Estimation of breeding value for milk yield from the first and second dimensions of metabolites change in young calves exposed to 1 day of fasting

O. Sasaki[1], N. Yamamoto[1], K. Togashi[1] and M. Minezawa[2]

[1]Hokkaido National Agricultural Experiment Station, Sapporo, Japan 062
[2]National Institute of Animal Industry, Ibaraki-ken, Japan 305

SUMMARY

The rate of improvement of milk production increases, if the characters related milk production can measure in calves and young bulls. Many reports assumed that the relationship between physiological characters related with energy metabolism and genetic ability for milk production is linear. In this study, two traits and quadratic covariance analysis was employed to investigate the relationship between the genetic ability for milk production and metabolites change during 1 day of fasting in young calves. Four different types of covariates were used; first dimension of one metabolite (Method 1), first and second dimensions of one metabolite (Method 2), first dimensions of two metabolites (Method 3), first and second dimensions of two metabolites (Method 4). Contribution ratio of regression (R^2) in Method 4 among all the four methods ($p<0.01$) and highest during 36 hours of fasting among the other length of fasting ($p<0.01$). Especially, Method 4 at 36 hours of fasting gave high (0.70, 0.64 and 0.61) R^2 values in TG and NEFA, TG and Ket and Glu and NEFA, respectively. Therefore, the first and second dimensions of two metabolite change during 36 hours of fasting at early growing stage of calves can give estimation of future breeding value for milk yield. Environmental factors should be considered since the environmental group effects in the changes of concentrations of Glu, TG and Ket during fasting were significant ($p<0.01$).

Key words: dairy cattle, genetics, covariance analysis, physiology, metabolites

INTRODUCTION

The exact estimate of genetic ability of cow requires many milking data of her own and her relatives. The improvement of milk production by genetic selection is based on the expression of the trait in mature females only (Sinnett-Smith *et al.* 1987). The rate of improvement of milk production increases, if the characters related milk production can measure in calves and young bulls (Sejrsen *et al.* 1984). The genetic variations of energy metabolism should partly be to a cause of variance of milk production. The genetic ability for milk production may be estimated by measuring the concentrations of metabolites related with energy metabolism (Hart *et al.* 1978). The increase of concentration of non-esterified fatty acid (NEFA) during fasting positively correlated with breeding value for milk fat production (Sejrsen *et al.* 1984; Robinson *et al.* 1992). The increase of concentration of urea nitrogen (UN) during fasting negatively correlated to breeding value for milk yield (Tilakaratne *et al.* 1980; Sejrsen *et al.* 1984; Sinnett-Smith *et al.* 1987). These studies on relationships between physiological characters related with energy metabolism and genetic potential for milk

production have been carried out under the assumption that the relationship between two characters is linear. Apart from water, substrates required by the mammary gland for milk synthesis are glucose (Glu), amino acids, acetate, 3-hydroxybutyrate and long-chain fatty acids (Bines and Hart, 1982). Concentration of ketone increases with decreasing concentration of Glu. Change of concentration in Glu causes change of concentration of other metabolites (Dale *et al.* 1979). These studies indicated that changes of concentrations in metabolites influence with each other. Sasaki *et al.* (1997) have indicated quadratic relation between concentrations of metabolite and breeding value for milk yield using calves at 5 month of age. In this study, similar experiment was conducted using much younger calves at around 1 month of age for implementation of early stage of selection.

MATHERIALS AND METHODS

Experiment 1. 8 females and 4 males Holstein calves (60.5±6.8 kg) at 42.2±6.3 day of age were fasted for 1 day. They were fed twice daily (09.00 and 16.00 h) with 2.5 kg milk and 0.3 kg calfstarter with hay provided *ad libitum* in first day. The food was withdrawn at 09.00 h in second day and fasted until 09.00 h in third day. Blood samples were taken at 2 hours intervals from 09.00 h in first day to 09.00 h in third day.

Experiment 2. 15 females and 10 males Holstein calves (63.3±7.7 kg) at 40.4±4.2 day of age were fasted for 1 day. These were treated with the same method as experiment 1. Blood samples were taken at 30 minutes intervals from 07.00 to 09.00 h in first, second and third day and from 19.00 to 21.00 h in first and second day.

Analytical method. After sampling, the blood was centrifuged, and plasma was stored at –20 °C until analysis. The plasma samples were analyzed for Glu, triglyceride (TG), NEFA and UN by enzymatic methods using commercially availables from Kinos and for total ketone (Ket) by enzymatic method using commercially available from Nittobo.

Covariance analysis. A total of 37 calves were divided into four environmental groups; 11 calves were fed outside of cowshed and fasted between April to June (Environment 1), 9 calves were fed inside of cowshed and fasted between April to June (Environment 2), 6 calves were fed outside of cowshed and fasted between July to September (Environment 3), 11 calves were fed inside of cowshed and fasted between April to June (Environment 4). However, the calves of experiment 2 were divided into three environmental groups, so the calves of experiment 2 did not include the calves under Environment 2. Relationships between breeding value for milk yield and the changes of concentrations of metabolites in reaction to 1 day of fasting were investigated by covariance analysis using four different types of covariates; first dimension of one metabolite (Method 1), first and second dimensions of one metabolite (Method 2), first dimensions of two metabolites (Method 3), first and second dimensions of two metabolites (Method 4). Covariance analysis was conducted treating dependent variable, independent variable and classification effects as breeding value for milk yield, concentrations of metabolites of each environmental group and environmental group effect, respectively. General linear model procedure of Statistical Analysis Systems (1985) was used for covariance analysis. The means of concentrations of metabolites from 19.00 to 21.00 h in first day (0 h

fast), from 7.00 to 9.00 h in second day (12 h fast), from 19.00 to 21.00 h in second day (24 h fast) and from 7.00 to 9.00 of third day (36 h fast) were obtained. The changes of concentrations of metabolites from 1 h to 12, 24 and 36 hours of fasting were used for covariance analysis.

Estimation of breeding value. Milk yield records of length 240 to 305 days were collected from January 1, 1983 to April 30, 1997 in Hokkaido National Agricultural Experiment Station. The data of milk yield over 240 days were expanded to 305 data (Wood 1976). A total of 495 data of 216 head were used. The statistical model for estimate of breeding value for milk yield used the following model (Sasaki *et al.* 1993):

$$X_{ijkl}=Y_i+S_j+A_k+P_l+e_{ijkl}$$

Where X_{ijkl} is an observation on the k th animal in the ijl th subclass; Y_i is the effect of calving month i; S_j is the effect of calving season j; A_k is additive genetic effect of animal k; P_l is permanent environmental effect of cow l and e_{ijkl} is random residual associated with each record. The additive genetic variance is 720,878, permanent environment variance is 59,205 and error variance is 749,648 (Sasaki *et al.* 1993).

RESULT AND DISCUSSION

Many reports showed that concentration of Glu decreased (Emmanuel and Kennelly 1984; Rule *et al.* 1985; Trenkle 1976) and concentration of TG (DiMacro and Beitz 1981; Rule *et al.* 1985), NEFA (Pothoven and Beitz 1975; DiMacro and Beitz 1981; Emmanuel and Kennelly 1984; Rule *et al.* 1985), Ket (Emmanuel and Kennelly 1984; Rule *et al.* 1985) and UN (Rule *et al.* 1985) increased during fasting. In our study showed the same result. The concentration of NEFA in genetically high dairy merit calves during 44 hours of fasting was higher than in genetically low counterparts (Tilakaratne *et al.* 1980). Sejrsen *et al.* (1984) and Robinson *et al.* (1992) showed the same result. The concentration of UN in genetically low dairy merit calves during 44 hours of fasting was higher than in genetically high counterparts (Tilakaratne *et al.* 1980). Woolliams and Smith (1988) showed that the genetic correlations between the increase of concentration of UN during fast and breeding value for milk yield was –0.47 at 3.5 month of age, -0.26 during 3 to 5 month of age and –0.13 at 7 month of age from result of Tilakaratne *et al.* (1980), Sejrsen *et al.* (1984) and Sinnett-Smith *et al.* (1987). These reports assumed that the relationship between physiological characters related with energy metabolism and genetic potential for milk production is linear. The concentrations of metabolites had not close linear relation to breeding value. The rate of change of concentration of TG at 36 h fast had tight relation (R^2=0.32) among all the five metabolites by Method 1. Bines and Hart (1982) showed that substrates required by the mammary gland for milk synthesis are Glu, amino acids, acetate, 3-hydroxybutyrate and long-chain fatty acid. Increase of concentration of ketone during lactating period is responsible for decrease of concentration of Glu. The peak of concentration of ketone followed the peak of NEFA (Deal *et al.* 1979). In our study showed the same result. These studies indicated those change of metabolites influence each other. Contribution ratio of regression (R^2) were different among the methods ($p<0.01$) and these were different among the length of fasting ($p<0.01$). Method 4 showed the highest R^2 among the all four methods ($p<0.01$). R^2 was highest at 36 h fast among the all the length of

fasting time ($p<0.01$) (Table 1). Especially, Method 4 at 36 h fast gave high (0.70, 0.64 and 0.61) R^2 values in TG and NEFA, TG and Ket and Glu and NEFA, respectively. Therefore, the first and second dimensions of two metabolite change during 1 day fasting at early growing stage of calves can give estimation of future breeding value for milk yield. Environmental factors should be considered since the environmental group effects in the change of concentrations of Glu, TG and Ket during fasting were significant ($p<0.01$).

Table 1. Means of contribution ratio of regression (R^2) from four different types of covariates; first dimension of one metabolite (Method 1), first and second dimensions of one metabolite (Method 2), first dimensions of two metabolites (Method 3), first and second dimensions of two metabolites (Method 4)

	Method 1		Method 2		Method 3		Method 4	
	R^2	s.e.	R^2	s.e.	R^2	s.e.	R^2	s.e.
12 hours of fasting	0.15^{a}	0.03	0.26^{b}	0.03	0.25^{b}	0.02	0.48^{c}	0.02
24 hours of fasting	0.16^{a}	0.03	0.24^{ab}	0.03	0.26^{b}	0.02	0.45^{c}	0.02
36 hours of fasing	0.18^{a}	0.03	0.34^{b}	0.03	0.29^{b}	0.02	0.58^{c}	0.02

^{abc}: Values with different superscripts are significantly different among the methods within each fasting time ($p<0.05$).

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