Effect of feeding sweet-potato condensed distillers solubles on intake and urinary excretion of minerals in Japanese Black steers

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Running Head: SWEET POTATO DISTILLERS RESIDUE AND URINE

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ABSTRACT

Four Japanese Black steers (16 months of age) were assigned to a 4 × 4 Latin square design to investigate the effect of graded levels of sweet-potato condensed distillers soluble (SCDS) in their diets on intake and urinary excretion of minerals. The four diets consisted of 0%, 10%, 20% and 30% (dry matter (DM) basis) SCDS, with SCDS replacing commercial concentrate (CC). Intake of K, Cl, S, P and Mg increased linearly with increasing SCDS content. Urinary pH increased linearly with increasing dietary SCDS content. SCDS feeding increased urinary K concentrations (linear and quadratic effects). Urinary concentrations of Cl increased linearly with increasing SCDS content. In contrast, urinary concentrations of Mg decreased with increasing SCDS content. Feeding of SCDS did not apparently affect urinary NH_3, P, Na or Ca concentration. These results suggest that high SCDS feeding is not a risk for crystallization of minerals leading to the formation of magnesium-phosphate type calculi: although SCDS contains large amounts of P and Mg, high SCDS feeding decreased the Mg concentration and did not affect the P concentration in urine. Additionally, high SCDS feeding had no apparent effects on plasma concentrations of Na, K, Cl, Ca or inorganic P.

Key words: Japanese Black cattle, mineral, sweet-potato condensed distillers soluble, urine

INTRODUCTION

A recent increase of shochu (Japanese traditional hard liquor) production has resulted in large quantities of shochu by-products. Sweet-potato condensed distiller soluble (SCDS) is one of these by-products having high nutritive value, namely, a high content of total digestible nutrients (TDN) and crude protein (CP). Thus, SCDS is considered useful as a cattle feed (Kamiya *et al.* 2010; Suzuki *et al.* 2010, 2011). SCDS contains a high amount of potassium (K). Additionally, the concentrations of magnesium (Mg) and phosphorus (P) are relatively high in SCDS, close to their levels in wheat bran. A high-K diet was reported to increase urinary K excretion, urinary pH (Kume *et al.* 2011) and urine volume (Suzuki *et al.* 2010) in ruminants. High dietary levels of cations such as K induce metabolic alkalosis in cows, which reduces the ability of the cows to maintain plasma Mg and calcium (Ca) (Goff & Horst 1997). Therefore, feeding beef steers large amount of SCDS could possibly affects theirs mineral metabolism.

In beef steers, urolithiasis has long been an important problem. Many factors have been implicated in its incidence, such as vitamins, minerals, water intake, infections and hormonal balance (National Agriculture and Food Research Organization, NARO 2008). Dietary mineral imbalances are particularly well known to induce urolithiasis. Uroliths are frequently seen in beef steers when urinary pH is high and urinary P and Mg concentrations increase (National Agriculture and Food Research Organization, NARO 2008).

Our preliminary study (Kamiya *et al.* 2011) indicated that feeding of fermented TMR containing SCDS when compared with commercial concentrate (CC) has some effects on the urinary excretion of minerals such

as K and Mg. However, the results of our preliminary study were not sufficient to clarify the direct effects of SCDS feeding on urinary mineral excretion because SCDS was one of the ingredients in TMR. Further, the dose response to dietary SCDS level was not clarified in the previous report.

The effects of 4 levels of dietary SCDS on feed dry matter intake, digestibility and nitrogen metabolism in Japanese Black steers were reported by Kamiya *et al.* (2013). In the present report, we examined the effects of dietary SCDS on mineral intake, urinary excretion and plasma concentrations of minerals of Japanese Black steers used by the Kamiya *et al.* (2013).

MATERIALS AND METHODS

Animals and procedure

The experiment was conducted as previously described (Kamiya *et al.* 2013). Briefly, four Japanese Black steers (16 months of age) were randomly assigned to a 4 × 4 Latin square design. Each experimental period consisted of 14 d, which included 9 d of adaptation to the diets and 5 d of the sample collection period. Experimental steers were fed daily experimental concentrate (CC replaced with SCDS (0%, 10%, 20% and 30% as DM basis)) on an *ad libitum* basis, together with 1.5 kg/day of rice straw as the upper limit. Calcium carbonate (120 g/day) was added to experimental concentrate so that the Ca-to-phosphorus (P) ratio in the diet would be no less than 1:1. The chemical compositions of experimental diets were described in a previous study (Kamiya *et al.* 2013). The steers were offered the experimental diet at 09.00 hours, once in a day. Mineral blocks and water were available

throughout the study. Feed refusals were collected and weighed daily in the experimental periods. Mineral blocks were weighed at the beginning and end of the experiment period. Urine was collected as spontaneous samples into a plastic bag hung under the abdomen on the third and fifth day of the collection period. Urine pH value was measured by a pH meter (Piccolo+ Hanna Instruments Japan, Chiba, Japan), immediately after urination and urine was frozen at –20 °C until analysis. Blood samples taken from the jugular vein were collected in heparinized tubes before feeding on the final day of the experimental period.

The management of steers was conducted as previously described (Kamiya *et al.* 2013).

Sample analysis

For analysis of sodium (Na), K, sulfur (S), P, Ca, and Mg in diets and urine, dietary samples and urine samples were digested in nitric–perchloric acid. The concentrations of Na, K, Ca and Mg were determined by atomic absorption spectrophotometry (SOLAAR M6; Nippon Jarrell-Ash Co., Ltd., Kyoto, Japan). The S content was determined by ICP-MS (SPS4000; Hitachi high-Tech Science Co., Tokyo, Japan). The P content was determined using the colorimetric method of Gomori (1942). For analysis of chlorine (Cl), diets and urine were dry ashed at 550 °C. The Cl concentrations were determined using the titration methods of Mohr (1856). The urinary total ammonia concentration was measured using a commercial kit (F-kit Ammonia; Roche Diagnostics, Basel, Switzerland). Urinary creatinine excretion are closely correlated with body weight (BW) and the excretion rates of urinary

creatinine is considered to be constant (Jones *et al.* 1990; Chen *et al* 1992, Asai *et al.* 2005); therefore the urinary creatinine concentration has been used as an indicator in estimating urine volume and assessing the balance of nutrients in beef cattle digestion (Devant *et al.* 2000; Padilla *et al.* 2007; Ceconi *et al.* 2015). Urinary creatinine concentration was measured using a commercial kit (Labo Assay Creatinine; Wako Pure Chemical Industries, Ltd, Osaka, Japan). The urinary excretion of minerals and ammonia were expressed as the ratio to urinary creatinine (O'Kelley & Fontenot 1973; Roch *et al.* 2003). The concentrations of plasma Na, K, Cl, inorganic P (Pi), Ca and Mg were determined by an analyzer (DRI-CHEM 7070; Fujifilm, Tokyo, Japan) using DRI-CHEM slides (Fujifilm). Mineral contents of the experimental diets are shown in Table 1. The dietary mineral intake was calculated from determined mineral contents and feed intake described in the previous report (Kamiya *et al.* 2013). The dietary cation-anion difference (DCAD) was calculated from determined mineral contents as (Na+K)–(Cl+S) (Ender *et al.* 1971). To evaluate the likelihood of urolithiasis, the solubility of struvite crystals was determined on the basis of struvite activity products (SAP; $[Mg^{2+}]\times[NH_4^+]\times[PO_4^{3-}]$) according to Buffington *et al* (1990). Urinary NH_4^+ and PO_4^{3-} concentrations were estimated from urinary pH and total concentrations of ammonia and inorganic P (Shimizu *et al.* 2006). For convenience, the SAP is expressed as pSAP, the negative logarithm of SAP.

Statistical analysis

All data were analyzed according to the 4 × 4 Latin square design using the mixed procedure of SAS (2004), including diet and period as the fixed effects

and steers as the random effect in the model. Orthogonal polynomial contrasts were used to determine linear, quadratic and cubic responses to dietary level of SCDS in diet and the significance among treatments was tested by the PDIFF option (SAS 2004).

RESULTS

The DCAD in experimental concentrate increased with increasing dietary SCDS content because of the high cation-anion difference in SCDS (Table 1). The feed intake was previously described in detail (Kamiya *et al.* 2013). The experimental concentrate intake showed high values in 10% and 20% SCDS groups (0%:6.57 kg/day, 10%:7.88 kg/day, 20%:7.52 kg/day, 30%:7.23 kg/day). The SCDS content of the experimental concentrate did not significantly affect the steer's intake of rice straw (0%:1.06 kg/day, 10%:0.97 kg/day, 20%:0.95 kg/day, 30%:1.29 kg/day) or mineral blocks (0%:8.8 g/day, 10%:11.5 g/day, 20%:11.0 g/day, 30%:12.5 g/day). Increasing dietary SCDS from 0% to 30% resulted in linear increases in K, Cl, S, P and Mg intake ($P<0.01$). There were no effects of SCDS feeding on Na and Ca intake (Table 2).

The effects of the SCDS feeding level on urinary mineral excretions are shown in Table 3. Urine pH ($P<0.05$) increased linearly with increasing dietary SCDS level. The urinary creatinine concentrations ($P<0.01$) decreased linearly with increasing dietary SCDS level. The urinary K concentration showed linear and quadratic increases ($P<0.05$) with SCDS feeding. Urinary estimated K excretions increased linearly ($P<0.01$) with increasing dietary SCDS level. The urinary Cl concentration ($P<0.05$) and estimated excretion ($P<0.01$) increased linearly with increasing dietary SCDS level. The urinary

Mg concentration decreased linearly with increasing dietary SCDS level ($P<0.05$) while the SCDS level had no apparent effects on the estimated Mg excretion in urine. The SCDS level had no apparent effects on urinary NH_3, Na, P and Ca concentrations of experimental steers. The SCDS level had no apparent effects on the pSAP of experimental steers.

The effects of SCDS feeding on plasma mineral concentrations are shown in Table 4. There were no effects of SCDS feeding on concentrations of plasma Na, K, Cl, inorganic P or Ca. The plasma Mg concentration showed quadratic increase ($P<0.05$) with SCDS feeding; i.e., the plasma Mg concentration was higher in the steers fed 10 and 20% SCDS than in the others.

DISCUSSION

The present study was conducted to examine the effects of 4 levels of SCDS feeding on intake, urinary excretion and plasma concentrations of minerals in Japanese Black steers. The SCDS feeding significantly increased urinary pH, although feeding of TMR containing SCDS did not affect urinary pH in our previous report (Kamiya *et al.* 2011). Kume *et al.* (2011) reported that there were positive correlations between urine pH and urinary K concentration or K intake in dairy cows. On the other hand, SCDS also contained higher Cl compared to CC. Chloride such as NH_4Cl is often added to diets as a urine acidifier. Chlorine is almost completely absorbed in the gut and excess Cl is excreted into urine (NRC 2001). The amount of both absorbed Cl and Cl excretion into urine were increased in cows and sheep fed diets containing chloride (Takagi & Block 1991; Schonewille *et al.* 1999; Charbonneau *et al.* 2009). It is well known that urinary electrolytes and acid-

base status directly affect urine pH. Tucker *et al.* (1988) indicated that the changes in DCAD were responsible for the alterations in acid-base physiology of cows. The DCAD has been known to be highly associated with urinary pH in ruminants (Sanchez *et al.* 1994; Charbonneau *et al* 2006; Hersom *et al* 2009). In the present experiment, DCAD calculated from mineral intake was shown to be increased with increasing dietary SCDS. Although the concentration of Cl and S were higher in the SCDS than in the CC, DCAD was high in SCDS because of the large amount of K in SCDS. Thus we suggest that urinary pH is increased with increasing dietary SCDS through increasing DCAD.

The urinary creatinine concentration was decreased with increasing dietary SCDS level. Since daily creatinine production and consequently urinary creatinine excretion are constant to the individual (Albin & Clanton 1966; Asai *et al.* 2005), urine volume could be estimated by dividing the daily urinary excretion of creatinine by the creatinine concentration in the urine of the spot samples. Therefore, urine volume was thought to be increased with increasing dietary SCDS level. Several reports on cows and sheep have indicated that high dietary K results in higher urine volume (Yano *et al.* 1977; Bannink *et al.* 1999; Suzuki *et al.* 2010; Ohtani *et al.* 2010). Intake of K was increased with increasing dietary SCDS in the present experiment because SCDS contained a large amount of K. High K intake would contribute to the increase of urine volume in this experiment. High protein in diet or high urea concentrations of plasma also increase urine volume in ruminants (Wholt *et al.* 1976; Ohtani *et al.* 2014). Kamiya *et al.* (2013) has shown that plasma urea nitrogen concentration was higher in steers fed a high-SCDS diet, which

would have partially affected the urine volume in this experiment.

Although Mg intake was increased with increasing SCDS in diet and the highest level of dietary SCDS increased Mg intake by 40%, the urinary Mg excretion was not significantly affected by the graded levels of dietary SCDS. Feeding a high level of K has been found to depress apparent Mg absorption in ruminants (Greene *et al.* 1983; Fontenot *et al.* 1989). The high K in SCDS in the present experiment probably depressed Mg absorption and thus urinary Mg excretion was not increased in steer fed SCDS containing a large amount of K and Mg. Further, the high K intake increased urine volume of steers fed SCDS, which dilutes the Mg concentration in the urine. As a result, the urine Mg concentration was decreased in steers fed high SCDS. Kamiya *et al.* (2011) also reported that SCDS feeding decreased urinary Mg concentration, though SCDS was one of the ingredients in TMR in that report.

The intake of P was increased with dietary SCDS level but the concentration of plasma inorganic P was not affected by the dietary treatment, which indicated that P homeostasis was maintained even in steers given the highest level of SCDS. Urinary excretion and concentration of P was not affected by the dietary treatment. Phosphorus metabolism is regulated by its absorption, urinary and endogenous excretion, and bone metabolism. The regulation of P absorption and/or endogenous excretion may contribute to its homeostasis in steers given SCDS because urinary excretion of P is not affected by the dietary treatment.

In the mineral nutrition of beef steers, urolithiasis has long been an important problem. Calculi of the magnesium-phosphate type are commonly found in ruminant urolithiasis (Lindley *et al.* 1953; Robbins *et al.* 1965). The

calculi have been reported to consist of magnesium and phosphate (Munakata *et al.* 1974) or magnesium, ammonium and phosphate (Osborne *et al.* 1985; Tsuchiya & Sato 1988). The urolith material consisting of magnesium, ammonium and phosphate is referred to as struvite.

When the urinary concentrations of Mg and P are at a high level combined with high urinary pH, they tend to crystallize and form calculi. Some researchers (Packett & Hauschild 1964; Bushuman *et al.* 1965) reported that urinary P concentration was high when the calculi were found in the bladders of ruminants. To evaluate the effects of SCDS feeding on urolithiasis throughout the fattening period, it is necessary to discuss the changes of mineral concentrations and pH in urine. In addition, the crystallization of struvite in feline urine was evaluated using the index, strutive activity product (SAP, $[Mg^{2+}] \times [NH_4^+] \times [PO_4^{3-}]$) according to Buffington *et al.* (1990). Shimizu *et al.* (2006) tried to investigate the pSAP value and struvite crystallization of cats, suckling calves and dry cows, and indicated that pSAP would reflect struvite crystal formation in urine.

In the present study, although urinary pH was high in the steers fed SCDS, the urinary P concentration was not affected by dietary SCDS and the urinary Mg concentration was decreased with SCDS consumption increased. Furthermore, the present experiment indicated that dietary SCDS did not affect the pSAP value of urine. Therefore, these results suggest that SCDS feeding is not a risk factor for urolithiasis of magnesium-phosphate type calculi in beef steers.

The dietary SCDS level did not affect the plasma concentrations of Na, K, Cl, Ca or inorganic P. Plasma Mg concentration was increased in the steers

given 10% and 20% SCDS but interestingly, not so in steers fed 30% SCDS. Plasma Mg concentrations are affected by both Mg absorption in the intestine and urinary excretions. However, the highest SCDS intake did not result in the highest Mg of plasma concentration or urinary excretion. It is well known that feeding a high level of K depress apparent Mg absorption in ruminants (Greene *et al.* 1983; Fontenot *et al.* 1989). It was suggested that the high K concentration of SCDS affected Mg absorption and plasma Mg concentration. It is still necessary to clarify the effect of feeding SCDS on the plasma Mg concentration.

Although the intakes of K and Cl were increased with dietary SCDS level, plasma concentrations of these minerals were not affected by the dietary treatment, which can be explained by the increase in urinary excretion of these minerals. The kidney is the major organ controlling K and Cl metabolism because the absorptions of these minerals are not regulated and these minerals in the diet are almost completely absorbed (NRC 2001). The steers fed diets high in SCDS can adapt to the high intakes of K and Cl by increasing urinary excretion of these minerals.

In summary, SCDS feeding increased K, Cl, S, P and Mg intake of steers. SCDS feeding elevated urinary pH and urinary K and Cl concentrations and decreased the urinary Mg concentration. SCDS feeding did not affect the urinary P concentration. Our findings suggest that high SCDS feeding should not influence the risk for crystallization of urinary minerals despite the fact that SCDS contains large amounts of P and Mg. However, it is still necessary to clarify the effect of feeding SCDS throughout fattening period on the formation of uroliths of beef steers.

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REFERENCES

Albin RC, Clanton DC. 1996. Factors contributing to the variation in urinary creatinine and creatinine-nitrogen ratios in beef steers. *Journal of animal science* **25**, 107-112.

Asai H, Hayashi N, Takai N, Yoshimura Y, Nakamura Y, Yokota H, Kita K. 2005. Estimation of dairy urinary potassium excretion using urinary creatinine as an index substance in prepartum dairy cows. *Animal Science Journal* **76**, 51-54.

Bannink A., Valk A, Van Vuuren AM. 1999. Intake and excretion of sodium, potassium, and nitrogen and the effects on urine production by lactating dairy cows. *Journal of Dairy Science* **82**, 1008–1018.

Buffington CA, Rogers RQ, Morris JG. 1990. Effect of diet on struvite activity product in feline urine. *American Journal of Veterinary Research* **51**, 2025-2030.

Bushuman DH, Emerick RJ, Embby LB. 1965. Incidence of urinary calculi in sheep as affected by various dietary phosphorus. *Journal of Animal Science* **24**, 671-675.

Charbonneau E, Pellerin D, Oetzel GR. 2006. Impact of lowering dietary cation-anion difference in nonlactating dairy cows: a meta-analysis.

Journal of Dairy Science **89**, 537-548.

Charbonneau E, Chouinard PY, Tremblay GF, Allard G,Pellerin D. 2009. Timothy silage with low dietary cation-anion difference fed to nonlactating cows. *Journal of Dairy Science* **92**, 2067–2077.

Chen XB, Grubic G, Ørskov ER, Osuji P. 1992. Effects of feeding frequency on diurnal variation in plasma and urinary purine derivatives in steers. *Animal Production* 55, 185-191.

Ceconi I, Ruiz-Moreno MJ, DiLorenzo N, DiCostanzo A, Crawford GI. 2015. Effect of urea inclusion in diets containing corn dried distillers grains on feedlot cattle performance, carcass characteristics, ruminal fermentation, total tract digestibility, and purine derivatives-to-creatinine index. *Journal of Animal S*cience 93, 357–369.

Devant M, Ferret A, Gasa J, Calsamiglia S, Casals R. 2000. Effects of protein concentration and degradability on performance, ruminal fermentation, and nitrogen metabolism in rapidly growing heifers fed high concentrate diets from 100 to 230 kg body weight. *Journal of Animal Science* **78**, 1667-1676.

Ender F, Dishington IW, Helgebostad A. 1971. Calcium balance studies in dairy cows under experimental induction and prevention of hypocalcaemic paresis puerperalis. *Zeitschrift für Tierphysiologie, Tierernährung und Futtermittelkunde* **28**, 233-256.

Fontenot JP, Allen VG, Bunce BG, Goff JP. 1989. Factors influencing Magnesium absorption and metabolism in ruminants. *Journal of Animal Science* **67**, 3445-3455

Goff JP, Horst RL. 1997. Effects of the addition of potassium or sodium, but

not calcium, to prepartum rations on milk fever in dairy cows. *Journal of Dairy Science* **80**, 176-186.

Gomori G. 1942. A modification of the colorimetric phosphorus determination for use with the photoelectric colorimeter. *The Journal of Laboratory and Clinical Medicine* **27**, 955-960.

Greene LW, Fontenot JP, Webb, Jr. KE. 1983. Site of Magnesium and other macromineral absorption in steers fed high level of Potassium. *Journal of Animal Science* **57**, 503-510.

Hersom MJ, Hansen GR, Arthington JD. 2009. Effect of dietary cation-anion difference on measures of acid-base physiology and performance in beef cattle. *Journal of Animal Science* **88**, 374-382

Jones SJ, Starkey DL, Calkins CR, Crouse JD. 1990. Myofibrillar protein turnover in feed-restructed and realimented beef cattle. *Journal of Animal Science* **68**, 2707-2715.

Kamiya M, Hattori I, Tsuneishi E, Kamimura M, Hidaka A, Nagahama S, Nakamura Y, Sato K. 2010. Effects of fermented TMR containing brown rice and by-products on fattening performance,plasma metabolite concentration and enzyme activity, carcass and meat traits of Japanese Black steers during finishing period. *Nihon Chikusan Gakkaiho* **81**, 481-488. (In Japanese)

Kamiya M, Hattori I, Kamiya Y, Soto K, Hayashi Y. 2013. Effects of sweet-potate condensed distillers soluble on feed intake, feed digestibility, plasma urea nitrogen concentration, and urinary nitrogen excretion of Japanese Black steers. *Nihon Chikusan Gakkaiho* **84**, 395-401. (In Japanese)

Kamiya Y, Kamiya M, Hattori I, Sato K, Suzuki T. 2011. The effect of

fermented TMR containing condensed sweet-potato distillers soluble on mineral excretion into urine of Japanese black steers. *Journal of Warm Regional Society of Animal Science* **54**, 169-175. (In Japanese)

Kume S, Sato T, Murai I, Kitagawa M, Nonaka K, Oshita T. 2011. Relationship between urine pH and electrolyte status in cows fed forages. *Animal Science Journal* **82**, 456-460.

Lindley CE, Taysom ED, Ham WE and Schneider BH. 1953. Urinary calculi in sheep. *Journal of Animal Science* **12**, 704-714.

Mohr FR. 1856. Neue massanalytische bestimmung des chlors in verbindungen. *Justus Liebigs Annalen der Chemie* **97**, 335-338.

Munakata K, Ikeda K, Tanaka K, Suda H. 1974. Urolithiasis syndrome of beef cattle in Japan. *National Institute of Animal Health Quarterly* **14**, 17-28.

National Agriculture and Food Research Organization, NARO. 2008. *Japanese feeding standard for beef cattle*. Japan Livestock Industry Association, Tokyo.

National Reseaich Council (NRC). 2001. Nutrient Requirements of Dairy Cattle. 7th Edn. National Academy Press, Washington DC.

Ohtani F, Takusari N, Amari M, Ogasawara S, Morita S, Matsuura S, Suzuki T, Kurihara M, Higuchi K, Nonaka I. 2010. Effect of low potassium diet feeding on urine volume reduction for lactating dairy cows. *Bulletin of NARO Institute of Livestock and Grassland Science* **10**, 1-8. (In Japanese)

Ohtani F, Higushi K, Kobayashi Y, Nonaka I. 2014. The effects of dietary protein level and rumen degradability on urine volume in lactating dairy

cows. *Bulletin of NARO Institute of Livestock and Grassland Science* **14**, 23-35. (In Japanese)

Osborne CA, Polzin DJ, Abdullahi SU, Leininger JR, Clinton CW, Griffith DP. 1985. Struvite urolithiasis in animal and man: Formation, detection, and dissolution. *Advances in Veterinary Science and Comparative Medicine* **29**, 1-101.

O'Kelley RE, Fontenot JP. 1973. Effects of feeding different magnesium levels to drylot-fed gestating beef cows. *Journal of Animal Science* **35**, 994-1000.

Packett LV, Hauschild JP. 1964. Phosphorus, calcium and magnesium relationships in ovine urolithiasis. *Journal of Nutrition* **84**, 185-190.

Padilla L, Matsui T, Ikeda S, Kitagawa M, Yano H. 2007. The effect of vitamin C supplementation on plasma concentration and urinary excretion of vitamin C in cattle. *Journal of Animal Science* **85**, 3367-3370.

Robbins JD, Kunkel HO, Crookshank HR. 1965. Relationship of dietary mineral intake to urinary mineral excretion and the incidence of urinary calculi in lambs. *Journal of Animal Science* 24, 76-82.

Roche JR, Dalley D, Moate P, Grainger C, Rath M, O' Mara F. 2003. Dietary Cation-Anion Difference and the Health and Production of Pasture-Fed Dairy Cows 2. Nonlactating Periparturient Cows. *Journal of Dairy Science* **86**, 979-987.

Sanchez WK, Beede DK, Cornell JA. 1994. Interactions of sodium, potassium, and chloride on lactation, acid-base status, and mineral concentrations. *Journal of Dairy Science* 77, 1661-1675.

SAS Institute. 2004. SAS Institute, Version Release 9.2. SAS Institute Inc, Cary, NC.

Schonewille JT, Van't Klooster AT, Wouterse H, Beynen AC. 1999. Hypocalcemia induced by intravenous administration of disodium ethylenediaminotetraacetate and its effects on excretion of calcium in urine of cows fed a high chloride diet. *Journal of Dairy Science* **82**, 1317-1324.

Shimizu H, Kaneko M, Funaba M, Iriki T, Hatano Y, Abe M. 2006. Factors affecting struvite crystallization inferine urine: a comparison of urinary elements between cats and cattle. *Journal of Pet Animal Nutrition* **9**, 76-81. (In Japanese)

Suzuki T, Kamiya Y, Tanaka M, Hattori I, Nonaka I, Sato K. 2010. Effect of condensed sweet-potato distillers solubles as an additive of fermented TMR on fermentation quality and milk production by lactating cows. *Nihon Chikusan Gakkaiho* **81**, 449-456. (In Japanese)

Suzuki T, Kamiya Y, Tanaka M, Hattori I, Nonaka I, Sato K. 2011. Chemical composition and nutritional value of condensed distillers soluble derived from rice, barley and sweet-potato. *Journal of Warm Regional Society of Animal Science* **54**, 79-86. (In Japanese)

Takagi H, Block E. 1991. Effects of manipulating dietary cation-anion balance on macromineral balance in sheep. *Journal of Dairy Science* **74**, 4202-4214.

Tsuchiya R, Sato M. 1988. Incidence and Countermeasure of Urolithiasis in Fattening Cattle. *Journal of Japan Veterinary Medical Association* **41**, 36-39.

Tucker WB, Harrison GA, Hemken RW. 1988. Influence of dietary cation-anion balance on milk, blood, urine, and rumen fluid in lactating dairy cattle. *Journal of Dairy Science* **71**, 346-354.

Wholt JE, Sniffen CJ, Hoover WH, Johnson LL, Walker CK. 1976. Nitrogen

metabolism in wethers as affected by dietary protein solubility and amino acid profile. *Journal of Animal Science* **42**, 1280-1289.

Yano H, Kobayashi T, Kawashima R. 1977. Effects of high potassium intake on mineral metabolism in sheep. *Japanese Journal of Zootechnical Science* **48**, 319-324. (In Japanese)

カンショ焼酎粕濃縮液の給与が肥育牛のミネラル摂取量および尿中への
ミネラル排泄量に及ぼす影響

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配合飼料へのカンショ焼酎粕濃縮液の混合割合の異なる 4 種類の濃厚飼料（乾物ベースでの混合割合 0%，10%，20%，30%）を黒毛和種肥育牛 4 頭（試験開始時 16 ヶ月齢）に給与し，1 期 2 週間の 4×4 ラテン方格法による飼養試験を行い，ミネラル摂取量および尿中へのミネラル排泄を比較検討した．配合飼料のミネラル含量は，K が 5.6 g/kg，P が 5.0 g/kg，Mg が 1.8 g/kg であった．カンショ焼酎粕濃縮液のミネラル含量は乾物あたりで K が 63.3 g/kg，P が 9.4 g/kg，Mg が 3.9 g/kg であった．カンショ焼酎粕濃縮液の混合割合の増加に伴い，K，Cl，S，P および Mg 摂取量が増加した．カンショ焼酎粕濃縮液の給与割合の増加に伴い，尿 pH が上昇した．カンショ焼酎粕濃縮液の給与割

1 合の増加に伴い，尿中 K および Cl 濃度は増加したが，尿中 Mg 濃度は低下し
2 た．カンショ焼酎粕濃縮液の給与は，尿中 NH_3，Na，P および Ca 濃度には影
3 響を及ぼさなかった．カンショ焼酎粕濃縮液給与は，血漿中 Na，K，Cl，Ca
4 および Pi 濃度に影響を及ぼさなかった．さらに，カンショ焼酎粕濃縮液の給
5 与は，リン酸マグネシウム塩結晶の生成要因に大きな影響を及ぼさないと推測
6 された．

Table 1 The mineral contents of commercial concentrate, sweet-potate condensed distillers solubles (SCDS), rice straw, mineral block and experimental concentrate

					Experimental concentrate†			
	Commercial concentrate	SCDS	Rice straw	Mineral block	0%	10%	20%	30%
Na (g/kgDM)	0.5	0.8	0.3	315.1	0.5	0.5	0.6	0.6
K (g/kgDM)	5.6	63.3	19.9	0.0	5.6	10.6	15.6	21.0
Cl (g/kgDM)	4.7	14.9	3.1	533.3	4.6	5.5	6.4	7.4
S (g/kgDM)	1.5	3.2	0.8	2.3	1.5	1.7	1.8	2.0
P (g/kgDM)	5.0	9.4	2.1	16.4	5.0	5.4	5.7	6.1
Ca (g/kgDM)	2.9	0.2	0.7	31.4	7.5	7.0	6.5	6.4
Mg (g/kgDM)	1.8	3.9	1.0	0.9	1.8	2.0	2.2	2.4
DCAD (mEq/100gDM)††	-5.7	103.3	38.3	-146.8	-5.9	3.5	13.1	23.2

†Experimental concentrate; 0%:98.7% commecial concentrate (CC) and 1.3% calcium carbonate on a dry matter basis, 10%:90.1% CC, 8.7% SCDS and 1.2% calcium carbonate on a dry matter basis, 20%: 81.4% CC, 17.4% SCDS and 1.2% calcium carbonate on a dry matter basis, 30%:72.1% CC and 26.7% SCDS and 1.2% calcium carbonate on a dry matter basis

Na: sodium, K: potassium, Cl: chlorine, S: sulfur, P: phosphorus, Ca: calcium, Mg: magnesium

††: DCAD: Dietary cation anion difference (mEq/100gDM) =(Na+K)-(Cl+S)

Table 2 The effct of feeding sweet-potato condensed distillers solubles (SCDS) on mineral intake of experimental steers

	Diet (SCDS)					P values		
	0%	10%	20%	30%	SE	Linear	Quadratic	Cubic
Na (g/day)	6.4	8.2	8.0	8.6	1.0	NS	NS	NS
K (g/day)	57.6	102.5	136.4	177.4	9.1	**	NS	NS
Cl (g/day)	38.3	52.6	57.0	64.0	3.4	**	NS	NS
S (g/day)	10.8	13.9	14.4	15.3	0.8	**	NS	NS
P (g/day)	35.0	44.4	45.3	47.3	2.5	**	NS	NS
Ca (g/day)	50.1	56.4	50.1	47.3	2.7	NS	NS	NS
Mg (g/day)	12.9	16.7	17.3	18.4	1.0	**	NS	NS

Na: sodium, K: potassium, Cl: chlorine, S: sulfur, P: phosphorus, Ca: calcium, Mg: magnesium

**: $P<0.01$, NS: not significant.

Table 3 The effct of feeding sweet-potato distillers solubles (SCDS) on urinary creatinine, mineral excretion and pSAP of experimental steers

	Diet (SCDS)					P values		
	0%	10%	20%	30%	SE	Linear	Quadratic	Cubic
Urinary pH	7.92	8.11	8.06	8.17	0.07	*	NS	NS
Urinary concentrations								
Creatinine (mg/dl)	200.2	135.2	99.1	95.5	31.4	*	NS	NS
NH_3(mg/l)	137.4	156.6	93.3	167.0	59.6	NS	NS	NS
Na (mg/l)	126.3	531.0	793.6	542.3	298.3	NS	NS	NS
K (mg/l)	6736.1	10945.0	10147.8	10563.0	1705.0	*	*	NS
Cl (mg/l)	2213.8	3916.1	4024.1	4104.5	596.3	*	NS	NS
P (mg/l)	191.6	173.1	189.2	145.6	55.2	NS	NS	NS
Ca (mg/l)	8.9	7.9	8.6	8.9	2.4	NS	NS	NS
Mg (mg/l)	646.6	561.8	423.4	382.3	121.5	*	NS	NS
Urinary estimated excretion (Ratios of urinary NH_3 and minerals to urinary creatinine, mg:mg)								
NH_3	0.12	0.12	0.12	0.28	0.07	NS	NS	NS
Na	0.10	0.41	0.93	0.89	0.41	NS	NS	NS
K	4.3	8.4	10.3	13.9	1.5	**	NS	Ns
Cl	1.6	3.3	4.3	4.8	0.6	**	NS	NS
P	0.13	0.16	0.22	0.20	0.07	NS	NS	NS
Ca	0.005	0.006	0.010	0.015	0.004	NS	NS	NS
Mg	0.34	0.44	0.43	0.40	0.04	NS	NS	NS
pSAP†	9.5	9.4	9.5	9.5	0.2	NS	NS	NS

NH_3:ammonium, Na: sodium, K: potassium, Cl: chlorine, P: phosphorus, Ca: calcium, Mg: magnesium

*: $P<0.05$, **: $P<0.01$, NS: not significant.

†:the negative logarithm of SAP (SAP: [Mg2+]×[NH4+]×[PO43-]) according to Buffington et al. (1990)

Table 4 The effct of feeding sweet potato distillers solubles (SCDS) on plasma metabolites

	Diet (SCDS)					P values		
	0%	10%	20%	30%	SE	Linear	Quadratic	Cubic
Na (mEq/l)	139.8	138.8	138.3	141.0	1.0	NS	NS	NS
K (mEq/l)	3.8	4.0	3.9	3.9	0.1	NS	NS	NS
Cl (mEq/l)	90.5	90.8	89.5	91.3	0.9	NS	NS	NS
Pi (mg/dl)	8.3	8.6	8.6	8.4	0.3	NS	NS	NS
Ca (mg/dl)	11.1	11.1	10.8	11.0	0.2	NS	NS	NS
Mg (mg/dl)	2.4	2.7	2.7	2.5	0.1	NS	*	NS

*: $P<0.05$, NS: not significant.

Na: sodium, K: potassium, Cl: chlorine, Pi: inorganic phosphorus, Ca: calcium, Mg: magnesium