Original Article

Current Dairy Herd Management Practices and their Influence on Milk Yield and Subclinical Ketosis in an Intensive Dairy Production Region of Uganda

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Summary

Dairy production in Uganda has recently shown steady growth. Development and intensification of dairy production may bring about the issue of negative energy balance (NEB) followed by ketosis in cattle. However, the current dairy herd health and management status in the southwestern region of Uganda has not been reported. The objective of this study was to identify current herd management status in this area by describing herd management practices and production status, and by investigating relationships between feeding management practices, nutritional status, and daily milk yield of dairy cows.

Thirty farms participated in this study. Herd attributes, management practices, nutritional and production status of the cows were collected by interviews and inspections from October 2016 to March 2017. In order to estimate the total effects of feeding management on blood β -hydroxybutyrate (BHB) and milk yield, a causal diagram was created. Multivariable analyses were performed using linear mixed-effects models, setting BHB of cows within 21 days after calving and milk yield as response variables, feeding management factors as exposure variables, potential confounders as covariates, and herd as a random effect variable.

The mean herd size of adult cows on participating farms ($n = 30$) was 35.5 and average milk yield 9.8 L/cow/day. The proportion of exotic breeds was 74.5% of 506 adult cows. Supplementary concentrates and fodder were used in 40% and 70% of farms, respectively; grazing was conducted at 93.3%. The prevalence of ketosis including subclinical ketosis (SCK) for cows within 21 days after calving was 10.8% (4/37, 95% confidence interval (CI): 3.0–25.4%). From the multivariable models estimating the total effect, cows fed concentrates had higher milk yield (9.20 L/cow/day) than cows not (5.95 L/cow/day, ratio between groups: 1.55, 95% CI: 1.02–2.34, $p = 0.041$). Cows in the farm where rotational grazing was conducted had higher milk yield (5.78 L) than those in the farms where rotational grazing was not (3.46 L, ratio between groups: 1.67, 95% CI: 1.11–2.51, $p = 0.017$). No significant effect of feeding management on BHB was estimated ($p = 0.092$).

Exotic dairy cattle breeds are dominant on dairy farms in southwestern Uganda. This study revealed that exotic and cross-breed cows have the potential to produce higher milk yields, given sufficient nutrition. SCK cows were observed in this study area. Cows with high ketone concentrations require special precautions. In order to increase milk yield without nutritional disorders in Uganda where the dairy industry is fast developing, introduction of adequate feeding management is important.

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1. Introduction

Dairy production in Uganda has recently shown steady annual growth of 8%²⁾, and increased 2.7-fold from 585,374 tons in 1991 to 1,600,861 tons in 2015⁷⁾. The total population in Uganda has been increasing by 3.0% annually, and showed a 1.4-fold increase from 24.2 million in 2002 to 34.6 million in 2014²¹⁾. This population growth and the almost two-fold increase of annual per capita milk consumption from 28.5 liters in 1997 to 50 liters in 2007²⁵⁾, as well as a sharp increase of dairy exports from USD 299,032 in 2000 to USD 79,021,937 in 2017²³⁾, are pushing the dairy industry into a more important position for both food security and economy of the country.

Development of the dairy industry is determined by technical interventions: an increase in the cattle population, improved reproductive management such as introduction of exotic breeds and use of artificial insemination (AI), and feeding management. Although indigenous breeds such as Ankole and Zebu still predominate (13 million) over exotic breeds such as Friesian, Guernsey and Jersey (1 million) in Uganda as of 2016²²⁾, the southwestern region of Uganda has intensified dairy production through introduction of exotic and cross-breeds cattle²⁾. The demand for AI is high, but the proportion of farms using it is still limited (12.3%)²⁾, and the insemination rate in the region is still low²⁵⁾. A previous report in 2011 characterized the dairy industry in the region further as having a dominance of grazing farms, limited use of commercial supplement feeds, and 2–3 times higher milk yields in exotic and cross-breed cattle which are genetically improved than indigenous breeds²⁾.

From the viewpoint of milking physiology, dairy intensification involving a change of breeds and management style may increase ketotic risk in dairy herds. During the transition period around calving, from 3 weeks before to 3 weeks after, nutrition requirements for the fetus and milk production exceed energy intake, inducing a physiological state of negative energy balance (NEB)⁶⁾. The adaptation of cows to NEB can be measured as suppressed levels of non-esterified fatty acids and β -hydroxybutyrate (BHB) in the blood, and if adaptation fails, ketosis occurs, characterized by a lack of appetite and decreased milk production¹⁸⁾. Even without clear clinical signs, subclinical ketosis (SCK) may occur when cows have >1.2 to 1.4 mmol BHB/L blood^{15, 18)}, resulting in reduced milk production²⁶⁾ and economic loss¹⁵⁾. Exotic breed cattle with a higher milk yield are more susceptible to NEB than indigenous breeds, and thus require careful feeding management during the transition period. In peri-urban Kampala, Uganda, the prevalence of SCK of dairy cows in early lactation was reported as 18.8% in 2013 and 13.9% in 2014⁴⁾; however, SCK prevalence and feeding management in the southwestern region of Uganda have not been reported.

The objective of this study was to identify current herd management status in this area by describing the milk yield and nutri-

tional status (using BHB as an indicator) of dairy cattle, and dairy management practices (in particular feeding management of dairy farms in the Mbarara district, the central area of the region in terms of culture and history), and by investigating the relationships between feeding management practices, and milk production and nutritional status of dairy cows.

2. Materials and methods

2.1. Study area

This study was conducted in the Mbarara district in southwestern Uganda (Fig. 1). The average annual rainfall is 1,200 mm, with two rainy seasons from February to May and September to December; the temperature ranges between 17°C and 30°C with a humidity of 80–90%¹²⁾ at an altitude of mostly 1,000–1,400 m. This area is located in the cattle corridor¹⁰⁾. Farms participating in the study were located in 10 of the 17 sub-counties in Mbarara district, namely Biharwe, Bubaare, Bukiro, Kagongi, Kakiika, Kakoba, Kashare, Rubaya, Rubindi, and Rwanyamahembe. Mbarara district contains the high cattle population¹³⁾ and most of the improved dairy breeds²⁾ in the country. According to the District Veterinary Office in Mbarara, the total cattle population

Fig. 1 Map showing the locations and herd size of dairy farms sampled in Mbarara district, Uganda

in Mbarara district is currently estimated to be 185,680 on 10,200 dairy farms (personal communication).

2.2. Study design and farm selection

A cross-sectional study was conducted from October 2016 to November 2016, and from the middle of February 2017 to March 2017. Thirty farms belonging to the Uganda Crane Creameries Cooperative Union were selected by purposive sampling in Mbarara district, based on the following criteria: (a) herd size: 5 farms with small herds (< 10 adult cows per herd, including both milking and dry cows), 20 with medium herds (between 10 and 40 adults per herd), and 5 with large herds (> 40 adults per herd); (b) herd management type: 5 to 10 zero-grazing farms, and 20 to 25 grazing farms; (c) accessibility: farms accessible by the project team during regular visits; (d) geographic distribution of farms: 2 to 5 farms per sub-county and 5 to 6 farms per milk collection center, to facilitate diffusion of techniques; and (e) willingness to continue participation in a dairy development project funded by Japan International Cooperation Agency (JICA) for three years.

In total, 506 adult cows were involved in the study, including primiparous and multiparous cows, and heifers which would deliver within the succeeding month after the survey. All the cows were assumed to be sampled only once.

2.3. Data collection

2.3.1. Reproduction data

Reproductive data were collected at the time of farm visits when reproductive and nutritional assessments were being performed. Reproductive information including dates of last calving at the cow-level and breeding practice information (use of bulls, AI, or both) at the herd-level were collected by interviewing owners and/or workers, and the cow-level information was updated at following farm visits until December 2017. These data collections were conducted mainly on those animals that delivered within averagely 3 months prior to the visits to avoid recall bias since many of the farms did not keep written reproductive records. From the data days after calving was calculated.

2.3.2. Nutrition status

Body condition scoring (BCS)^{8,24} was performed for all the cows selected based on a factsheet provided by the UK Agriculture & Horticulture Development Board: 5-point scale, 0.25 increments¹. Training on scoring was conducted before implementation of the study in order to reduce bias among assessors. After body condition scoring of all the cows in the early lactation stage ($n = 62$ from 14 farms), blood samples were collected from coccygeal vessels using 2 mL syringes, and tested for BHB using Precision Xceed (Abbott Japan, Tokyo, Japan) pen-side test kit immediately after sampling. Ketosis was diagnosed when BHB was more than or equal to 1.2 mmol/L blood^{15,18,20}. Besides the condition of BHB above, SCK and clinical ketosis (CK) were diagnosed with the symptom of appetite and non-appetite conditions, respectively.

2.3.3. Feeding and herd management

Feeding management data were collected by interviews conducted at the time of farm visits. The practice of grazing/non-grazing and, if they applied grazing, rotational/non-rotational grazing and size of grazing area were asked. The recording sheet of the interview also included: contents and quantity (kg, as sampled basis, i.e. including water, not dry matter basis) of supplementary feed (concentrates or fodder). Average grazing area per cow was calculated from the collected data, by dividing the size of grazing area by the number of adult cows at the farm. The feeding combination pattern was classified into the following categories: a) pasture from grazing only (no supplementary feeding), b) pasture from grazing and fodder supplement, c) pasture from grazing and concentrate supplement, d) pasture from grazing and both fodder and concentrate supplement, and e) zero-grazing (i.e. supplementary concentrate and fodder but no pasture from grazing).

Other herd-level information collected by the interviews included herd size and milking time per day, and at cow-level, daily milk yield (L), parity and breed. Herd size was calculated as the number of adult cows at the farm. Breed was classified as either an exotic dairy breed, mainly Holstein Friesian, or a cross with the local Ankole breed based on the appearance, as there were no pure Ankole breed cattle on the selected farms.

2.4. Data management

All data collected from interviews, scoring, and ketone diagnostic tests were initially recorded on hand-written record sheets in English. Recording criteria for sheet contents, also written in English, were confirmed among the assessors and record keepers before the survey to avoid information bias. Data were then digitized using Excel spreadsheets (Microsoft Office 2013, USA) and imported to Access (Microsoft Office 2013) for assembly.

2.5. Statistical analysis

2.5.1. Descriptive statistics

Data collected were summarized at herd and cow levels. For numerical data, the mean, median and range were calculated, and for categorical data, the response counts and proportions. The average number of cows per herd was used for herd-level numerical data. A farm which kept at least one exotic breed cow was categorized as a farm keeping an exotic breed. Prevalence of SCK and CK were calculated for cows within 21 days after calving²⁰.

2.5.2. Causal diagram for association between feeding management, milk yield and blood β -hydroxybutyrate (BHB) concentration

A causal diagram was built to describe the relationship between feeding management, milk yield and blood BHB concentration with potential confounders (Fig. 2). Biologically, feeding management has an effect on milk yield and nutritional status of cows (blood BHB concentration in this case), and milk yield also affects the nutritional status^{6,9} because feed intake and milk production represent energy intake and output, respectively. Breed,

Fig. 2 Diagram of the relationships between feeding management, milk yield and blood β -hydroxybutyrate concentration

parity, days after calving and milking time per day were selected as potential confounders because these attributes affect milk yield and BHB, and would have an association with the feeding management^{5,9,11,17,26}.

2.5.3. Effect of feeding management on blood BHB concentration

Univariable linear mixed-effects models (LMMs) were performed selecting the BHB concentration of cows within 21 days after calving as a response variable, and feeding management factors (practice of grazing and rotational grazing, grazing area per cow, concentrate/fodder feeding and quantity) as explanatory variables. The herd, as a nominal variable, was set as a random effect. Cows with missing data were excluded from analyses. Next, in order to estimate the total effect of feeding management on BHB, a multivariable model was built using LMMs for each variable whose p -value from the univariable analyses above was <0.2 , setting the variable of interest (feed management factors) as the exposure variable with potential confounders (breed, parity, days after calving and milking time per day) as the covariates. The logarithm of BHB concentration was used for analyses because the assumption of normality did not meet on the original scale, but on the log scale.

2.5.4. Effect of feeding management on daily milk yield

Total effect of feeding management on daily milk yield per cow was analyzed using linear mixed-effects models (LMMs) setting the herd as a random effect. First, univariable models and second, multivariable models were built. A logarithm of milk yield was chosen as a response variable. The logarithm of milk yield was used for analyses because the assumption of normality did not meet on the original scale, but on the log scale. Practice of grazing and rotational grazing, grazing area per cow, conduct of concentrate/fodder feeding and that of quantity were chosen as the predictors of interest in the univariable analyses. The variables whose p -values were <0.2 from the univariable analyses were selected for the multivariable analyses by controlling the potential confounders, which were breed, parity, days after calving and

milking time per day to estimate the total effect of each exposure variable. Furthermore, to make milk yield prediction models, the multivariable model including all the variables whose p -values were <0.2 with the potential confounders above was built using LMMs. The final model was created by the stepwise backward model simplification, forcing the confounders remained in the model. All these statistical analyses were performed using the statistical software R, version 3.5.1¹⁹.

2.5.5. Power calculation

To ensure the power for multivariable analyses, calculations were performed using the “pwr” package in the statistical software R³, with a confidence level at 95%, effect size of small (0.2), medium (0.15) and large (0.35)³, and intraclass correlation coefficient of 0.1 for samples from the same herd. With these assumptions, the milk yield data analysis, including 506 cows, had 99.3% power to detect a medium effect size for a model including 5 explanatory variables, and that of blood ketone body ($n = 35$) had 56.8% power to detect a large effect size for a model with 5 explanatory variables.

2.6. Ethical consideration

This study was performed as the baseline survey of JICA Safe Milk Promotion in Mbarara Project, based on a bilateral agreement between JICA and Mbarara District Local Government. Animals in this study were properly handled using crush during sampling to avoid their stress and injury. Informed consent was obtained from all farms included in this study.

3. Results

3.1. Dairy production system

The mean herd size of farms was 35.5 cattle ($n = 30$). The means for herd average days after calving and that of milk yield were 106.8 days ($n = 26$) and 9.8 L/cow/day ($n = 30$), respectively (Table 1). The mean milk yields of cross-breed and exotic breed cattle were 7.3 (median: 7, range: 1–20) and 11.2 L/cow/day (median: 10, range: 1–32), respectively. The mean herd average blood BHB for cows within 21 days after calving ($n = 37$ from 10 farms) was 0.82 (range: 0.40–1.41) mmol/L (Table 1), and that for individual-level was 0.83 (range: 0.20–3.20) mmol/L. In Fig. 3, the blood BHB (y-axis) and days after calving (x-axis) of all cows sampled were plotted for the general understanding of a relationship between them in the study population. The prevalence of SCK and CK within 21 days in milk were 8.1% (3/37, 95% confidence interval (CI): 1.7–21.9%) and 2.7% (1/37, 95% CI: 0.1–14.2%), respectively. The blood BHB concentration of the CK cow was 3.2 mmol/L which exceeded the blood BHB concentration threshold of CK (3.0 mmol/L)^{15,18,20}. The overall proportion of exotic cows among total number of adult cows was 74.5% (377/506), and 83.3% (25/30) of farms kept at least one exotic breed cow. Use of bulls, AI, and both breeding methods were practiced in 60.0% (18/30), 33.3% (10/30) and 6.7% (2/30) of farms, respectively. Supplementary concentrate and fodder feed-

Table 1 Herd-level information of cows, farms and feeding management in the study

	Mean	Median	Range	<i>n</i>
Herd size	35.5	28.5	4.0–250.0	30
Average parity	2.7	2.8	0.7–4.5	28
Average days after calving	106.8	115.4	13.6–233.7	26
Average milk yield (L/cow/day)	9.8	9.2	1.8–23.3	30
Average BCS	3.0	3.1	2.3–3.4	22
Average blood BHB concentration (mmol/L)	0.82	0.75	0.40–1.41	10
Concentrate feeds ^{a)} (kg/cow/day)	6.6	4.0	1.0–22.0	11
Fodder ^{b)} (kg/cow/day)	11.2	11	1.0–36.0	12
Grazing intensity (ha/cow/day)	2.8	1.6	0.2–11.9	26

BCS: body condition score, BHB: β -hydroxybutyrate, *n*: number of observations

^{a)} Concentrate feeds: brewers waste, maize bran, formula feed, barley, sunflower meal. The weights of feedings are as sampled basis.

^{b)} Fodder: fresh grass, corn silage, grass silage, haylage, hay, banana peel. The weights of feedings are as sampled basis.

Fig. 3 Blood β -hydroxybutyrate (BHB) concentration of dairy cows in early lactation stage in Mbarara, southwestern Uganda. All the cows in the early lactation stage during the study period were tested for BHB ($n = 62$ from 14 farms). Dashed-lines indicate the BHB threshold for subclinical (1.2 mmol/L) and clinical ketosis (3.0 mmol/L). Darker plots indicate multiple data points. The prevalence of SCK and CK within 21 days (dotted-line) after calving were 8.1% (3/37, 95% confidence interval (CI): 1.7–21.9%) and 2.7% (1/37, 95% CI: 0.1–14.2%), respectively.

ing were used in 40% (12/30) and 70% (21/30) of farms, respectively. Brewers waste (30%, 9/30 farms), maize bran (13.3%, 4/30), formula feed (13.3%, 4/30), barley (3.3%, 1/30), and sunflower meal (3.3%, 1/30) were fed in the farms studied and categorized as concentrates. Fresh grass [Napier (*Pennisetum purpureum*), sorghum (*Sorghum bicolor*), Rhodes grass (*Chloris gayana*),

lablab (*Dolichos lablab*), 40%, 12/30], corn silage (20%, 6/30), grass silage (10%, 3/30), haylage (16.7%, 5/30), hay (10%, 3/30), and banana peels (10%, 3/30) were fed and classified as fodder. Grazing was conducted at 93.3% of farms (28/30), and 56.7% (17/30) used rotational grazing. The mean grazing area was 2.8 ha/cow/day ($n = 26$, Table 1). Feeding combination patterns were: grazing only (26.7%, 8/30), fodder (cut and carry) and grazing (33.3%, 10/30), concentrates and grazing (3.3%, 1/30), concentrates, fodder and grazing (30%, 9/30), and zero-grazing (6.7%, 2/30).

3.2. Effect of supplementary concentrates and fodder, their combination, and rotational grazing on the milk yield

From the univariable analysis, variables with p -value < 0.2 were: feeding concentrates ($p = 0.006$) and its quantity ($p = 0.050$), feeding fodder ($p = 0.090$) and its quantity ($p = 0.124$), feeding combination ($p = 0.009$), and conduct of rotational grazing ($p = 0.118$). The six multivariable models were built for the variables above by controlling potential confounders, and results are shown in Table 2. Cows fed supplementary concentrates had higher milk yield (9.20 L/cow/day) than those which were not (5.95 L/cow/day, difference in log: 0.44, 95% CI: 0.02–0.85, ratio between groups in original scale (L/cow/day): 1.55, 95% CI: 1.02–2.34, $p = 0.041$, Model 1 in Table 2). Cows on farms where rotational grazing was conducted had higher milk yield (5.78 L) than those in the farms where rotational grazing was not practiced (3.46 L, difference in log: 0.51, 95% CI: 0.10–0.92, ratio between groups in original scale (L/cow/day): 1.67, 95% CI: 1.11–2.51, $p = 0.017$, Model 5 in Table 2). The feeding combination did not have a statistically significant effect on milk yield, but it showed a trend that the combination pattern (feeding pasture from grazing, supplementary fodder and concentrates) had a positive impact on milk yield compared to feeding pasture only (difference in log:

Table 2 Multivariable analysis results on daily milk yield, adjusting potential confounders as covariates

Variable	Estimate in log	95% CI	p-value
<i>Model 1</i>			
Feeding concentrates ^{a)}	0.44	0.02–0.85	0.041
Breed ^{b)}	0.08	–0.13–0.29	0.457
Parity	0.01	–0.01–0.04	0.284
Days after calving	–0.00	–0.00–0.00	<0.001
Milking time/day	0.12	–0.37–0.61	0.618
<i>Model 2</i>			
Concentrates quantity	0.04	–0.01–0.09	0.092
Breed ^{b)}	0.08	–0.14–0.30	0.469
Parity	0.01	–0.01–0.04	0.296
Days after calving	–0.00	–0.00–0.00	<0.001
Milking time/day	0.12	–0.40–0.65	0.634
<i>Model 3</i>			
Feeding fodder ^{c)}	0.33	–0.16–0.82	0.181
Breed ^{b)}	0.06	–0.15–0.27	0.554
Parity	0.01	–0.01–0.04	0.287
Days after calving	–0.00	–0.00–0.00	<0.001
Milking time/day	0.10	–0.44–0.65	0.696
<i>Model 4</i>			
Fodder quantity	0.04	–0.01–0.09	0.137
Breed ^{b)}	–0.16	–0.45–0.13	0.280
Parity	0.03	0.00–0.06	0.096
Days after calving	–0.00	–0.00–0.00	<0.001
Milking time/day	–0.10	–0.77–0.57	0.754
<i>Model 5</i>			
Rotation ^{d)}	0.51	0.10–0.92	0.017
Breed ^{b)}	0.08	–0.12–0.29	0.428
Parity	0.02	–0.01–0.04	0.245
Days after calving	–0.00	–0.00–0.00	<0.001
Milking time/day	0.33	–0.14–0.80	0.157
<i>Model 6</i>			
Feeding combination			
a) Pasture only	Reference		
b) Pasture & fodder	0.19	–0.41–0.80	0.513
c) Pasture & concentrates	0.34	–0.80–1.47	0.539
d) Pasture, fodder & concentrates	0.60	–0.01–1.21	0.055
e) Zero-grazing	0.50	–0.63–1.63	0.363
Breed ^{b)}	0.06	–0.15–0.28	0.555
Parity	0.01	–0.01–0.04	0.285
Days after calving	–0.00	–0.00–0.00	<0.001
Milking time/day	0.06	–0.52–0.64	0.826
<i>Final model</i>			
Rotation ^{d)}	0.51	0.10–0.92	0.017
Breed ^{b)}	0.08	–0.12–0.29	0.428
Parity	0.02	–0.01–0.04	0.245
Days after calving	–0.00	–0.00–0.00	<0.001
Milking time/day	0.33	–0.14–0.80	0.157

CI: confidence interval

^{a)} Feeding concentrates: feeding or not (not feeding as reference); ^{b)} Breed: exotic or cross breed (cross breed as reference); ^{c)} Feeding fodder: feeding fodder supplementary or not (not feeding as reference); ^{d)} Rotation: practicing rotational grazing or not (not practicing as reference)

0.60, 95% CI: -0.01 – 1.21 , $p = 0.055$, Model 6 in Table 2). The rotational grazing remained in the final model, the same model as Model 5 in Table 2.

3.3. Effect of supplementary concentrate feeding on BHB

From the univariable analysis, variables with p -value < 0.2 were: feeding concentrates ($p = 0.031$) and its quantity ($p = 0.010$), feeding combination ($p = 0.049$), and conduct of rotational grazing ($p = 0.032$). In the multivariable analysis, however, no significant effect of supplementary concentrates on BHB was observed: feeding concentrates (difference in log: 0.56 , 95% CI: -0.14 – 1.26 , $p = 0.092$) and its quantity (difference in log: 0.19 , 95% CI: -0.04 – 0.42 , $p = 0.082$), feeding combination (difference in log: 0.61 , 95% CI: -1.99 – 3.21 , $p = 0.419$), and conduct of rotational grazing (difference in log: 0.59 , 95% CI: -0.59 – 1.77 , $p = 0.237$).

4. Discussion

Previous studies reported that the mean herd size of the dairy farms in western Uganda in 2008 was 8.9 cattle^{2,13}). Due to the recent high demand of dairy products, the cattle population has been increasing dramatically, and according to the Mbarara District Veterinary Officer (personal communication), the current mean herd size in Mbarara district is 18.2 cattle, which is about twice larger than that of the western region in 2008. Cattle breeds were also dramatically changed and local Ankole breed is predominantly used for beef production (personal communication with dairy farmers). The exotic-breed cows and their crosses were dominant in the dairy herds. Characteristics of the cattle population including herd size and cattle breed might be a result of the milk demand that has caused an increase in milk production in recent years. However, it should be noted that because of the purposive sampling, the mean herd size of the study population was probably higher than the target population and the proportion of exotic and/or cross-breed cattle might be overestimated, as motivated farmers were invited to the project.

The adaption rate of AI in this study (40% of the farms sampled) was higher than in previous reports (12.3% in southwestern Uganda²) and 25.1% in Rwanda¹¹), though the majority of farms in Mbarara still use a bull for breeding. This suggested a potential of rapid improvement of breeds to increase milk yield in Uganda. On the other hand, although the majority of farmers considered that introducing a new breed was crucial to improve milk production, their major concern with new breeds was sensitivity to the local environment and diseases¹⁶). A study of a decade ago reported the insufficiency of AI service to meet the demand of dairy farmers and limited insemination rate in the southwestern region²⁵). However, such a high adaption rate of AI observed in this study might suggest a rapid improvement of AI service delivery infrastructure in Mbarara district.

More than 70% of farms in the study fed their cows not only natural pastures from grazing, but also supplementary fodder and/

or concentrates. Our findings show that cows fed concentrates had higher milk yield than those that were not. Also, the trend shown in the results suggests the importance of feeding a combination of supplementary concentrates and fodder together with pasture from grazing to increase the milk production. Diets should be properly balanced for energy, protein, fiber and minerals, and taking fiber with concentrates is important to digest matter and intake energy properly¹⁴). Otherwise, lack of rumination, loose manure formation and low milk fat composition occur, and consequently milk yield will not increase adequately. To increase milk production in the current situation in Mbarara, feeding balanced supplementary materials to suffice nutritional requirements of the cows is essential. Besides, supplementary feeding is also important in terms of meeting feeding shortages during the dry seasons. Due to the shortage of natural pasture, milk production decreases and milk price increases during the dry seasons²). To cover this shortage, pasture harvesting and storage techniques should be expanded. Applying a rotational grazing system, which increases the feed intake efficiency and saves the pasture resource, had a positive impact on milk yield in this study. The majority (88.2%, 15/17) of farms who used rotational grazing had no rule for the rotation but mainly rotated depending on the grass availability. Applying well-managed rotational grazing techniques should have much better potential for milk production, and detailed technical information about pasture management should be extended to local farmers. Further studies are required to assess the effect of the rotation method, and also to find adequate/reasonable practices that can be applied in the current situation in Uganda.

Cows fed with concentrates had higher milk yield than those which never fed concentrates. The blood BHB concentration was not significantly different between cows fed with concentrates and those not fed. These facts might suggest that the current feeding strategy in Mbarara had a potential to increase milk production, and at the same time the cows' energy balance were stable with the management. This is reasonable because in a biological sense, an adequate feeding management which enhances nutrient intake can contribute to the milk production and nutritional status of cows^{9,18}). However, this study also revealed that SCK and CK cows were observed with the prevalence of 8.1% and 2.7%, respectively. Moreover, although the effect of feeding supplementary concentrates on BHB was not statistically significant, it showed the trend that feeding concentrates had a positive association with blood BHB concentration ($p = 0.092$) indicating that the feeding management tends not to suffice NEB. It is highly possible that the number of SCK/CK cows would be increased in near future since the herd management in Mbarara had been changing into more intensive due to high milk production demands. For those SCK/CK cows, special care such as close observation of their appetite and propylene glycol administration for cows with poor appetite in early lactation is needed in order

not to lose production. It should be noted that the blood BHB concentration may be biased because the time to blood sampling after feeding was not fixed among farms in this study. Also, dry matter intake of each feeding should be considered to estimate the effect of feedings precisely, and these factors are limitations of this study. Proper herd management will help dairy farmers in Mbarara to prevent and control CK/SCK cases and improve milk yield at farm level as the proportion of exotic-breed cows is likely to continue growing. To increase milk production and to overcome the NEB status of cows in the dairy production area in Uganda, knowledge of proper herd management practices should be extended to the farmers.

From the final prediction models, rotational grazing and days after calving were identified as statistically significant predictors for milk yield. The other factors among the confounders were not significant. Although they should be controlled in models that estimate causal effects to secure generalizability, the fact seen in our data (i.e. some confounders were not significant predictors) did not completely meet a priori knowledge. This might be due to the limited sample size and/or information bias.

In conclusion, exotic dairy cattle breeds were dominant and quite a few cross-breeds are present in dairy farms in southwestern Uganda. The present study revealed that exotic and cross-breed cows have the potential to produce more milk, given sufficient supplementary feeding, recommended as concentrates together with fodder. SCK/CK cows were observed in this study area. Cows with high ketone concentrations require special precautions. In order to increase milk yield without nutritional disorders, training of dairy farmers about adequate feeding management practices is important in Uganda where the dairy industry is fast developing.

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原 著

ウガンダの集約酪農地域における牛群管理方法の現状と 牛群管理が産乳量・潜在性ケトーシスへ及ぼす影響

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要旨

近年ウガンダの酪農業は集約化が進み、牛群管理と乳牛の栄養状態への影響が懸念されるが、ウガンダ南西部の牛群管理の現況は報告されていない。本横断研究は、牛群の飼養管理状況を記述し、飼料給与と乳量・血中ケトン体濃度の関係を調査することにより、この地域における飼養方法の現状を把握し今後の発展のための方向性を見いだすことを目的に実施した。

2016 年 10 月から 2017 年 3 月に 30 農場の 506 成乳牛を対象に聞き取り調査を実施した。飼料給与が乳量と血中 β -hydroxybutyrate 濃度 (BHB) へ及ぼす効果を推定するため原因図式により交絡因子を選択し、混合効果モデルを用いた多変数解析を実施した。

平均牛群規模は 35.5 頭、平均乳量は 9.8 L、外来種は 74.5% を占めた。濃厚飼料は 40%、粗飼料は 70% の農場で給与され、放牧は 93.3% の農場で実施されていた。分

娩後 21 日以内の牛のケトーシス (潜在性ケトーシス (SCK) を含む) の有病率は 10.8% (4/37, 95% 信頼区間: 3.0-25.4 %) であった。濃厚飼料を給与した牛の乳量 (9.20 L) は非給与牛 (5.95 L, $p=0.041$) より高かった。全対象牛のうち輪換放牧を実施していた牛の乳量 (5.78 L) は輪換放牧を実施していなかった牛 (3.46 L, $p=0.017$) より高かった。飼料給与は BHB に有意な影響を与えなかった ($p=0.092$)。

ウガンダ南西部では外来種が多く導入されており、適切に栄養管理をすることで高い産乳性を期待できることが示された。

キーワード : ウガンダ, 産乳量, 飼料給与管理, 潜在性ケトーシス, 乳用牛

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