Day to day variation in milk composition at udder quarter level

by

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Institutionen för husdjurens utfodring och vård **Examensarbete 265**

Swedish University of Agricultural Sciences ***Uppsala 2008***

Department of Animal Nutrition and Management

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Abstract

This paper was carried out to study the natural day-to-day variation in milk composition at udder quarter level. Another aim was to see if there are any differences in milk composition between quarters in cows with different udder health. In this study, 10 cows managed by the University of Agricultural Sciences in Uppsala were continually milked; 2 times a day over a period of 21 days at udder quarter level. The milk was weighed at udder quarter level during each milking session and then analyzed for somatic cell count (SCC), lactose, fat, protein and whey protein. The results show that there are significant differences in milk composition between udder quarters, despite udder health but the difference is much smaller between healthy udder quarters compared to those with decreased udder health. The results for variation showed that milk yield is the parameter that varies the most and varies a lot between udder quarters. Fat also shows some larger variations but for fat is the variation larger for cows and days than the variation at udder quarter level. Protein, casein and whey vary comparable even though the variation for whey is slightly higher. The variation in lactose was lowest compared to the other analyzed parameters.

Sammanfattning

Syftet med försöket har varit att utröna hur den naturliga variationen ser ut från dag till dag i mjölk från separata juverdelar och hur sammansättningen i mjölken skiljer sig inom kor med olika juverhälsa. I den här studien användes 10 kor från Sveriges Lantbruks Universitet som mjölkades kontinuerligt, 2 gånger per dag i 21 dagar på juverfjärdedelsnivå. Mjölken vägdes vid varje mjölkning och analyserades sedan på antal somatiska celler (SCC), laktos, fett, protein, kasein och vassle protein. Resultaten visar att det är signifikanta skillnader i mjölksammansättning mellan juverfjärdedel inom ko. För variation är mjölkmängd den parameter som varierar mest och varierar väldigt mycket mellan juverfjärdedelar. Fett visar också stora variationer men där visar sig skillnaderna större mellan kor och dagar och variationen på fjärdedelsnivå är för parametern fett som lägst. Protein, kasein och vassle varierar likartat även om variationen är något större för vassle. Laktos varierar i detta försök minst av de analyserade parametrarna.

Introduction

Day to Day Variation

Day-to-day variation in this study is the variation not caused by the individual cow, her udder quarters or week of lactation. The day-to-day variation at udder quarter level is usable when to distinguish between healthy and affected udder quarters. It is also important to know differences in day to day variation in milk composition because when data from cows is used to estimate nutrition needs and for breeding purposes the samples are often collected from one day per month and can also differ between morning and evening milkings. If the milk composition varies a lot over days, and within days, it could lead to miscalculations (Syrstad, 1977). Today, when milk components due to the automatic milking systems, are analyzed on-

line, it is to a larger extent more important to know the normal day-to-day variation. If not, how are we then going to be able to detect abnormalities? It is also necessary for evaluation of how often milk samples needs to be collected (Sjauna, 1986). The milk composition is also important to know about as the protein content as well as the fat content is considered in milk pricing. It is also important for the dairymen to know if the milk composition changes as it could indicate abnormalities such as inadequate feeding, diseases or fertility problems (Keawpromman, 1988).

Data recording at udder quarter level

In the modern dairy industry, a high productive and efficient dairy cow is profitable. However, these demands on the cow also expose the cow for some stress that could cause health disturbances like mastitis, both clinical and subclinical. Clinical mastitis is easily detected visually by lumps and sometimes even by blood in the milk, whereas a subclinical mastitis is harder to detect, since there are no visible signs (Schalm *et al.,* 1971). A clinical mastitis will not only show visually but it will also, like a subclinical mastitis, lower the milk production and change the composition of the milk; fat, protein and lactose decreases while whey protein increases (Harmon, 1994, Korhonen and Kaartinen, 1995). One way to measure milk quality is to analyze SCC in the composite milk, raised SCC indicates both subclinical and clinical mastitis. Since the milk is produced in separate udder cisterns, one affected quarter with raised SSC could be hidden, because of the dilution factor in the composite milk (Berglund *et al.,* 2003). This could be of relevance for dairymen when many litres of milk are wasted every year because of subclinical and clinical mastitis. If only one quarter of the udder is affected, would it be possible to exclude only the affected udder quarter? If so, it would mean tremendous savings for the dairy farmer. Because then the dairy farmer would not lose the total income from that particular cow. Hamann and Reichtmuth (1990) found that drying of only one udder quarter in an older cow (lactation 2 or more) would give a 26% decrease in milk production, but the cow will increase her milk production with 4.2 % in the three remaining udder quarters as a compensatory effects. Therefore, the total loss will not be as considerable as if the milk was wasted.

Milk Production and Consumption in Sweden today

There are about 400,000 dairy cows in Sweden today and as the number of cows decrease the production per cow increase. A dairy cow produce on an average 9 400 kg energy corrected milk (ECM) per year, compared to 6 500 kg ECM in the year of 1985. The herds has also grown bigger while the number of herds has decreased remarkably the last two decades, from about 17 000 herds to about 5 000, 2007. The consumption of liquid milk has during the last two decades gone down 50 kg per person, from 155,2 kg to 105,6 kg and instead has the consumption switched from liquid milk to soured milk products and cheese. Per capita during 2007 the consumption of soured milk products and cheese were 36,4kg and 18,4 kg respectively, compared to 26,1 and 14,8 kg, 1985 (Swedish Dairy Association, 2008).

What is variation?

The definition of variance is

$$Var(X) = \sigma^2 = \sum_X (x - \mu)^2 P(x)$$

Variance is an average of the squared distance of its possible values from the expected value (Mean). Mean is a way to describe the location of the distribution whereas variance is a way to capture its scale or degree of being spread out.

Standard Deviation is the root mean square deviation of the values from their mean or it could also be explained as the square root of variance ($Var\ (X) = \sigma^2$)

$$\sigma = \sqrt{\sum_x (x - \mu)^2 P(x)}$$

$$\sigma = \sqrt{Var(X)}$$

The Coefficient of variance (CV) is the ratio of the standard deviation to the mean, by multiplying by 100 the CV is expressed in percentage.

$$C_v = \frac{\sigma}{\mu}$$

(Engstrand, 2003)

Aim and Hypothesis

The hypothesis for this trial was that the variation at udder quarter level is smaller than the variation in composite milk. The intention with this research has been to confirm that there are differences in the variation between milk at udder quarter level, composite milk and for different parameters. The aim has been to achieve a better understanding regarding the normal day-to-day variation in milk composition at udder quarter level. Also, the purpose of this study was to take a closer look at three individual cows with different udder health status.

Literature study

Variations in Milk Yield

Variations in milk yield could be caused by several different factors, for example; milking intervals (Syrstad, 1977; Sjauna, 1686) and diet (Rook, *et al*., 1992). Day to day variation in milk yield decrease as the time interval between test days decreases. In Sjauna´s study (1986) the standard deviation for milk yield between days, was 1.5 kg, 7.8 % when looking at data from one month. Two month gave a higher standard deviation (1.9 kg) and a larger variation; 10.4 %, a shorter interval, one week, gave a lower standard deviation (1.1 kg) and the variation 5.8%. It is not known in which week of lactation the 77 cows were in this study (Sjauna, 1686). Milk yield differ also between milkings; if they occur unevenly over a 24 hour period. Milk yield was in Syrstads (1977) study higher by 2.8 kg in a.m milkings than p.m milkings. In a study made by Larsson (1998) variation in milk yield showed great differences when cows were milked 2 or 3 times a day, but when looking at the results from a 24 hour period it did not differ that much. When milking 2 times a day, the CV for p.m milking was 9.2 %, a.m milking 7.2 % and for the 24 hour period it was 5.3 %. It is interestingly that when the milkings were performed 3 times a day, spread out over a 24 hour period with 8 hours intervals the CV were larger for a.m and p.m, 11.3 % and 12 % respectively and it is 8.2 % at night and for the 24 hour period only 4.9 %.

In studies were the daily milkrecords were done by combining a.m and p.m milkings the standard deviation for milk yield was 1.57 kg, while the standard deviation between records of consecutive days were 1.24 kg (Syrstad, 1977). The variation in milk yield over one year for composite milk was 7.6 % in a study from 1952, in this study, variation in milk yield was significantly less than variation in fat content (Erb, 1952).

Milk yield is to a large extent affected by variations among cows and udder quarters. The variation for milk yield in one study was 33.2 % between udder quarters, which the author believes is because of the 40:60 ratio between front and rear udder quarters (Natzke, 1965). As for fat, the variation in milk yield is also depending on the level of udder emptying (Syrstad, 1977; Nielsen, 2005).

According to Andersson and Nilsson (1983) study variation in milk yield is not affected by SCC, an increase in SCC does not result in a larger variation in milk yield, while others have found a connection between milk yield and SCC. Korhonen and Kaartinen (1995) found a linear relation to decrease in milk yield and increase in somatic cell count (logarithmic value). According to this study, udder quarters infected with mastitis will have a reduced milk production by 25-35 % per day.

Variations in Fat Content

Milk fat composition is highly depending on the stage of lactation. Because of the cow being in a negative energy balance at the beginning of lactation the proportion of short chain fatty acids *(De Novo*) is low due to mobilization of adipose fatty acids and incorporation of these

long fatty acids into milk fat. About eight to ten weeks into lactation the short fatty acids will increase as the uptake of long fatty acids no longer inhibits the *De Novo* synthesis (Palmquist, 1993). Another factor that influences the milk fat composition is the composition of fat in the diet. It can be influenced by amount of roughage, forage:concentrate ratio, the carbohydrate composition of the concentrate, lipids, intake and meal frequency (Sutton, 1989; Palmquist, 1993; Laben, 1963; Wiking, 2005).

Fat content increases during the milking progress, therefore the residual milk, the milk left after an incomplete milking is often rich in fat. Consequently, fat content increases in milk when the level of udder emptying is high (Syrstad, 1977; Nielsen, 2005).

Fat content in composite milk vary from day to day with 9.6 %.When combining daily milk records from a.m and p.m milkings the fat contents standard deviation was 0.39 percentage units in Syrstads (1977) first trial and 0.36 units in his second one. When comparing milk records in the second trial from consecutive days the standard deviation were 0.35 percentage units. The difference between fat content in a.m and p.m milkings was in this study significant ($P<0.05$), it was about 0.06 percentage units lower at a.m than at p.m milkings. But variation between days was not significant even though variation between cows was highly significant. In Natzke´s (1965) study at udder quarter level, the variation was found to be 3.6% between quarters and 3.6% between days for composite milk.

When looking at udder quarters affected by high SCC, fat content seem to be lower in udder quarters affected by high SCC then in those considered healthy. One theory is that this could be because of damage of the secretory epithelial cells due to infections. Such damage may impair milk fat synthesis leading to a lower fat content at the end of the milking (Nielsen, 2005).

As for milk yield fat content vary a little bit less when the milkings are performed 3 times a day instead of 2; 5.3 % (milking 3 times) and 5.6%(milking 2 times), but varies more at each occasion, just like the milk yield does (Larsson, 1998).

Variations in Protein Content

Protein varies in composite milk over a period of a month with 3.4 % (0.12 percentage units) (Sjauna, 1986). In Syrstads study (1977) the standard deviation were from 0.06 percentage units to 0.10 units depending on where the data came from. Consecutive days had the lowest variation and the records obtained by combining a.m and p.m milkings had the highest variation. The variation between days was not significant even though variation between cows was significant ($P<0.05$).

Diet only has a small influence on protein content (Sutton, 1989), whereas the cows age and state of lactation has an impact on the protein content (Tancin, 2006, Ng-Kwai-Hang, 1982).

Udder quarters with low cell counts has less ($P<0.01$) protein than unhealthy i.e. udder quarters with sub clinic mastitis (Nielsen, 2005) Several studies support this at composite milk level, where its shown that an increase in SCC also results in a increase in protein content (Urech, 1999, Korhonen & Kaartinen, 1995, Ng-Kwai-Hang, 1982). Protein contain approximately 80 % casein and 20 % whey (Mantere-Alhonen, 1995). A change in SCC

causes a switch in the casein and whey ratio. Casein decreases while the not so desirable whey increases (Ng-Kwai-Hang, 1982, Korhonen & Kaartinen, 1995). This could be caused by the proteolytic enzymes that breakdown milk casein and the increased proportions of blood proteins and lactoferrin in the total protein (Barbano, 1991; Urech, 1999; Korhonen & Kaartinen, 1995).

Variations in Lactose Content

Lactose is the milk sugar and it is a disaccharide of a α- or β-glucose and β-galactose, the lactose content in milk varies between 3.5-5.5% (Mantere-Alhonen, 1995). Lactose percentage varies over one month with 0.09 percentage units (1.9 per cent) for composite milk (Sjauna, 1986). Larsson (1998) found the day-to-day variation to be 1.4 % when milking 2 times a day and 1.3 % when milking 3 times a day. Barnes (1989) found the day-to-day variation to be very small for lactose; it varied with only 0.07-0.09 percent units. Bansal (2005) found the standard deviation for lactose to be 0.18 % in healthy udder quarters and 0.25 % in mastitic udder quarters.

Lactose in udder quarters affected by a subclinic mastitis is lower than in those not affected by a subclinic mastitis (Nielsen, 2005; Berglund, 2003) There is (as for protein and milk yield) a strong correlation between high SCC and a decrease in lactose content also at udder level. Lactose is reduced by approximately 10 % when the udder is affected by mastitis. Lactose is an important osmotic component in milk and because of that, disturbances in lactose content could affect the osmotic balance between milk and blood (Korhonen & Kaartinen, 1995).

Variations in Somatic Cell Counts and Effects of Mastitis

Somatic cells are for the most part (80%) cells from the body immune system; they contain a large number of lymphocytes, macrophages, polymorphonuclear cells and some epithelial cells (Schukken, 2003). On a quarter level, a mean somatic cell count is about 70 000 cells/ml (Schepers, 1997).

Andersson and Nilsson (1983) found out in a research about how different feeds affect the cell count in composite milk, that the feed has a very small impact, 0.23 % of the total variation in SCC. It was not affected by the changes in feed sort. In the healthy cows, negative in test for bacteria's, (*Staphylococcus*, *aureus* and other *Staphylococcus)* the standard deviation for daily variation in cell count was 0.0940 and it differed significant ($P< 0.001$) between cows. Among the cows that tested positive for the bacteria's was the standard deviation 0,1601 and also among these cows it was a significant diffrence between cows ($P< 0.001$).

Composition of milk changes over the time of milking and the pattern of variation differs between udder quarters considered healthy and udder quarters with subclinical mastitis. (Bansal, *et al*., 2004; Vangroenweghe, 2002). Woolford *et al*. (1997) found that the variation in uninfected udder quarters is 8.1-14.2 % and in infected udder quarters 8.5-13.5 %. In contrast to what others have found that the day-to-day variation for SCC is larger in an infected udder than in a healthy udder (Saloneimi, 1995). These significant differences

support the theory of the interdependence of quarters, and indicate an inconsistent effect of mastitic quarters on the milk from neighbouring healthy quarters (Bansal, *et al*., 2004).

As long as the udder is healthy, SCC is not influenced by milk yield and stage of lactation, except later on in the lactation when the cow produce less than 4 kg milk per day, which will result in a slightly increase in SCC (Saloneimi, 1995).

Material and Method

The trial was performed at Kungsängens Research Centre, at The Swedish university of Agriculture Sciences. It took place from April 16th to May 7th 2007. The study was approved by Uppsala ethics committee.

Cows

The study involved 10 cows of Swedish red and white breed (SRB). Cows chosen for the study had to be healthy i.e. have a cell count (SCC) lower than 100 000 somatic cells/ml in cow composite milk, and were tested negative for bacteria's the week before the trial started. The milking was performed in a stanchion barn. The cows were in lactation week 12-42, see table 1, and were all pregnant at the time for the trial. They were fed according to the Swedish recommendations (Spörndly, 2003).

Table 1. Data from cows in the trial, from cow composite milk, the week before the trial started

Cow ID	Cow ID in trial	Cell count (somatic cells/ml)	Lactation week	Lactation number
1313	A	9 000	19	1
1272	B	53 000	33	1
1077	C	10 000	42	3
1230	D	43 000	31	2
1234	E	40 000	30	2
1297	F	14 000	17	1
1317	G	36 000	20	1
1261	H	14 000	12	2
828	I	72 000	33	7
1235	J	34 000	25	2
Average		32 500	26.2	2.2

Example cows

Since the milk is produce separately within each udder quarter it is interesting to see how the milk composition differs between udder quarters within the same cow. Two cows A and C considered healthy (SCC in cow composite milk lower than 100 000 cells/ml during the trial), and one cow, B, with SCC over 100 000 cells/ml was picked out to represent the other ten in the trial.

Medical history for example cows

The three cows that were picked out to be evaluated had no history of mastitis, except cow B. Her cell count has been fluctuated over time from her last calving. She had on four different occasions been registered with a bacterial infection in left rear udder quarter. Three days after calving (060905) she were tested positive for E. coli on right rear udder quarter. At two times (061108, 070306) she had an enterobactero cloacae.

Cow C had a significant higher level of SCC in right front udder quarter throughout the whole trial. She had a biopsy done on that udder quarter two years before the trial (050113), she also had biopsies done on her left front udder quarter at one time one year before the trial (060418) and three times two years before the trial (050126, 050222, 050310).

Milking Equipment

Milking was performed two times a day, at 6.30 am and 3.30 pm. The milking equipment was provided by DeLaval and each udder quarter was milked separately into individually containers. The milking was performed with monovac, pulsation ratio 70:30 and system vacuum 42 kPa. Teats were cleaned with a wet towel and the cow's foremilk was hand milked and inspected before putting on the milking machine. Milk flow was registered continuously at udder quarter level and when the milk flow was lower than 300 g/min at udder quarter level the milking machine was taken off each quarter separately.

Registrations and analyses

The milk was weighed for each quarter and quarter milk samples and representative cow composite milk samples were collected. The milk was carefully stirred before samples were collected and the same routine was done when collecting cow composite milk samples. Milk yield at udder quarter level were registered. The milk sampling tubes were prepared with Bronopol, 2-bromo-2-nitropropane-1,3-diol (VWR, International AB, Stockholm Sweden) to give a concentration of 0,02% total Bronopol in the milk samples. Milk samples were analyzed for total protein, fat, lactose, citric acid, whey protein and somatic cells/ml (SCC). The milk samples were stored in +4° C before analysis. The analyses were done with an infrared spectroscopy method (Fourier Transform Instrument, FT 120, Foss Electric, Denmark). SCC was measured by electronic fluorescence based cell counting (Fossomatic 5000, A/S N. Foss Electric, Hillerød, Denmark). Milk from cows with a larger variation in SCC as well as one cow with low and stable SCC was also analyzed on casein. The proportion of casein was calculated from the whey protein and total protein proportions, using rennet casein method (Arla Foods, Analysföreskrift, kapitel 30-6, utgåva 004, 001210).

Statistical Analyses

Afternoon milk records for all parameters were removed from the data at day 3 because of unrealistic milk yield values.

The results are divided into two parts, one where the variation were studied; day-to-day, cow, udder quarter and week of lactation, and one where differences between udder quarters were compared.

In the part where variation were studied data were statistically analyzed (SAS institute) with a nested model (PROC NESTED) with week of lactation nested within udder quarter and udder quarter nested within cow.

$Y_{ijkl} = \mu + \alpha_i + \beta_{ij} + \gamma_{ijk} + e_{ijkl}$

Where;

Y_{ijkl} = is the ijklth observation of each trait

μ = Mean

α_i = The effect of the ith cow

β_{ij} = The effect of the jth udder quarter within the ith cow

γ_{ijk} = The effect of the kth lactation week within the jth udder quarter

e_{ijkl} = Random Error

In the other part, the milk compositions were compared respectively between the front and rear udder quarters within cows and tested if they differed from zero. This was done on three individual cows that were selected. Differences between right and left udder quarters for example cows were determined by paired t-test using SAS.

Results from morning and afternoon milk should be considered with care. Because of the uneven milking intervals, milk from a 24 hour period will give a more fare and accurate result. Afternoon milk has been shown to vary more in composition than morning milk or composite milk from a 24 hour period (Sjauna 1986; Syrstad, 1977), and that is why we chose to work with the 24 hour milk data.

Results

The results are divided into two parts, one where the variation were studied; day-to-day, cow, udder quarter and week of lactation and one where the differences in milk composition of three individual cows that was picked out as example cows were studied.

SCC

Variation in SCC

As seen in table 2 the SCC is highly depending on udder quarter, but there are also large variations within cow. Whereas week of lactation has less influence on the variation.

Table 2. Day to day variation in somatic cell count (logarithm cell counts) (n=10)

	X[1]	CV day-to-day[2]	CV cow[3]	CV udder quarter[4]	CV week[5]
Morning	4.27	3.83	10.31	9.45	1.21
Afternoon	4.54	3.31	8.34	9.01	0.91
24 h period	4.40	2.91	9.13	9.27	1.30

[1]mean (logarithm cells/ml), [2]day to day coefficient of variance (%), [3]cow coefficient of variance (%), [4]udder quarter coefficient of variance (%), [5] coefficient of variance (%) for week of lactation

Differences in SCC for Example Cows

Cow A show significant differences in SCC in front udder quarters. Cow C had significant higher SCC in right front udder quarter throughout the whole trial even tough the SCC in that quarter never exceeded 100 000 cells/ml. Cow B had a significant higher SCC in left rear udder quarter throughout the test period and even if the SCC did not exceeded the 100 000 cells/ml in cow composite milk her left rear udder quarter did several times. She also had raised SCC in her right front udder quarter throughout the trial, see table 3.

Table 3. Milk SCC (cells/ml) compared between left and right front udder quarter. Result displayed as average values of milk from a 24 hours period in right respective left udder quarter and average difference between right and left udder quarters, probability values and Standard Deviations (SD).

Cow, udder quarter	Average value of Right side udder quarters ±SD	Average value of Left side udder quarters ± SD	Average difference[1] (Right-Left)	P-value
A Front	5841 ± 1066	4462 ± 1040	0.12	<0.0001
A Rear	4631 ± 1267	5247 ± 1074	-0.06	0.0015
B Front	70989 ± 27435	24798 ± 17243	0.48	<0.0001
B Rear	21158 ± 4911	5596983 ± 6079589	-2.12	<0.0001
C Front	81366 ± 11007	16638 ± 2154	0.69	<0.0001
C Rear	14547 ± 2599	14032 ± 2100	0.01	0.3865

[1] Displayed as logarithmic values

Milk Yield

Variation in Milk Yield

The largest variation in milk yield seems to be due to udder quarter. Day to day variation plays an important role to explain the variation in milk yield as well. Week of lactation and cow also affect the variation but has less of an influence, see table 4.

Table 4. Day to day variation in milk yield (n=10)

	X[1]	CV day-to-day[2]	CV cow[3]	CV udder quarter[4]	Week[5]
Morning	3.64	9.69	0	17.37	3.00
Afternoon	2.19	17.24	5.22	18.45	3.18
24 h period	5.84	8.18	0	17.81	2.41

[1]mean, kg milk, [2]day to day coefficient of variance (%), [3]cow coefficient of variance (%), [4]udder quarter coefficient of variance (%), [5] coefficient of variance (%) for week of lactation

Differences in Milk Yield for Example Cows

When comparing udder quarters for the three example cows (A, B and C) there were a significant difference in milk yield between right and left side of the udder except for one cow C were the front udder quarters did not differ in milk yield, see table 5.

Table 5. Milk yield (kg) compared between left and right udder quarter. Result displayed as average values of milk from a 24 hours period in right respective left udder quarter and average difference between right and left udder quarters, probability values and Standard Deviations (SD).

Cow, Udder quarter	Average value of Right side udder quarters ± SD	Average value of Left side udder quarters ± SD	Average difference (Right-Left)	P-value
A Front	5.96 ± 0.54	6.34 ± 0.48	-0.38	0.0050
A Rear	5.87 ± 0.43	5.37 ± 0.37	0.50	0.0002
B Front	7.11 ± 0.55	6.64 ± 0.75	0.47	0.0013
B Rear	6.43 ± 0.58	5.14 ± 0.78	1.29	<0.0001
C Front	4.76 ± 0.41	4.99 ± 0.71	-0.23	0.1432
C Rear	5.30 ± 0.70	7.48 ± 0.82	-2.18	<0.0001

Fat

Variation in Fat

Variations in fat content are to a larger extent depending on cow and day to day variation and not on udder quarters or week of lactation, see table 6.

Table 6. Day to day variation in fat (n=10)

	X[1]	CV day-to-day[2]	CV cow[3]	CV udder quarter[4]	Week[5]
Morning	3.75	14.27	13.78	1.04	2.90
Afternoon	5.70	10.41	14.45	0	2.98
24 h period	4.49	8.67	11.89	0	2.43

[1]mean, (% of content in milk), [2]day to day coefficient of variance (%), [3]cow coefficient of variance (%), [4]udder quarter coefficient of variance (%), [5] coefficient of variance (%) for week of lactation

Differences in Fat for Example Cows

Fat seem to stay on a stabilized level no matter other fluctuations within cow. Example cow C shows a slightly higher fat content in her right rear udder quarter though, see table 7.

Table 7. Fat content (%) compared between left and right udder quarter. Result displayed as average values of milk from a 24 hours period in right respective left udder quarter and average difference between right and left udder quarters, probability values and Standard Deviations (SD).

Cow, Udder quarter	Average value of Right side udder quarters ± SD	Average value of Left side udder quarters ± SD	Average difference (Right-Left)	P-value
A Front	4.12 ± 0.37	4.17 ± 0.46	-0.05	0.6374
A Rear	4.13 ± 0.33	4.23 ± 0.33	-0.10	0.0166
B Front	4.17 ± 0.43	4.19 ± 0.62	-0.02	0.8567
B Rear	4.21 ± 0.44	4.31 ± 0.67	-0.10	0.3839
C Front	4.93 ± 0.25	4.89 ± 0.34	0.04	0.5319
C Rear	5.14 ± 0.28	4.89 ± 0.31	0.25	0.0169

Lactose

Variation in lactose

Lactose does not vary very much and is to a larger extent depending on cow whereas variation caused by udder quarters, week and days are neglectible, see table 8.

Table 8. Day to day variation in lactose (n=10)

	X[1]	CV day-to-day[2]	CV cow[3]	CV udder quarter[4]	Week[5]
Morning	4.72	1.56	3.89	1.64	0.68
Afternoon	4.68	1.71	4.25	1.64	0.85
24 h period	4.70	1.46	4.01	1.60	0.77

[1]mean, % of content in milk, [2]day to day coefficient of variance (%), [3]cow coefficient of variance (%), [4]udder quarter coefficient of variance (%), [5] coefficient of variance (%) for week of lactation

Differences in Lactose for Example Cows

There are significant differences in lactose content between the udder quarters according to table 9. Cow A produce significant more lactose in left front udder quarter compared to right udder quarter but no differences between rear udder quarters. Cow C produce significant more lactose in her front left side udder quarter throughout the whole trial whereas there are no differences between the rear udder quarters. Cow B produces significant more lactose in left front udder quarter compared to right front udder quarter and vice versa for rear udder quarters.

Table 9. Lactose content (%) compared between left and right udder quarter. Result displayed as average values of milk from a 24 hours period in right respective left udder quarter and average difference between right and left udder quarters, probability values and Standard Deviations (SD).

Cow, Udder quarter	Average value of Right side udder quarters ± SD	Average value of Left side udder quarters ± SD	Average difference (Right-Left)	P-value
A Front	4.94 ± 0.04	4.95 ± 0.05	-0.01	0.0470
A Rear	4.95 ± 0.04	4.94 ± 0.04	0.01	0.1688
B Front	4.56 ± 0.06	4.60 ± 0.05	-0.04	<0.0001
B Rear	4.58 ± 0.05	4.14 ± 0.36	0.44	<0.0001
C Front	4.62 ± 0.04	4.73 ± 0.05	-0.11	<0.0001
C Rear	4.73 ± 0.04	4.73 ± 0.04	-0.00	0.7454

Protein

Variation in Protein

Protein content vary moderate and seem to be mostly depending on cow. The day-to-day variation for protein is relatively small. Variation in protein content does not seem to be affected very much by week of lactation, see table 10.

Table 10. Day to day variation in protein (n=10)

	X[1]	CV day-to-day[2]	CV cow[3]	CV udder quarter[4]	Week[5]
Morning	3.42	2.58	6.66	1.40	0.81
Afternoon	3.56	2.26	6.13	1.24	0.82
24 h period	3.47	2.05	6.40	1.33	0.70

[1]mean, % of content in milk, [2]day to day coefficient of variance (%), [3]cow coefficient of variance (%), [4]udder quarter coefficient of variance (%), [5] coefficient of variance (%) for week of lactation

Differences in Protein for Example Cows

When comparing udder quarters within cow, protein content differ significantly between udder quarters in all three example cows milk samples both front and rear, except for one cow C were there were no differences in protein content between her front udder quarters. Cow C has a significant difference in protein content in milk from her rear udder quarters. Cow B has a significant lower content of protein in her right rear udder quarter, in which she under a considerable time of the trial also has a high SCC, see table 11.

Table 11. Protein content in % compared between left and right udder quarter. Result displayed as average values of milk from a 24 hours period in right respective left udder quarter and average difference between right and left udder quarters, probability values and Standard Deviations (SD).

Cow, Udder quarter	Average value of Right side udder quarters ± SD	Average value of Left side udder quarters ± SD	Average difference (Right-Left)	P-value
A Front	3.27 ± 0.04	3.26 ± 0.05	0.01	0.0660
A Rear	3.28 ± 0.04	3.29 ± 0.04	-0.01	0.0017
B Front	3.45 ± 0.06	3.46 ± 0.07	-0.01	0.0076
B Rear	3.48 ± 0.06	3.74 ± 0.31	-0.26	0.0018
C Front	3.88 ± 0.07	3.89 ± 0.07	-0.01	0.1213
C Rear	3.92 ± 0.06	3.80 ± 0.06	0.12	<0.0001

Casein

Variation in Casein

Casein varies moderate, the largest variation factor occurs within cow, see table12.

Table 12. Day to day variation in casein (n=7)

	X[1]	CV day-to-day[2]	CV cow[3]	CV udder quarter[4]	Week[5]
Morning	2.47	3.51	6.82	3.71	0.69
Afternoon	2.56	4.82	6.20	1.77	0
24 h period	2.51	2.93	6.57	2.42	0.37

[1]mean, % of content in milk, [2]day to day coefficient of variance (%), [3]cow coefficient of variance (%), [4]udder quarter coefficient of variance (%), [5] coefficient of variance (%) for week of lactation

Differences in Casein for Example Cows

Healthy cow A did not show any significant differences in front and rear udder quarters. Healthy cow C had a significant difference in casein content in both front and rear udder quarters. Cow B does not show a great difference in her rear udder quarters, despite her differences in protein content and high SCC, but there is here a larger difference in front udder quarters, see table 13.

Table 13. Casein content (%) compared between left and right udder quarter. Result displayed as average values of milk from a 24 hours period in right respective left udder quarter and average difference between right and left udder quarters, probability values and Standard Deviations (SD).

Cow, Udder quarter	Average value of Right side udder quarters ± SD	Average value of Left side udder quarters ± SD	Average difference (Right-Left)	P-value
A Front	2.36 ± 0.03	2.35 ± 0.04	0.01	0.0904
A Rear	2.37 ± 0.04	2.38 ± 0.03	-0.01	0.0582
B Front	2.67 ± 0.07	2.60 ± 0.05	0.07	<0.0001
B Rear	2.50 ± 0.21	2.30 ± 0.24	0.20	0.0250
C Front	2.81 ± 0.07	2.83 ± 0.06	-0.02	0.0004
C Rear	2.86 ± 0.05	2.76 ± 0.06	0.10	<0.0001

Whey Protein

Variation in Whey Protein

Whey varies a lot more than casein even though they are both highly depending on each other. Week of lactation doesn't seem to have a large influence on the variation in whey, but both cow and udder quarter, as well as the day to day variation affects the whey content. Here, as seen on the other traits analyzed; afternoon results show a slightly different picture than morning and composite milk, see table14.

Table 14. Day to day variation in whey (n=7)

	X[1]	CV day-to-day[2]	CV cow[3]	CV udder quarter[4]	Week[5]
Morning	0.95	7.09	7.52	6.90	0.92
Afternoon	0.99	10.49	6.31	5.10	0
24 h period	0.96	5.79	7.28	4.93	0

[1]mean. % of content in milk. [2]day to day coefficient of variance (%), [3]cow coefficient of variance (%), [4]udder quarter coefficient of variance (%), [5] coefficient of variance (%) for week of lactation

Differences in Whey Protein for Example Cows

Cow A doesn't show any differences in Whey protein content. Cow C produce significant more whey protein in her right front and rear udder quarter compared to her left front and rear udder quarter. Cow B show no differences between front udder quarters but produced more whey in left rear where she also had an increase in SCC, see table 15.

Table 15. Whey protein (%) content compared between left and right udder quarter. Result displayed as average values of milk from a 24 hours period in right respective left udder quarter and average difference between right and left udder quarters. probability values and Standard Deviations (SD).

Cow, Udder quarter	Average value of Right side udder quarters ± SD	Average value of Left side udder quarters ± SD	Average difference (Right-Left)	P-value
A Front	0.91 ± 0.02	0.91 ± 0.02	0.00	0.3904
A Rear	0.91 ± 0.02	0.91 ± 0.02	0.00	0.0239
B Front	0.89 ± 0.02	0.89 ± 0.02	0.00	0.0802
B Rear	0.94 ± 0.20	1.16 ± 0.20	-0.22	0.0159
C Front	1.08 ± 0.02	1.06 ± 0.03	0.02	<0.0001
C Rear	1.06 ± 0.03	1.04 ± 0.02	0.02	<0.0001

Comparison between different parameters for example cows

Cow B constantly has a lower production of milk and content of lactose in left rear udder quarter. Figure 1 displays how her SCC vary over time and how milk production and lactose content goes down when SCC increases.

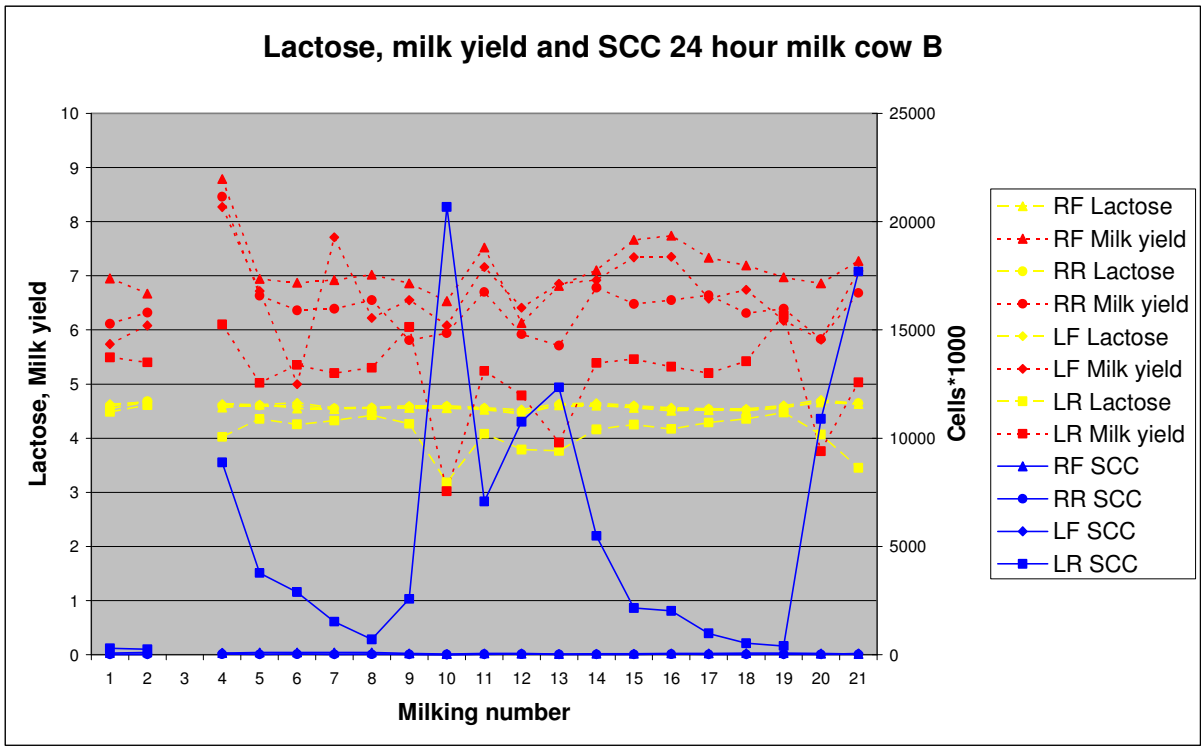

Figure 1. Somatic cell count presented as cells/ml milk, lactose as % of milk content and milk yield in kg for cow B.

Even though milk yield in composite milk doesn't show any variations figure 2 shows how milk yield fluctuate at udder quarter level for cow A.

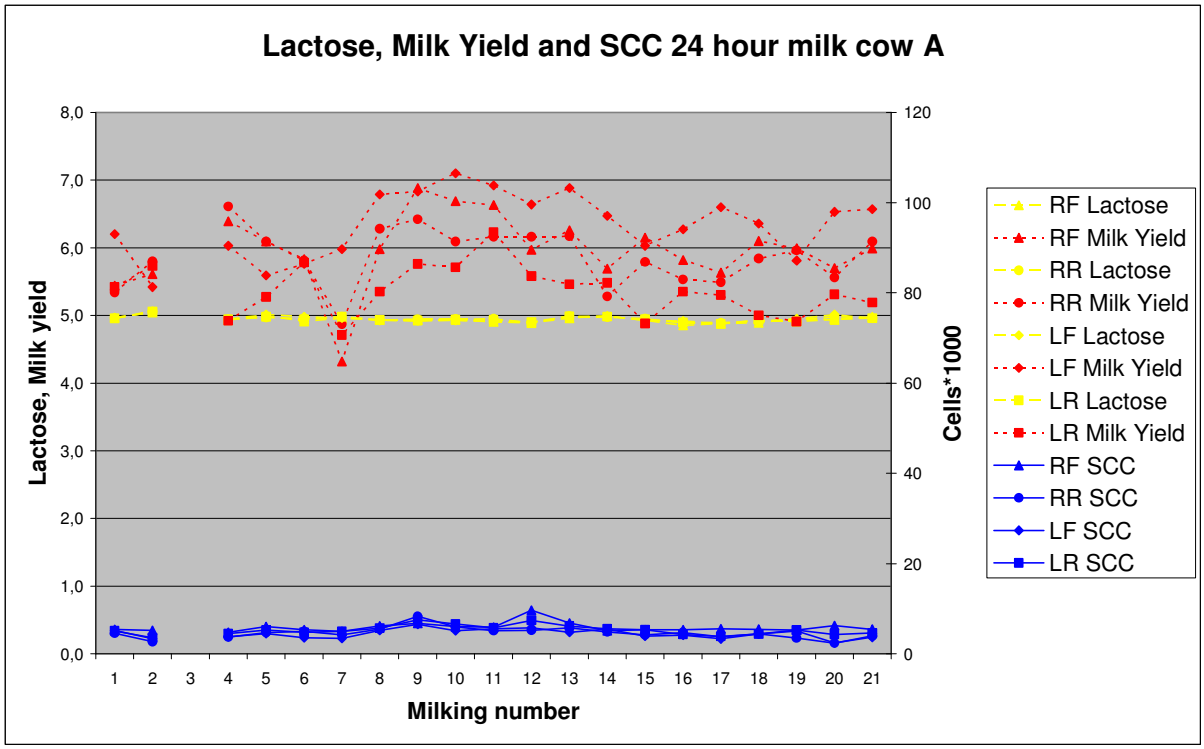

Figure 2. Somatic cell count presented as cells/ml milk, lactose as % of milk content and milk yield in kg, for cow A

Figure 3 shows lactose, milk yield and SCC for cow C. This shows how her right front udder quarter constantly has a higher cell count without exceeding the 100 000 cells/ml limit. Milk yield follows and decreases when cell count increases. She produced significantly more milk from left rear udder quarter during the test period.

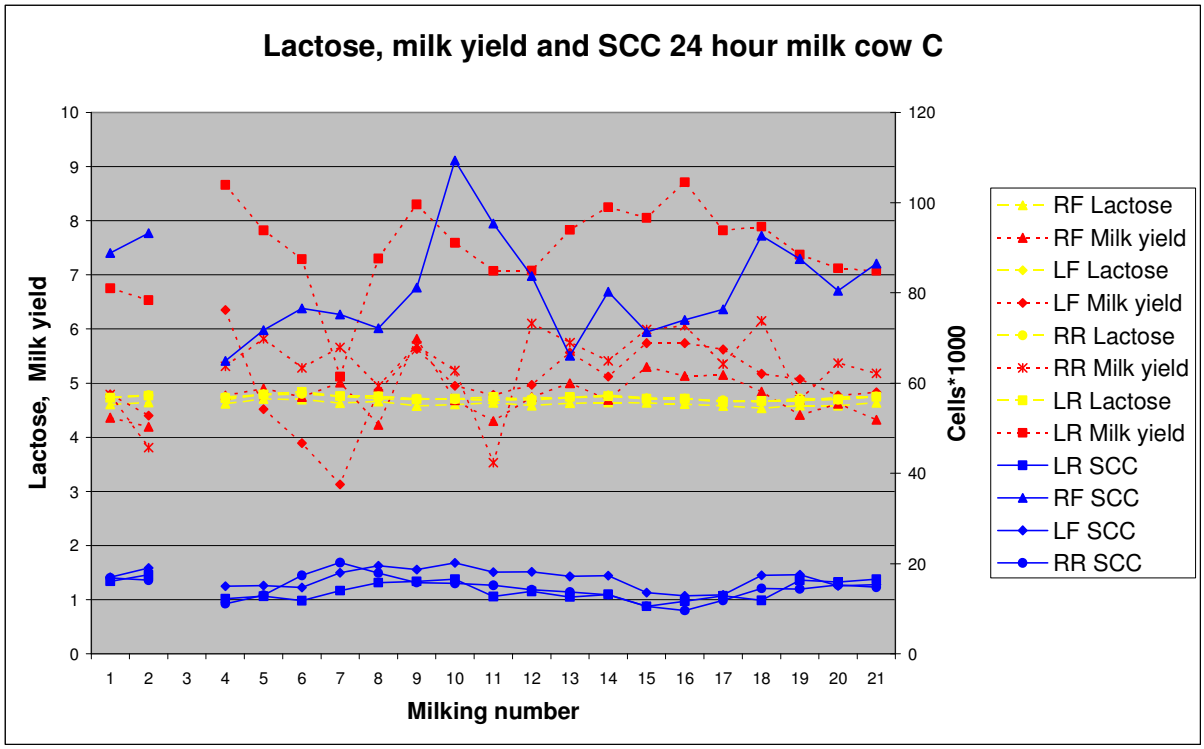

Figure 3. Somatic cell count presented as cells/ml milk, lactose as % of milk content and milk yield in kg, for cow C

As seen in figure 4, protein and casein is highly affected by the higher cell count in cow B´s left rear udder quarter. Protein content increases as the casein content decreases noticeable.

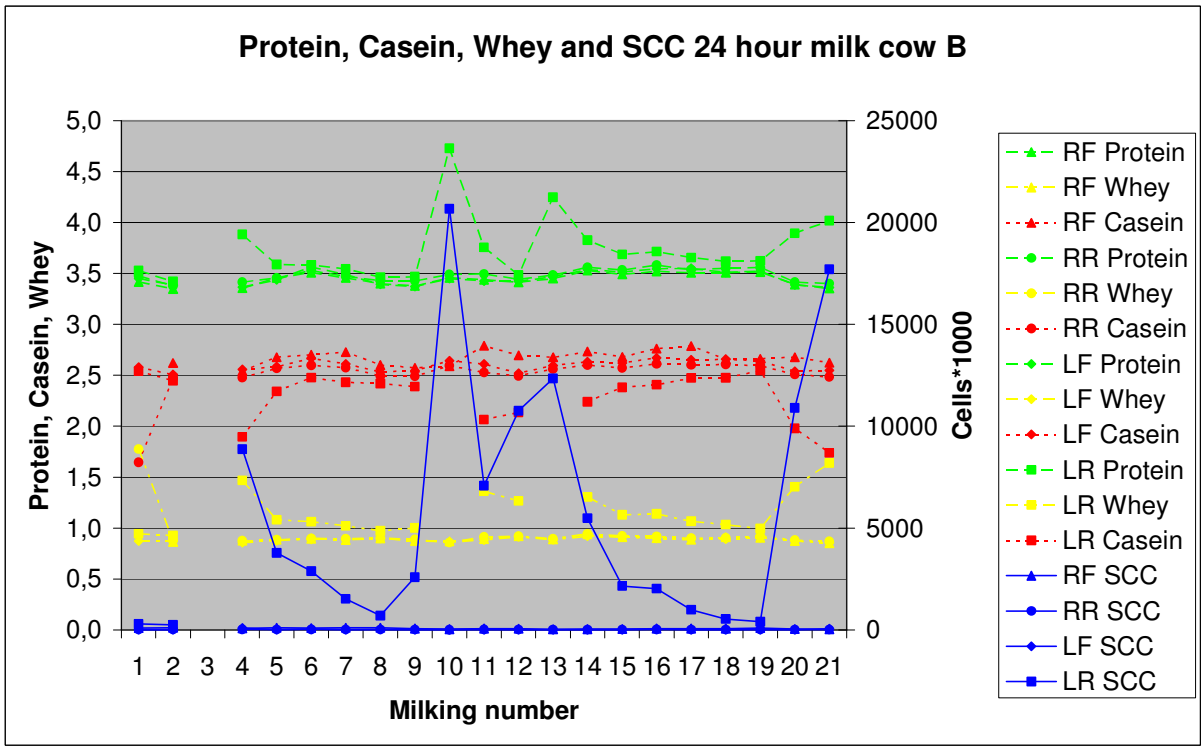

Figure 4. Somatic cell count presented as cells/ml, protein, casein and whey as % of content in milk, for cow B.

Figure 5 shows how protein and casein seem to follow each other very well for cow C, there is a rather small influence on whey protein. Even though SCC for right front udder quarter is so well above the other three, it does not seem to affect the other traits.

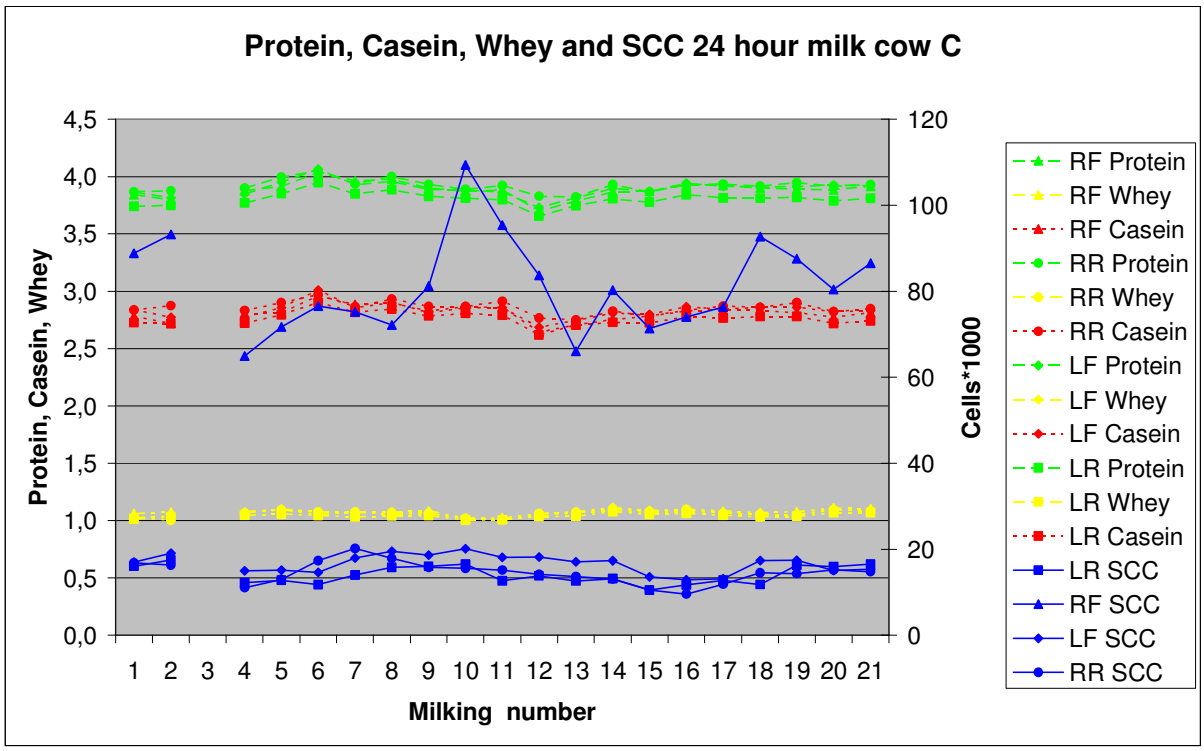

Figure 5. Somatic cell count presented as cells/ml, protein, casein and whey as % of content in milk, for cow C.

Figure 6 displays how protein and casein follow the same curve but whey stays stabilized on the same level for cow A.

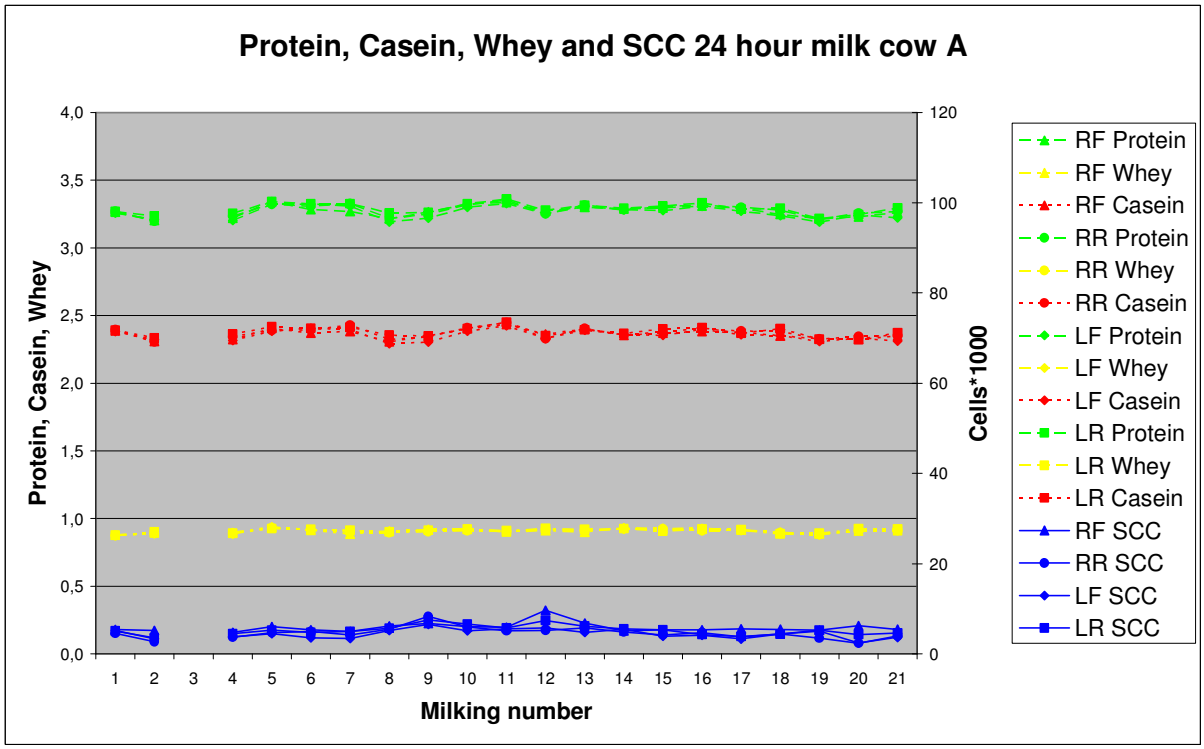

Figure 6. Somatic cell count presented as cells/ml, protein, casein and whey as % of content in milk, for cow A

Discussion

Variation

When looking at all cows there seem to be a larger variation between cows than between udder quarters. Over all is cow the factor with the highest variation for every trait, except for milk yield. Milk yield varies a lot and udder quarter is the factor that varies the most. The day to day variation is largest for milk yield, but as seen varies less than what udder quarter does. The day-to-day variation in milk yield seen in this study (9.83 %) is well above what Larsson (1998) found in her day-to-day variation study were it was 5.3 %. As seen here as well as in Larssons study the variation in milk yield is larger for afternoon milk than for morning milk but the variation decreases for 24 hour milk. The variation in milk yield between udder quarters could be caused by the level of udder empting and who perform the milking (Nielsen, 2005; Wiking, 2004). The larger variation in milk yield and SCC than what's seen in the other parameters could be explained by milk yield being highly correlated to SCC and decreases when SCC increases (Harmon, 1994; Korhonen and Kaartinen, 1995) and because of the compensatory effect of milk production in the other udder quarters when an udder quarter is affected by a subclinical or clinical mastitis (Hamann and Reichmuth, 1990). SCC varies approximately the same for cow and udder quarter, but not so much for day-to-day and week of lactation.

Lactose varies the least of all the analyzed traits; cow dominates the variation, whereas udder quarter, day-to-day and week of lactation don't varied so much. Lactose would therefore be a trait to consider when to detect subclinical mastitis. A 10 % decrease in lactose content is a confidently sign of mastitis (Sjaunja, 1986; Korhornen and Kaartinen, 1995). There is a strong correlation between lactose content and SCC (Korhornen and Kaartinen, 1995, Vangroenwegehe, 2002).

Fat varies also a little bit more than the other analyzed traits. Cow varies the most for fat and udder quarter varies the least. Larger variation in day to day variation for fat may depend on the milking equipment. The "human factor" could also have played an important role since there were different people performing the milking, although the milkflow measurer decided when each teat cup was removed. These factors could affect the degree of udder emptying that play an important role in fat content (Syrstad, 1977; Nielsen, 2005).

Protein, casein and whey protein vary comparable; Cow varies the most followed by day-to-day, udder quarter and week of lactation the least. Whey shows a larger variation for cow, day-to-day and udder quarter, than protein and casein. This larger variation for whey protein could be affected by variations in SCC. Because many of the whey proteins filtrate into the udder from blood where they originate from and as the inflammation becomes more severe the amount of whey proteins will increase (Korhornen and Kaartinen, 1995).

Differences between Udder Quarters for Example Cows

There are clearly significant differences between udder quarters. However, when looking at these results the extremely small differences has to be considered, if the variation for a parameter is small, then the difference in each udder quarter could be very small but still

significant. Berglund *et al.* (2007) did not find any differences in milk composition between front and rear udder quarters respectively. Differences between udder quarters could likely be caused by tissue damages caused by previous mastitis. Therefore a healthy cow could show differences between udder quarters because of tissue damages (Nielsen, 2005).

Healthy cow A did show significant differences in SCC in front udder quarters. This could be due to natural variation because the SCC is very low for all udder quarters and the right front udder quarter had in comparison just a slighter higher cell count, see figure 2. Even though these differences are very small, the higher SCC could have an affect on milk yield and lactose that decreases in her right front udder quarter while protein in that udder quarter increases. As for cow A, cow C also had one udder quarter with raised SCC. She had in her right front with four times as high SCC as in the other three udder quarters. She follows the same pattern as cow A and as in Berglund's *et al*. (2007) study. She produce less of lactose and casein in right udder quarter, while she produce more whey protein in her right front udder quarter, which could be an effect from the elevated cell count.

Figure 1 show that somatic cell count differs a lot between udder quarters for cow B, who shows a deep decline in milk yield as well as lactose when cell counts reaches high numbers like 200 000 cells/ml. She had a lower production of casein but a higher content of protein and whey protein in her left rear udder quarter with the raised SCC. As seen in figure 4, protein and casein is strongly affected by the higher cell count in left rear udder quarter. Protein content increases as a consequence of high cell counts, this would in a national milk recording look like a positive trend but when comparing to casein there is a legible decrease for the desirable content of casein. She did not during the test period show any signs of a clinical mastitis until the very last day when her cell counts was as high as 21 500 000 cells/ml in her left rear udder quarter.

Even though we found these significant differences in udder quarters, the differences are at such a low level that it makes it hard to believe it could have an impact on the results. Still, SCC seems to affect the milk composition in healthy udder quarters in this trial very similar to what Berglund *et al*. (2007) found.

Conclusions

- Because of cows being individuals, the different parameters often vary more for cow than for day-to-day, udder quarter and week of lactation.
- Milk Yield is the one parameter with the largest variation and it varies the most at udder quarter level.
- Lactose varies the least so a change in lactose content could be a sign of changes in the milk production and health status.
- There are significant differences in milk composition between udder quarters within cows but much smaller for those cows with low SCC.

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