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Effects of feeding whey protein on growth rate and mucosal IgA induction in Japanese Black calves

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ABSTRACT

Data from 63 Japanese Black calves were collected to clarify the effects of feeding whey protein on the growth rate and mucosal IgA induction in calves. Dietary treatments in milk replacers were 1) 26% CP as in skim milk (control), 2) 26% CP as whey and skim milk and 3) 26% CP as whey. Diets were offered from 3 to 63 days of age in calves. Feeding whey protein had no effects on growth rate, fecal consistency and fecal water in calves. Compared with 2 days of age, fecal IgA concentration in calves decreased at 14 days of age, while fecal water increased. Feeding whey protein increased fecal IgA in calves after 14 days of age, which was thought to be the increased mucosal IgA induction in the gut. Serum cholesterol concentration tended to be lower in calves fed whey than in control group, but feeding whey protein had no clear effects on serum glucose, NEFA, total protein and urea-N concentrations. These results suggest that feeding whey protein enhances mucosal IgA induction in calves, but feeding whey protein has little effect on growth rate and fecal consistency in calves.

1. Introduction

Whey protein concentrate has an adequate amino acid profile than that in dried skim milk and casein, and higher proportion of whey protein concentrate in milk replacers improved calf performance when only milk replacer was fed (Lammers et al., 1998). The absorbed and retained N in dairy calves fed 16.1, 18.5, 22.9 and 25.8% of CP from whey protein sources increased linearly as dietary CP increased (Blome et al., 2003). In the previous study (Nishiyama et al., 2011b), daily gains of calves fed whey protein or skim milk at 26% CP were very similar, because the appropriate supply of CP in the diets maintained normal growth rate of calves.

Mortality and morbidity of neonates continue to be major problems in calves, and their most common disease is diarrhea, which can cause growth retardation and death of calves. Successful neonatal health depends on many factors related to management and nutrition, but the improvement of the immune system is required for preventing diarrhea. Whey protein concentrate contains antiviral and immunomodulatory components, and supplemental whey protein concentrate reduces rotavirus-induced disease symptoms in suckling mice (Wolber et al., 2005) and enhances mucosal innate immunity during early life in suckling rats (Perez-Cano et al., 2007).

Passive immunity is critical to the survival and health of neonates, and colostrum or milk is a source of nutrients and immune components for neonatal calves (Blum, 2006). IgA is the most abundant Ig isotype in mucosal secretions and

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provides protection against microbial antigens at mucosal surfaces (Fagarasan and Honjo, 2003; Mora and von Andrian, 2009). Most IgA antibody secreting cells (ASC) express chemokine receptor CCR10, but IgA ASC from CCR10-deficient mice do not efficiently accumulate in the lactating mammary gland and lead to a significant decrease in milk IgA and fecal IgA of neonatal mice (Morteau et al., 2008). Additionally, the mucosal immune induction is also needed in neonatal calves, because the disease resistance acquired from colostrum Ig is only temporary (Quigley and Drewry, 1998). In the previous studies (Nishiyama et al., 2011a, 2011b), supplemental β-carotene with whey to maternal mice during pregnancy and lactation is useful to increase IgA transfer from maternal milk to neonatal mice, while supplemental β-carotene with whey may have little effect on mucosal IgA induction in neonatal mice and calves. However, supplemental whey protein has been expected to enhance mucosal IgA induction in neonatal calves owing to the high level of fecal IgA at 14 days of age (Nishiyama et al., 2011b).

The objective of this study was to clarify the effects of feeding whey protein on daily gains, fecal consistency and levels of fecal IgA in Japanese Black calves in order to evaluate the role of whey protein on the growth rate and mucosal IgA induction in calves.

2. Materials and methods

2.1. Experimental design

This research was approved by the guide for the care and use of animal in Shiga Prefectural Livestock Technology Promotion Center (Hino, Japan), Northern Center of Agricultural Technology (Asago, Japan), Nara Prefectural Livestock Technology Center (Mitsue, Japan) and the Livestock Technology Center Department of The Kyoto Prefectural Agriculture, Forestry & Fisheries Technology Center (Ayabe, Japan). Sixty three Japanese Black calves born in their centers were used, and calves consisted of 43 males and 20 females.

Dietary treatments in milk replacers were 1) commercial milk replacer which contained 26% CP as in skim milk (control group, 14 males and 7 females), 2) experimental milk replacer which contained 26% CP as whey and skim milk (whey plus skim milk group, 14 males and 7 females) and 3) experimental milk replacer which contained 26% CP as whey (whey group, 15 males and 6 females). These milk replacers were provided by Chubu Shiryo Co. Ltd (Ohbu, Japan), and dietary ratio of protein source and chemical composition in milk replacers are shown in Table 1.

Table 1
Dietary ratio of protein source and chemical composition in milk replacers for control, whey plus skim milk (WS) and whey groups in calves.

	Control	WS	Whey
Ingredient (%)			
Skim milk	66.3	28.5	0
Dried whey	3.1	2.8	17.5
Whey protein concentrate	7.4	45.0	56.5
Soybean protein concentrate	2.0	2.0	0
Composition (as-fed basis)			
CP,%	26.3	26.4	26.1
Crude fat,%	17.2	17.3	17.3

Calves lived with their dams after birth and received only their dam's colostrum, but colostrum IgA was not determined. At 3 days of age, calves were separated from their dams and housed in individual pens. From 3 to 63 days of age, calves received appropriate amounts of milk replacers and calf starter pellets to meet recommendations (Agriculture, Forestry, and Fisheries Research Council Secretariat, 2000) for TDN, protein and minerals of calves. The amounts of milk replacers offered to calves were increased from 0.5 to 0.9 kg/d during 3 to 15 days of age, maintained at 1.0 to 1.3 kg/d (Mean ± SD, 1.05 ± 0.05 kg/d) during 16 to 50 days of age and decreased by 0.25 kg/d during 51 to 63 days of age. Milk replacers were diluted with warm water at 40 °C and offered twice a day throughout the experiment. Calf starter pellets (TDN, 75%; CP, 20%) were offered from 7 days of age, and the amounts of calf starter were gradually increased by 63 days of age, according to the pellet refusals of calves. Intake of milk replacers and calf starter pellets were measured every day, and their data were averaged by each week. Additionally, the calves were given free access to timothy hay from 20 days of age.

2.2. Sample collection and analyses of serum components and fecal IgA

Body weights of calves were measured on day 0, 7, 14, 21, 28, 42, 56 and 63 after birth. Fecal consistency of calves was observed every day throughout the experiment. Fecal scores were measured on a scale of 1 to 3 (1 = firm, normal; 2 = soft, 3 = watery), and their data were averaged by each week. Blood and fecal grab samples were collected at 13:00 h on day 2, 14, 28, 42 and 56 after birth. Blood was sampled by a jugular vein puncture into vacuum tubes, left to stand at room temperature for 1 h and centrifuged at 3000 × g for 15 min. Serum glucose, total protein, nonesterified fatty acid (NEFA), triglyceride, urea N and cholesterol were determined by an Automatic analyzer (7600, Hitachi, Tokyo, Japan). Fecal water and fecal IgA were determined as previously described (Nishiyama et al., 2011b).

2.3. Statistics

Data of body weight, daily gain, feed intake, fecal score and components of serum and feces were analyzed by least squares ANOVA using the general linear model procedure of SAS (1997). The model was as follows;

$$Yijk = u + D_i + E_j + C_{(ij)k} + T_l + DT_{il} + e_{ijkl}$$

where u is the overall mean, D_i is the effect of diet, E_j is the effect of the experimental center, $C_{(ij)k}$ is the random variable of calves nested in diet and experimental center, T_l is the effect of time, DT_{il} is the interactions, and e_{ijkl} is the residuals. Data obtained from serum and feces at 14, 28, 42 and 56 days of age were used for this model. In addition, the general linear model procedure of SAS (1997) was used to analyze the effect of time on fecal content and fecal IgA at 2, 14, 28, 42 and 56 days of age.

An ANOVA was performed, and the differences were tested by Tukey–Kramer's multiple comparisons. Significance was declared at $P<0.05$.