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Effects of Black Sugar Supplementation on Dry Matter Intake, Milk Yield, and Milk Composition in Holstein Dairy Cow

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ABSTRACT

This study was conducted to investigate the effects of supplementing additional sucrose, in the form of black sugar (BS), into the diet of Holstein dairy cows on dry matter intake (DMI), milk yield, and milk composition. Eight Holstein dairy cows (741 ± 65.8 kg body weight) were divided into two groups, including the control and BS groups. Animals in the control group were offered a total mixed ration (TMR) *ad libitum*, and the BS group was offered TMR with 300 g of BS/head/d. After two weeks of adaptation period, the animal performance, including DMI, milk yield and milk composition, was measured. Cows supplemented with BS appeared to consume more feed than that by the controls (i.e., 17.08 and 18.28 kg/d for the control and BS groups, respectively). However, there were no significant differences between treatments. Milk yield or milk composition, such as milk fat, milk protein, lactose, solids-non-fat, total solids and pH, did not differ between treatments. However, there was a significant difference ($p<0.05$) in the concentration of milk urea nitrogen (MUN). The MUN concentration of the BS group was approximately 15% lower than that of the control group (i.e., 18.75 vs. 16.05 mg/dL for the control and BS groups, respectively), which suggests improved nitrogen metabolism in the animals. The somatic cell count was numerically lower in the cows of the BS group compared to those in the control group. However, a significant difference was not noted due to the substantial amount of variation among cows. In terms of the trace mineral composition for milk, the concentration of Cu from BS animals was higher ($p<0.05$) than that of the control animals. In summary, supplementing the diets of dairy cows with BS marginally affected animal performance and improved nitrogen metabolism. The level of supplementation and other factors, such as animal variation were discussed.

(**Key words :** Black sugar, Dairy cow, Milk yield, Milk composition, Intake)

Ⅰ. INTRODUCTION

In the diet of dairy cows, carbohydrates were fed as an energy source, which represented about 60~70% of the rations used as feed for high-producing dairy cows (Hall et al., 2010; NRC, 2001). The carbohydrates have been classified into two major groups, including structural and non-structural carbohydrates. The structural carbohydrates are classified as neutral detergent fiber (NDF), which include lignin, cellulose, and hemicellulose, and are the indigestible and slowly digested components of the ration. However, starches and sugars are rapidly digested in the rumen and are categorized as non-fiber carbohydrates (Grant et al., 1995).

Sugars are available in different forms and amounts in forages (Berthiaume et al., 2010; Tas et al., 2006). Sugar cane is rich in sugar contents and consequently high in energy, but these benefits are limited by the high content of NDF and the low proportion of crude protein (Corrêa et al., 2003; Lascano et al., 2012). A food industry byproduct, such as citrus pulp, has a high proportion of carbohydrates and NDF. One study has shown that citrus pulp could replace corn grain in total mixed rations without affecting milk production (Solomon et al., 2000). Molasses is a cost-effective sugar source and is useful because of the energy it supplies and the physical benefits it gives to the diet by reducing diet selection in animals (DeVries and Gill, 2012; Firkins and Eastridge, 2010).

Sugars are rapidly, and almost entirely, fermented in the rumen (Chamberlain et al., 1993). Hence, a high level of sugar in the diet of ruminants is known to offer little benefit and, in particular, reduces the digestibility of fiber in the rumen. However, it provides nutritional benefits when diets have less than optimal rumen-degraded carbohydrates.

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For example, there have been several reports on the supplementation of sugar in ruminants fed grass-silage based diets. Broderick and Radloff (2004) reported that supplemental sugar levels between 2.5~5% were the most advantageous for dairy cows. Supplementations of sugar increase ration palatability and play an important role in dairy rations by improving microbial growth in the rumen of dairy cattle (Emanuele, 2004). Black sugar (BS) is widely used for human consumption in Asian cuisines and has a high concentration of carbohydrates; the main component is sucrose and BS is also rich in mineral contents. The trace minerals may play an important role in dairy cow performance (Nocek et al., 2006), which may lead to healthy udders for the improved quality of milk with low somatic cell counts. Therefore, the purpose of the present study was to evaluate the effects of BS on dry matter intake (DMI), milk production, and milk composition in lactating Holstein dairy cows.

Ⅱ. MATERIALS AND METHODS

1. Animal, diets and experimental design

This experiment was conducted from March to April 2013 at Euncheok, Sangju-si, Gyeongsangbuk-do, Korea. Eight Holstein lactating dairy cows were divided into two groups, including the control and BS groups. The experimental design and each cow's performance prior to the experiment are described in Table 1. All cows were healthy and did not show any signs of clinical complications.

For the control group, the cows were fed a total mixed ration (TMR) for their basal diets. For the BS group, 300 g (94% dry matter)/animal/d was top-dressed on TMR. Equal portions of the diets were offered at 05:00 and 17:00. The chemical compositions of the experimental diet and BS are presented in Table 2.

Table 1. Experimental design and animal performance at the beginning of the study

Item	Control	BS
Number of cows	4	4
Parity	3	3
Dry matter intake (kg/d)	17.98	17.39
Body weight (kg)	754 ± 44	728 ± 96
Milk yield (kg/d)	15.4 ± 6.08	15.2 ± 6.19
Days in milking (d)	314 ± 73	312 ± 127

Each value is mean ± standard deviation.
BS: Black sugar supplement group.

2. Data and sample collection

The whole experiment ran for 3 weeks. During the collection period, the weights of offered and refused feeds were measured from each pen to determine DMI. Milking was performed using a tandem parlor system (DeLaval, Sweden) twice a day at 04:00 and 16:00. The milk yields were recorded by in-parlor milk meters (alpha-Laval.

Table 2. Chemical composition of the experimental diet (Control; TMR) and black sugar (BS)

Item	Control	BS
Chemical composition of TMR (% of DM)		
Dry matter (%)	61.61	–
Crude protein	11.53	–
Crude fat	3.11	–
Crude ash	6.46	–
Non fiber carbohydrate (NFC)	12.92	–
Neutral-detergent fiber (NDF)	27.59	–
Forage NDF	13.79	–
Acid detergent fiber (ADF)	16.86	–
Total digestible nutrient (TDN)	43.15	–
Metabolizable energy (ME)	1.47	–
Net energy, lactation (NEl)	0.99	–
Calcium (Ca)	0.49	–
Phosphorus (P)	0.30	–
Energy (Kcal/100 g)	–	398.6
Carbohydrate (%)	–	98.65
Fructose (mg/100 g)	–	180.38
Glucose (mg/100 g)	–	544.28
Sucrose (mg/100 g)	–	81581.8
Calcium (mg/100 g)	–	26.447
Cobalt (mg/100 g)	–	0.017
Copper (mg/100 g)	–	0.197
Iron (mg/100 g)	–	3.166
Potassium (mg/100 g)	–	148.88
Magnesium (mg/100 g)	–	12.75
Manganese (mg/100 g)	–	0.592
Molybdenum (mg/100 g)	–	0.0185
Sodium (mg/100 g)	–	7.75
Phosphorus (mg/100 g)	–	29.75
Zinc (mg/100 g)	–	0.201

DeLaval, Sweden), and milk samples were collected once weekly for same day milk composition analyses. The milk sample for the analysis of mineral contents in raw milk was stored at −20°C.

3. Sample analysis

Feed ingredients of the TMR were analyzed for all nutrients on a common DM basis. Samples were dried at 105°C in a forced-air oven for >16 h. Crude ash was determined after 8 h of ignition at 550°C in a muffle furnace. Concentration of NDF was determined in the presence of sodium sulfite (Hintz et al., 1996). Crude protein was determined by the Kjeldahl method, crude fat was determined by ether extraction (AOAC, 2000). Individual milk samples were analyzed for the concentrations of fat, crude protein, lactose, total solids, solid-non-fat, milk urea nitrogen, pH and somatic cells count by the LactoScope FTIR Advance and SomaScope at the Meat and Dairy Processing Laboratory (Kyungpook National University, Sangju Campus).

Milk samples were frozen in a refrigerator at −20°C for analyzing the mineral contents. In brief, five g of the freeze-dried milk was weighed into a quartz crucible. Residual humidity was removed from an oven at 120°C for 6 h and the final weight was recorded. The crucible was transferred into a muffle furnace; the temperature was increased at a rate of 50°C/h up to 300°C. This value was kept constant for 2 h. The temperature was then increased at the same rate (i.e., 50°C/h) up to 420°C, whereby combustion continued for 6 h. If the ashes still contained carbon (i.e., black particles), 10 mL of distilled water and 10 mL of 60% HCO_3 were added, followed by evaporation on a hot plate until the dilution emitted white smoke. After cooling, the samples were filtered with filter paper (No. 2) into a 100 mL volumetric flask with high-quality double distilled water (Milli-Q). The samples were analyzed using Inductively Coupled Plasma (Thermo Elemental Co., UK).

4. Statistical analysis

Results from the present study were subjected to Student's *t*-test by using the SPSS software (SPSS graduate pack 16.0 for Windows) and the significance was set at $p<0.05$.

Ⅲ. RESULTS AND DISCUSSION

1. Dry matter intake

The results of the DMI of dairy cows throughout the experimental period are presented in Fig. 1. In the first week, DMI was 17.64 ± 0.64 and 16.85 ± 3.22 kg/d for the BS and control groups, respectively ($p>0.05$). However, cows appeared to consume more as the experiment progressed, and cows supplemented with 300 g/d of BS tended to consume more than the control group, although the results were not significant (Fig. 1). Previous studies have presented inconsistent results when sugar was included as a supplement in dairy diets. For example, McCormick et al. (2001) reported that 5% of sucrose supplements did not affect DMI in Holstein dairy cows. Similar results were observed in another study (Hristov and Ropp, 2003). In contrast, other studies have reported an increase in DMI (Penner and Oba, 2009; Varga et al., 2001). Variation in the response to sugar supplementation in the diet of dairy cows can be explained by two reasons. The first is a shift in rumen fermentation patterns due to sugar supplementation and a subsequent change in pH in the rumen (Belanche et al., 2012). The second reason is the efficiency of the utilization of sucrose by rumen microorganism for their growth (Emanuele, 2004). The level of sugar supplemented in the present study was about 1.7% of DMI and may not affect DMI at a significant level.

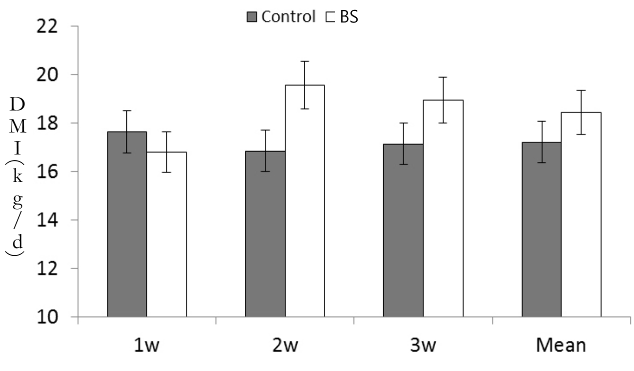

Fig. 1. Changes in daily dry matter intake (DMI) given the experimental diet (kg/d).
1w: 1st week, 2w: 2nd week, 3w: 3rd week, Mean: Overall mean, BS: Black sugar supplement.

2. Milk production

Milk production and milk composition between the control and BS groups are shown in Table 3. Milk production was not affected by BS supplementation in the diet of dairy cows, averaging 15.57 ± 7.24 kg/d and 16.80 ± 6.91 kg/d for the control and treatment groups, respectively. This is not surprising as the DMI of cows did not differ between treatments; the crude protein content of the diets was also similar.

3. Milk composition

Table 3 shows the results of the milk fat, protein, lactose, total solids, nonfat solids, and pH during the measurement period. As shown, the results were not significantly influenced by the supplementation of BS, except for MUN ($p<0.05$). On average, milk fat percentage was not different between the treatment and control groups at 4.68 ± 0.35% and 3.93 ± 0.98%, respectively. Milk protein and lactose contents were also similar between the treatment and control groups, averaging 3.40% and 4.69%, respectively. The total solids of the BS and control groups were 11.06 ± 0.3 and 10.32 ± 0.68%, respectively. The solids-non-fat of the BS and control groups were 8.77 ± 0.65 and 8.60 ± 0.55%, respectively, and the pH of both groups were constant at 6.53 ± 0.04 and 6.55 ± 0.03, respectively. However, MUN significantly ($p<0.05$) decreased in the BS group (16.05 ± 1.4 mg/dL) compared to the control group (18.75 ± 0.58 mg/dL).

Table 3. Milk yield and milk composition of Holstein dairy cow given the experimental diets

Item	Control	BS	SED
Milk yield (kg/d)	15.57	16.80	4.54
Milk fat (%)	4.68	3.93	0.74
Milk protein (%)	3.44	3.24	0.22
Lactose (%)	4.63	4.69	0.17
Total solid (%)	11.06	10.32	0.53
SNF (%)	8.77	8.60	0.39
MUN (mg/dL)	18.75[b]	16.05[a]	0.76
SCC (10^3 cells/mL)	209.8	86.8	101.46
pH	6.52	6.53	0.02

[a>b] within a row means without a common superscript letter differ at $p<0.05$.
SED: Standard error of the difference.
BS: Black sugar supplement.

The observed minimal change in milk composition was probably related to the level of supplementation. Oelker et al. (2009) reports that feeding containing less than 5% sugar rarely decrease ruminal pH. As such, it did not have much of an impact on milk fat depression, as indicated by Weimer et al. (2010). Nevertheless, BS supplementation numerically increased DMI and more importantly, reduced MUN, which is an important metabolic indicator of protein metabolism in cows. The response in the current study suggests that when additional sugar (the rapidly fermentable carbohydrate) is supplied into the rumen, it stimulates microbial growth by balancing the supply of nitrogen and energy for microbial protein synthesis (Chamberlain et al., 1993). For example, it has been speculated that the increased capture of ruminal ammonia by rumen bacteria leads to a decrease in ruminal ammonia concentration when additional sucrose is supplemented into the diet of dairy cows (Emanuele, 2004). Oelker et al. (2009) also reported that the addition of molasses decreased the concentration of ruminal ammonia. The ammonia produced may not be converted into microbial protein. Thus, the excess ammonia crosses the ruminal wall and is transported to the liver. The liver converts the ammonia to urea, which is released into the blood. Urea in the blood can return to the rumen and be excreted to the urine and as MUN in milk (Wattiaux, 1996).

Somatic cell counts between the control and BS groups were not different, and a large numerical difference was observed between the means (Table 3). SCC for the control and BS groups was 210 vs. 87×10^3/mL, respectively, with large variations (see Table 3). The limited number of animals used in the study makes it difficult to explain this response. However, additional minerals, such as Zn, Mn, and Cu, which comprise BS, may have contributed to improvements in the immune function of dairy cows. Such a response requires further research because the SCC is an important factor in the determination of milk quality and price at the farm gate.

4. Mineral contents in raw milk

The mineral concentration of raw milk for the control and BS groups is presented in Table 4. In general, the concentrations of the mineral contents did not differ, except for Cu. Initially, the concentrations of Cu in the milk of the BS and control groups were 0.04 ± 0.04 mg/100 g and 0.06 ± 0.03 mg/100 g, respectively (data not shown). However, after adaptation period the concentration of Cu significantly ($p<0.05$) increased in the BS group at 0.08 ± 0.03 mg/100 g, while that in the control group was 0.03 ± 0.01 mg/100 g.

The concentrations of trace elements in raw milk throughout the lactation period are normally variable, and such changes are primarily caused by two factors. The first is related to the metabolic changes in dairy cows, including the stage of lactation and udder status; the second is related to extraneous factors, such as season, nutritional status, and environmental conditions (Sola-Larrañaga and Navarro-Blasco, 2009). However, at the current level of supplementation, nutritional status does not appear to be a principal factor affecting concentrations of trace elements, and therefore whether additional concentrations of minerals from BS supplementation played a role in elevating Cu content in milk remained unclear. The overall mean of mineral concentrations of the current study were relatively similar to that in a previous study by Qin et al. (2009). For example, the concentration of Cu, Fe, K, Mg, Mn, Mo, Na, P, and Zn were 0.017, 0.193, 111.7, 1230, 0.02, 0.013, 38.4, 86.1, and 0.238 mg/100 g, respectively.

Table 4. Changes in mineral concentration of Holstein dairy cow given the experimental diets (mg/100 g)

Item	Control	BS	SED
Ca	17.07	16.64	0.917
Co	0.005	0.006	0.002
Cu	0.026[a]	0.084[b]	0.019
Fe	0.251	0.269	0.067
K	155.2	170.7	6.586
Mg	11.42	10.27	1.000
Mn	0.244	0.241	0.016
Mo	0.021	0.017	0.004
Na	34.03	30.09	3.916
P	12.45	12.41	1.038
Zn	0.626	0.546	0.113

[a>b] within a row mean without a common superscript letter differ at $p<0.05$.
SED: Standard error of the difference.
BS: Black sugar supplement.

Ⅳ. CONCLUSION

In conclusion, the present study demonstrated the effect of additional sucrose in the form of BS in the diet of dairy cow DMI and milk composition. When supplemented, MUN decreased significantly, and the concentration of Cu in milk increased. A decreasing trend in SCC was also observed, although animal variation was too large to reach a definitive conclusion. The effects on DMI, MUN, and SCC were closely related to milk price at the farm gate. Further research by using a large sample size with various levels is necessary to further elucidate the effects of BS.

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