Regulation of Periparturient Milk Composition in Jersey Cattle

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Summary

The composition of milk from dairy cows varies more in the colostral period than in other periods of lactation. The objective of this study was to determine which factors influence milk composition of Jersey cows during the colostral period. Composite milk samples were collected from 21 lactating Jersey cows of the Iowa State University Teaching Herd between February and July at 0, 12, 24, 30, 38, 46, 54, 62, 80, and 88 hours postpartum. The milk samples were analyzed for total fat, lactose, and protein content by infrared spectroscopy, for total protein nitrogen, non-casein nitrogen, and non-protein nitrogen content by Kjeldahl analyses, and for α_{S1}–casein, β-casein, κ-casein, α_{S2}-casein, α-lactalbumin, and β–lactoglobulin concentrations by reversed-phase HPLC. Milk composition changed during the first 4 days after parturition and was influenced by calving season, length of gestation, and parity; and all had significant interactions with time postpartum (all $P < 0.01$). Colostrum matured to normal milk in the first two days after parturition. The maturation of colostrum was associated with an increase in lactose content and a decrease in protein content, in particular of whey proteins other than α–lactalbumin. The colostrum of cows that calved between February and April had a lower lactose and a greater protein content, in particular of whey proteins other than α–lactalbumin and β–lactoglobulin, than did colostrum of cows that calved in May and June. The colostrum of multiparous cows was higher in protein content than was the colostrum of heifers because of higher concentrations of whey proteins. During the colostral period, milk of cows that calved before the predicted calving date had greater protein concentrations than did milk from cows that calved at or after the predicted calving date, which was the result of higher concentrations of whey proteins other than α–lactalbumin and β–lactoglobulin. We conclude that time postpartum, calving season, length of gestation, and parity affect the composition of milk in the early secretory period in lactating Jersey cows.

Introduction

Altering the milk composition is challenging because the secretion of milk constituents is tightly and concomitantly regulated by hormones. The concomitant control leads to strong positive correlations between the main milk constituents of triacylglycerol, lactose, and individual milk proteins. During the peripartal period, rapid hormonal changes occur, which result in larger variability of milk composition than in other periods of the lactation.

The mammary gland secretes colostrum around parturition, which provides the only source for nutrients and immunity in the neonatal calf. Colostrum contains low concentrations of lactose and high concentrations of proteins, in particular immunoglobulins, which are either actively synthesized by the mammary gland or reach the milk space by transcytosis and passive diffusion. Immunoglobulins are absorbed in the intestine of the calf and are the primary immune defense of the calf. The other proteins are degraded in the abomasum and the intestine and are used primarily as nutrients for the rapidly growing calf. Lactose is the only saccharide that is efficiently digested by the calf. Digestion of fats is limited in the calf.

The objective of the current study was to determine factors that alter the concentrations of triacylglycerol, lactose, and individual proteins during the early secretory period in milk of Jersey cows.

Materials and Methods

Composite milk samples were collected from 21 Jersey cows in the Iowa State University Teaching Herd in Ames at 0, 12, 24, 30, 38, 46, 54, 62, 80, 88 hours postpartum. Milk samples were sent refrigerated at 4°C to Dairy Lab Services (Dubuque, IA) to be analyzed for fat, protein, lactose, and total solids by mid-infrared spectrophotometry (Milk-O-Scan 203, Foss Food Technology Corp., Eden Prairie, MN) and for SCC by using a Fossomatic 90 (Foss Food Technology Corp.). Total protein nitrogen, non-casein nitrogen, and non-protein nitrogen were determined by Kjeldahl analysis. Concentrations of the casein proteins α_{S1}-casein (α_{S1}–CN), β-casein (β-CN), κ-casein (κ-CN), and α_{S2}-casein (α_{S2}-CN) and the whey proteins β-lactoglobulin (β–LG) and α-lactalbumin (α–LA) were determined by reversed-phase high performance liquid chromatography (RP-HPLC).

Data were analyzed by using mixed models procedures. The fixed effects in the model were time postpartum (0, 12, 24, 32, 40, 48, 56, 64, 72, 80, 88 hours postpartum), calving season (February – April, May – June), length of gestation (prior projected calving date, at or after projected calving date), parity (1, >1), and the interactions of time with calving season, length of gestation, and parity, respectively. A first order autoregressive variance-covariance matrix (for time after injection) was used to account for repeated measures taken on individual cows across time. Figures 1-4 show raw means and standard errors of means, whereas the text refers to least squares means.

Results and Discussion

As expected, variability of milk composition was greatest immediately after calving and decreased thereafter. Time postpartum, calving season, length of gestation, and parity affected the milk composition.

Colostrum matured to normal milk in most cows within 2 days (Figure 1A). The maturation was associated with an increase in lactose (3.2 to 4.3%) and an exponential decrease in true protein content (14.9 to 4.5%; Figure 1A). Of individual milk proteins, the largest proportional decreases were observed for other whey proteins (50.9 to 6.6 g/L), which are synthesized primarily outside of the mammary gland, and for β-LG (11.9 to 3.3 g/L; Figures 1B,C).

During the first two days after parturition, milk of cows that calved in February to April had a lower lactose content and a greater true protein and non-protein nitrogen content than did the colostrum of cows that calved in May and June (Figure 2A). The differences in concentrations were most pronounced at the first day postpartum ($P < 0.001$). The smallest proportional differences were observed for κ-CN content (Figure 2B), and the largest proportional difference were observed for other whey proteins, which are primarily immunoglobulins (Figure 2C).

At parturition, the colostrum of heifers had a lower true protein and non-protein nitrogen content than did colostrum of multiparous cows (Figure 3A). Of individual milk proteins, heifers had significantly lower concentrations of β-LG (9.6 vs. 14.3 g/L; $P = 0.004$) and α-LA (3.3 vs. 5.3 g/L; $P = 0.0004$; Figure 3C).

The colostrum of cows that calved prior to the expected calving date matured slower to milk than did the colostrum of cows that calved at or after the expected calving date. The differences in protein concentrations between the two groups were most pronounced 12 hrs after calving, when cows that calved early had lower concentrations of α_{S2}-CN (4.7 vs. 6.4 g/L; $P = 0.0002$; Figure 4B) and higher concentrations of other whey proteins (41.8 vs. 21.4 g/L; $P = 0.004$; Figure 4C).

The observed differences suggest that some milk proteins are under tighter concomitant hormonal control than others. The casein proteins seem to be stronger concomitantly controlled with each other than with the whey proteins. Within the whey proteins, β-LG and α-LA are correlated closer with each other than with other whey proteins. Within the casein proteins, the changes of α_{S1}–CN and β-CN are more similar than the changes of κ-CN and α_{S2}-CN, which both are heavily modified post-translationally.

Conclusion

The colostrum composition of Jersey cows is affected by time after parturition, length of gestation, parity, and calving season. The different secretory patterns of the components in colostrum suggest differences in the hormonal control of their synthesis, which are associated with time postpartum, length of gestation, parity, and calving season.

Acknowledgement

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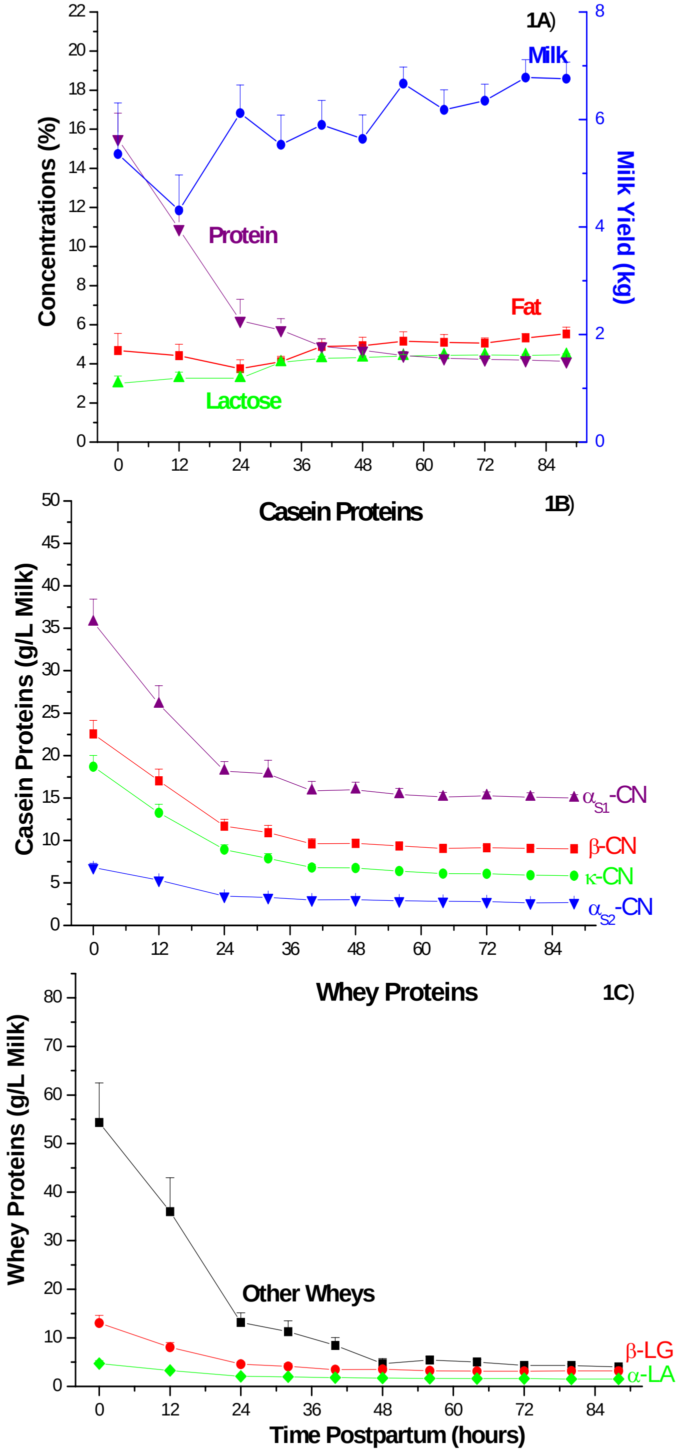


Figure 1. Changes in milk A) composition, B) casein protein content, and C) whey protein content during the first 4 days postpartum in Jersey cows.

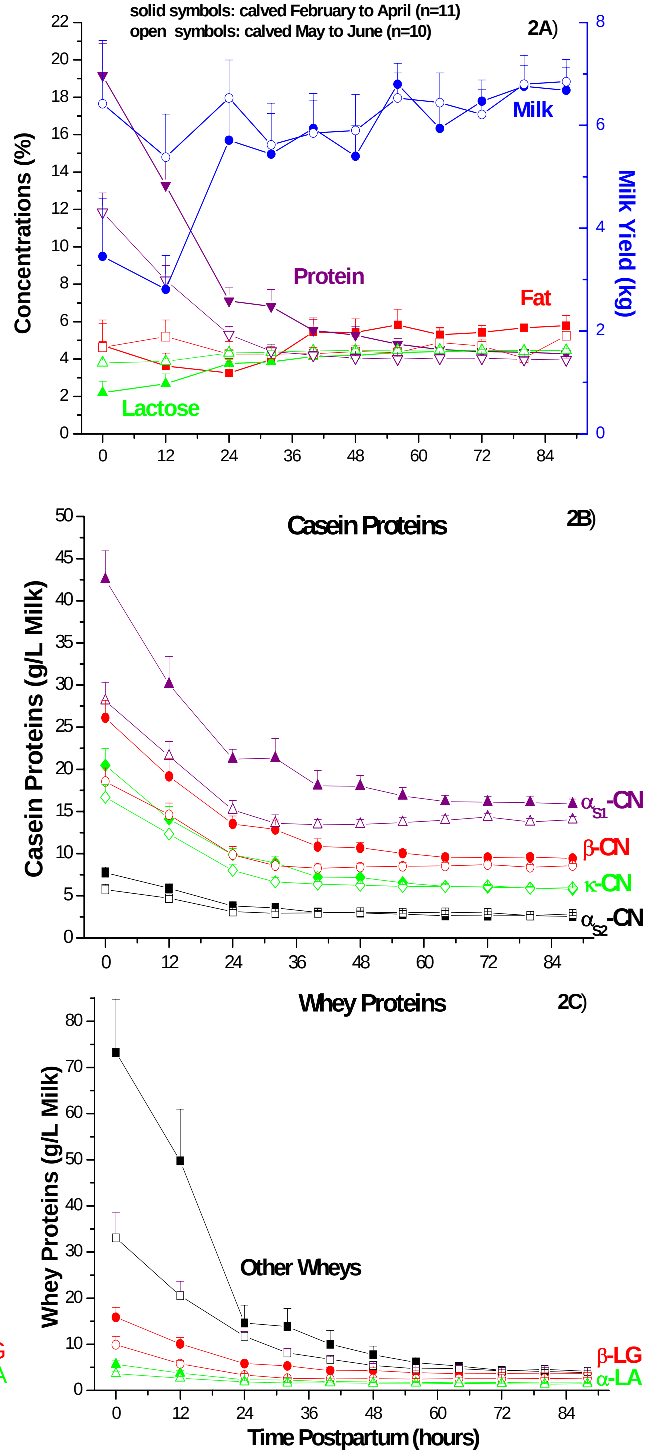
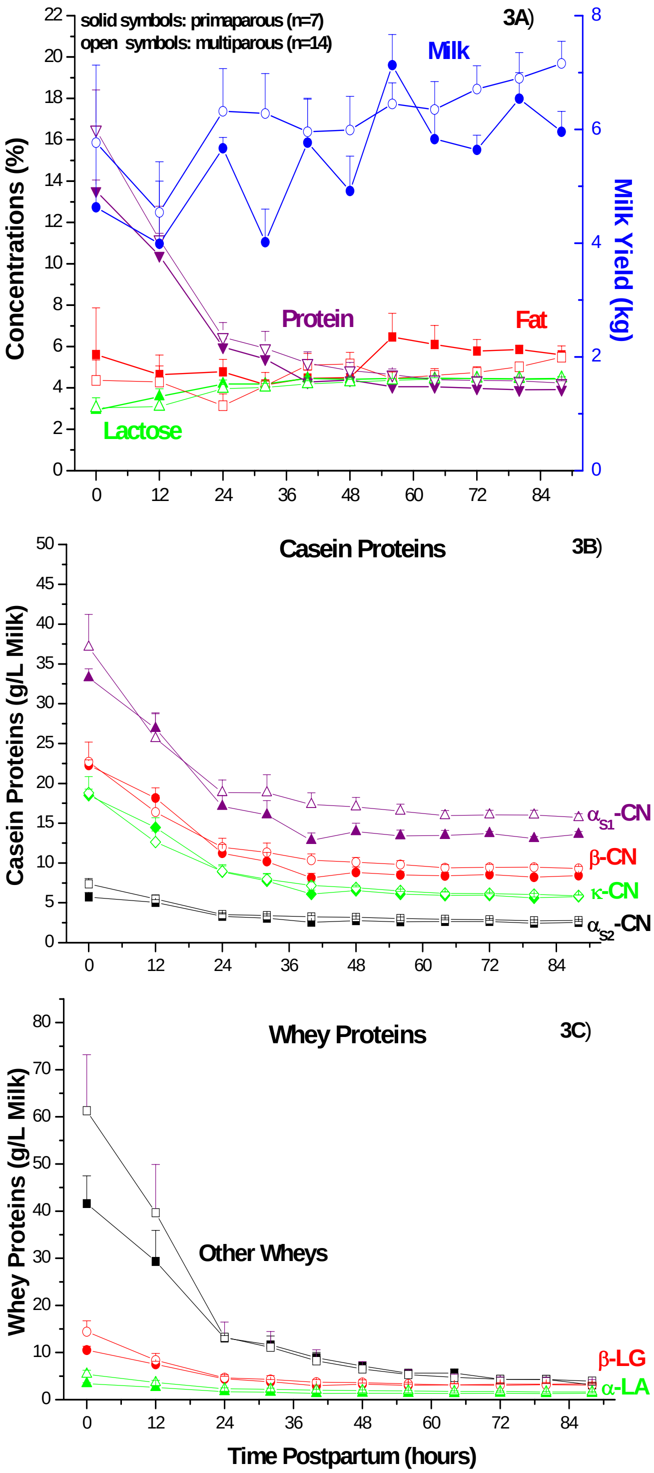


Figure 2. Changes in milk A) composition, B) casein protein content, and C) whey protein content during the first 4 days postpartum in Jersey cows as affected by calving season.



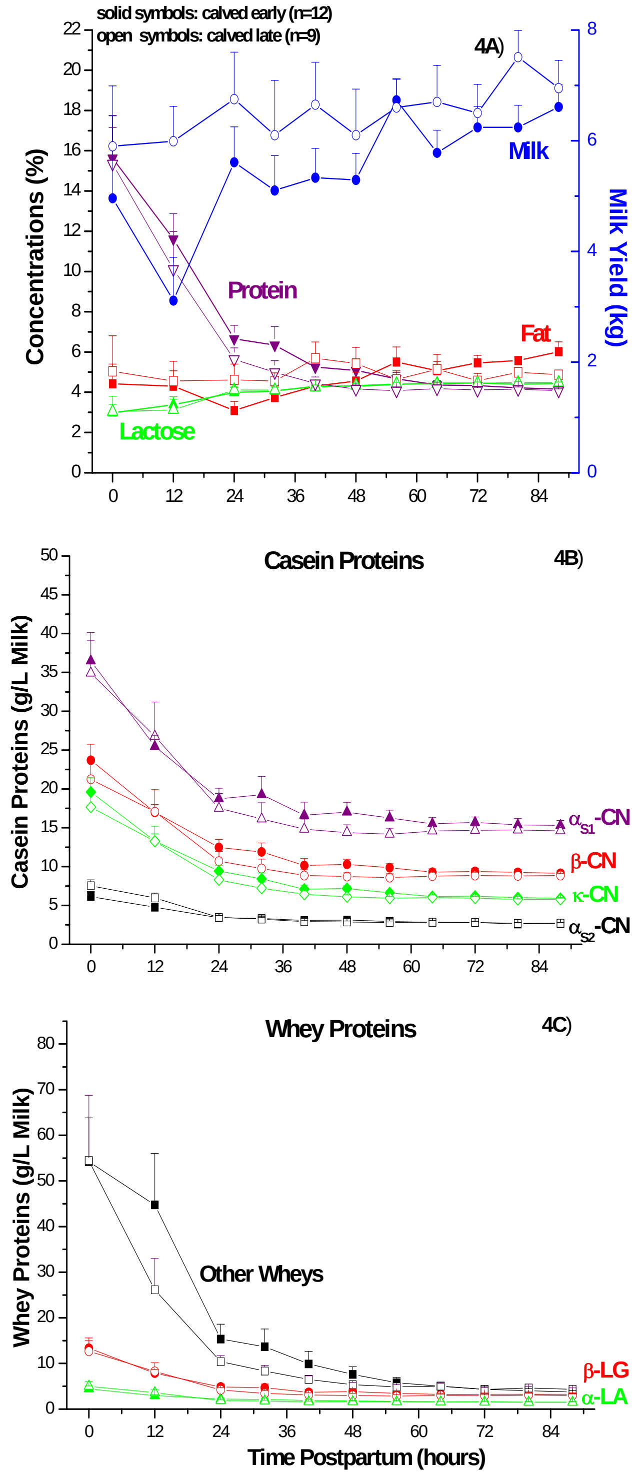


Figure 3. Changes in milk A) composition, B) casein protein content, and C) whey protein content during the first 4 days postpartum in Jersey cows as affected by parity.

Figure 4. Changes in milk A) composition, B) casein protein content, and C) whey protein content during the first 4 days postpartum in Jersey cows as affected by gestation length.