported to be 13 mg/kg in corn cob (Japanese feeding standard for poultry, 2011) but is less than 4 mg/kg in wheat bran (Liangli LY. 2007). Therefore, lower xanthophyll content in the SC diet might result in lower yellowness of egg yolk compared with the EC diet.

While HMSC consists of only corn grain, HMEC includes corn cob, which has lower nutritive value. Consequently, the ME content of HMEC is a little less than that of HMSC. However, the difference in ME content between HMSC and HMEC is as low as 0.233 Mcal/kg of DM. Therefore, HMEC could be available to hens as energy feed, in addition to dry corn and HMSC. Along with energy, the amino acid composition of HMEC and HMSC is important. Dry corn contains (% of DM) 0.28% lysine and 0.17% methionine (Japanese Feeding Standard for Poultry, 2011), whereas HMEC and HMSC contain 0.19 and 0.25% lysine, respectively, and 0.14 and 0.20% methionine, respectively (Cornell University and the Cornell Research Foundation, 2015). The lysine and methionine content of HMSC are similar to dry corn. However, they are less in HMEC compared with dry corn and HMSC. Therefore when HMEC and HMSC are used in hen diets, lysine and methionine composition in the diet should be optimized using protein feed.

The disadvantage of HMEC and HMSC is the reduced aerobic stability compared with dry corn. In our previous research, we observed that the temperature of HMEC and HMSC aerobically exposed at average ambient temperature of 26℃ did not rise more than 2℃ above the ambient temperature, which was the index of aerobic deterioration (Taylor and Kung, 2002). However, mold was observed in HMEC and HMSC on the 5th day after aerobic exposure (unpublished data). Considering the observation of mold growth on the 5th day, these results show that HMEC and HMSC remained stable for at least 4 days (96 hours). Similar results have been reported by Taylor and Kung (2002) who showed the aerobic stability of HMSC was 84 hours. When laying hens are fed once a day, it does not seem that HMEC and HMSC fed in a feed trough aerobically deteriorate. However, because aerobic exposure for more than 4 days allows mold to grow in HMEC and HMSC, orts should be removed from feed troughs and container bags or silos storing HMEC and HMSC should be sealed and not exposed to air.

The MPSs of HMEC and HMSC used in this study were 0.80 and 0.67 mm. Deaton *et al*. (1989) showed no difference in layer performance between hens fed hammer-milled corn diets with MPSs ranging from 0.814 to 0.873 mm or with roller-milled corn diets with MPSs ranging from 1.343 to 1.501 mm. Safaa *et al*. (2009) report that the MPS of corn did not affect the performance or egg quality of young brown hens, except by increasing feed intake with increasing particle sizes of ground corn (0.774, 0.922 or 1.165 mm). Meanwhile, the starch digestibility of fermented corn grain is higher compared with dry corn because proteins that encase the starch are degraded by silage acids (Hoffman *et al*., 2010). Grounding HMEC and HMSC requires a lot of energy and labor (Amerah *et al*., 2007). Thus, to reduce the cost of HMEC and HMSC, the optimum particle sizes of HMEC and HMSC for laying hens should be examined in future research.

We conclude that MEC and HMSC diets do not significantly affect laying hen performance and can be used as a main ingredient of the laying hen diet.

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