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Chemical Composition and Processability of Milks from Herds with Different Calving Patterns

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1. Summary

The primary objective of this project was to research the detailed composition and processability of milk produced by spring calving, autumn calving and combined herds. This information is required as it may influence the future value of milk and allow informed decisions to be made by the dairy industry regarding diversification of the present product range. Specific issues to be established included

(i) the processing characteristics of late lactation milk from well managed spring and autumn-calved herds and the lactation stage cut-off point for product manufacture from such milks, based on quality and functionality,

(ii) the processing characteristics of mid and early lactation milk from well managed spring and autumn-calved herds, respectively,

(iii) the volume of early lactation milk required to mix with late lactation milk in order to maintain milk processing quality and

(iv) the difference (if any) in processing characteristics of bulk spring/autumn milks mixed at the farm or the processing plant.

By maintaining spring-calved cows on a good plane of nutrition in late lactation, milk yield, composition and processing characteristics and quality of Mozzarella cheese can be sustained until late November/early December (~275 DIM [days in milk]). In general there were no notable adverse effects of stage of lactation on the composition or processing characteristics of late lactation autumn milk or on the quality and functionality of Mozzarella cheese made from it, during the lactation period 240-330 DIM (up to mid/late August).

Early lactation autumn and mid lactation spring milks generally had better processing characteristics than late lactation spring and autumn milks, respectively. Combining early lactation milk with late lactation milk improved the processing characteristics of the late lactation milk and overcame any processing problems associated with it.

Approximately 70 % of autumn milk is required in a spring/autumn bulk milk to maintain processability and to improve the milk sufficiently for cheesemaking from 275 DIM of the spring lactation.

Mixing of late lactation spring milk with early lactation autumn milk at the factory from separate herds would result in similar processing characteristics to milk from a mixed spring and autumn calving herd.

In conclusion, the manufacturing period for spring milk in late autumn/winter may be extended by good herd management practices on-farm. In addition, the production of autumn milk in combination with this allows a further extension of the manufacturing period. Alternatively, autumn milk may be used exclusively for short shelf-life products. This information suggests that it is possible to overcome the traditional milk processing problems experienced due to the seasonal pattern of milk production in Ireland.

2. Introduction

At present, there is a major constraint on the production of commodity products and the development and production of short/medium shelf-life products due to the poor quality and low volumes of milk available during the Winter months.

With a predominantly spring calving national herd, 85% of manufacturing milk is produced between March and October and a peak:trough ratio of 8:1 prevails. This seasonal supply results in a wide variation in the composition of milk throughout the year. These changes are in turn associated with defects in product quality, particularly in the late lactation period between October and December.

These defects include inconsistencies in butter flavour, rennet coagulation properties, cheese composition, yield and quality. Such variations in milk composition and product quality are associated with many factors including lactation stage, diet allowance and quality, herd management, milking practices and storage conditions at the farm.

Since product mix is determined largely by the seasonality of supply, the current product mix in Ireland is mainly orientated towards commodity products. The dairy industry has also responded to EU supports (which have concentrated on commodity products) in its product profile; up to 68 % manufacturing milk is being processed into butter.

However, the likelihood of future reductions in price supports, the increasing competitive advantage of New Zealand in commodity products and an expanding EU market for consumer products all suggest the need for diversification of the product portfolio of the Irish dairy industry. Both the Culliton Report (Industrial Policy Review Group, 1992) and the report of the Expert Group on the Food Industry (1993) proposed the view that seasonal production of milk needs to be reduced in parallel with the development of market led dairy products.

Thus, in order to improve efficiency and develop the dairy industry it is necessary to address two issues: (i) To what lactation stage can compositional and processing quality of milk be maintained by correct herd management in late lactation and (ii) could a wider range of dairy products be manufactured throughout the year with a mixture of milk from spring and autumn calving herds.

3. Chemical composition and processing characteristics of late-lactation milk from a spring-calved herd in the September to December period

The development of an efficient spring calving milk production system by *Dillon et al. (1995)* has produced milk of good composition and processing characteristics which has been used successfully to manufacture products in the mid-lactation period *(O'Brien et al., 1997; Guinee et al., 1998)*. This milk production system allows animals to end their lactation on a good plane of nutrition and at a higher milk yield than previously.

The objective of the current study was to monitor the composition and processing characteristics of milk and the yield and functionality

of mozzarella cheese manufactured from that milk, in the late lactation period of an efficient spring calving milk production system.

A herd of 26 cows with a mean calving date (MCD) of 16 February and a mean lactation number of 3 was established. Bulk milk from this group was collected and analysed weekly over an experimental period extending from 22 September to 21 December (13 weeks). Stocking rate was 2.48 cows/ha. Post-grazing sward surface height was 74 mm. Cows received 2 kg concentrate/day from 12 September onwards. Cows were indoors from 4 November onwards and had ad libitum access to good quality silage of 806 g/kg dry matter digestibility (DMD). The cows were dried off 8 weeks prior to calving or at a yield of ~6 kg milk/day. Milk yields of individual cows were measured at the morning and evening milkings on 3 d each week.

Bulk milk from two consecutive milkings weekly was sampled for gross and detailed compositional analysis and measurement of processing characteristics (fat, lactose, total protein, casein, casein number, non-protein N, whey protein, rennet coagulation properties [RCT-rennet coagulation time, K20-rate of curd aggregation and A60-curd firmness at 60 min], ethanol stability, free fatty acid [FFA] level, somatic cell count [SCC], polymorphonucular leucocyte [PMN] level, plasmin activity and plasminogen levels).

Bulk milk was collected at four consecutive milkings weekly until late November for Mozzarella cheese manufacture. The 13 weeks of the experiment were divided into three periods for statistical analysis: period 1, 22 September-2 November; period 2, 3 November-30 November; period 3, 1 December -21 December. There were six, four and three values for the various characteristics during periods 1, 2 and 3, respectively.

Table 1 Composition and processing characteristics of milk from spring-calved cows in late lactation

DIM*	Period 1 218-259	Period 2 260-287	Period 3 288-309	P1v'sP2 s.e.d.	P2v'sP3 s.e.d.
Milk yield, kg/c/d	17.0	13.4	10.8	1.10	1.12
Fat, g/kg	42.0	40.9	43.2	1.31	1.51
Protein†, g/kg	37.2	37.3	35.9	0.72	0.83
Lactose, g/kg	44.7	44.1	45.3	0.63	0.73
Total protein†, g/kg	37.1	37.0	35.7	0.83	0.96
NPN, g/kg	0.35	0.31	0.26	0.02	0.03
Casein, g/kg	28.3	28.3	27.3	0.57	0.66
Casein no., %	76.2	76.5	76.5	0.45	0.52
Whey protein, g/kg	6.7	6.8	6.8	0.36	0.41
RCT, min	19.8	20.5	20.2	1.66	2.04
K20, min	9.3	9.8	10.5	1.04	1.28
A60, mm	41.2	37.6	44.3	2.97	3.64
FFA, mmol/kg fat	5.94	14.90	19.20	2.950	3.41
Ethanol stability, %	73	69	69	2.7	3.1
SCC $x10^3$/ml	380	284	336	67.4	77.8
PMN $x10^3$/ml	173	150	286	49.6	57.2
Plasmin, AMC units/ml	0.33	0.37	0.39	0.056	0.065
Plasminogen, AMC units/ml	4.19	3.95	2.54	0.462	0.533
Ratio (Plasminogen:Plasmin)	13.5	11.1	6.7	2.100	2.425

**DIM=Days in milk*

†Protein, g/kg measured by NIR reflectance and total protein, g/kg measured by Kjeldahl

The composition and processing characteristics of milk from the spring herd in late lactation are shown in Table 1. Milk yield was reduced in period 2 ($p<0.01$) and period 3 ($p<0.05$). PMN level was increased and plasminogen reduced ($p<0.05$) in period 3 compared to period 2. While milk protein and casein concentrations were lower in period 3 compared to period 2 the effect was not significant and milk renneting properties were not affected. Generally the quality of Mozzarella cheese manufactured from this milk was maintained. The actual and moisture adjusted yields of cheese showed the same trend as casein with a non-significant increase in moisture observed between 275 and 287 DIM.

Despite variable grazing conditions from September onwards, cows were maintained on a good plane of nutrition. Cows had a daily herbage allowance of 21 kg DM (dry matter)/cow per day from 22 September until housing. In addition, concentrate supplementation from mid-September and good quality silage from housing in early November maintained milk yield and composition to the end of the trial. In conclusion, the compositional and processing quality of spring milk may be maintained up to December when good herd management practices are in place.

4. Chemical composition and processing characteristics of milk from spring and autumn calved herds in the August to December period

The previous study has shown that realistic and cost effective on-farm husbandry measures exist which can greatly reduce milk quality/processability problems in the late lactation period and that the manufacturing season can be extended to late November/early December. However, a supply of quality milk is required over the winter months to provide the opportunity for diversification into a wider range of products. This can be achieved by calving a proportion of the national herd in the autumn. The economic aspects of year round milk production have been researched *(Crosse et al., 1994)*. The present study was undertaken to confirm the results of the previous study on late lactation spring milk and to investigate composition, quality and processability characteristics of early lactation autumn milk and a combination of early and late lactation milks over the autumn/winter period.

Three herds of 26 cows each were established. The spring calved herd had a MCD of 22 February. The autumn calved herd had an MCD of September 28th. The mixed (spring/autumn) herd comprised 13 spring and 13 autumn calved cows. The experimental period extended from 5 August to 22 December (20 weeks). Cows were stocked at 2.56 cows/ha. Grass was not limiting. Spring calved cows received 2 kg concentrate/day from 11 October. Autumn calved cows received 4 kg concentrate/day while on grass and 8 kg/day when indoors on silage. All cows were indoors from 19 November onwards and were offered good quality silage of 755 g/kg DMD. Spring calved cows were dried-off 8 weeks prior to calving or at a yield of ~6 kg milk/day. Milk collection commenced on 5 August, 7 October and 14

October for spring, autumn and spring/autumn herd milks, respectively. The bulk milks were sampled after the am milking and analysed for gross and detailed composition and measurement of processing characteristics. Bulk milks from individual herds were also collected weekly until early December for Mozzarella cheese manufacture. The 20 weeks of the experiment were divided into three periods for statistical analysis: period 1, 5 August-13 October; period 2, 14 October-24 November; period 3, 25 November-22 December. There were ten, six and four values for the various characteristics during periods 1, 2 and 3, respectively.

Table 2 Composition of milk from spring and autumn -calved cows (August to December)

Spring, DIM* / Autumn, DIM	Period 1 164-233	Period 2 234-275 / 16-57	Period 3 276-303 / 58-85	P1v'sP2 s.e.d.	P2v'sP3 s.e.d.
Milk yield, kg/c/d					
Spring	17.8	13.3	12.0	1.02	1.22
Autumn		26.1	26.4		1.11
Spring/autumn		17.3	18.3		0.80
Fat, g/kg					
Spring	43.4	43.2	42.7	1.24	1.48
Autumn		42.2	44.3		1.30
Spring/autumn		46.5	46.6		0.90
Lactose, g/kg					
Spring	44.4	44.2	42.0	0.68	0.81
Autumn		46.8	47.2		0.26
Spring/autumn		47.5	46.9		0.16
Total protein, g/kg					
Spring	35.2	38.1	33.8	0.76	0.91
Autumn		34.2	33.2		0.50
Spring/autumn		36.9	35.3		0.52
Casein, g/kg					
Spring	26.7	28.7	25.9	0.56	0.68
Autumn		26.1	25.8		0.43
Spring/autumn		28.5	27.4		0.45
Casein no., %					
Spring	76.0	75.3	76.8	0.59	0.70
Autumn		76.4	77.7		0.55
Spring/autumn		76.9	77.4		0.21

**DIM=Days in milk*

Variation in milk composition and processability over time

Composition and processability of milk from autumn and spring-calved cows in early- and late-lactation and a combination of both are shown in Tables 2 and 3. Total protein and casein of spring milk were increased ($p<0.01$) in period 2 compared to period 1. This was accompanied by an improvement in K20 ($p<0.01$). Total protein and casein of spring milk were reduced ($p<0.001$) in period 3 compared to period 2 which was accompanied by a deterioration in RCT ($p<0.01$), K20 ($p<0.001$) and A60 ($p<0.01$). Total protein and casein of the spring/autumn milk was also reduced ($p<0.05$) in period 3 compared to period 2 and was accompanied by a deterioration in K20 ($p<0.01$). Composition and processing characteristics of autumn milk were unchanged in period 3, except for casein number which was increased ($p<0.05$).

Variation in composition and processability between milks

In the current study autumn milk had a higher casein number, lower FFA levels and generally better processing characteristics than spring milk. Combining autumn milk with spring milk resulted in a milk with processing characteristics similar to autumn herd milk.

Cheesemaking characteristics

There were no notable effects of stage of lactation up to 275 DIM, i.e. end of period 2, on rennet coagulation properties or on the composition or functionality of low-moisture Mozzarella cheese manufactured from spring milk. On extending the lactation period from 275 to 286 DIM (late November/early December), a higher cheese moisture of 2 % approximately, a softer cheese and lower chewiness in the melted cheese was observed. However, the use of autumn milk on its own or the blending of autumn milk with spring milk during this period overcame the problems associated with the spring milk.

Table 3 Processing characteristics of milk from spring and autumn-calved cows (August to December)

Spring, DIM* / Autumn, DIM	Period 1 164-233	Period 2 234-275 / 16-57	Period 3 276-303 / 58-85	P1v'sP2 s.e.d.	P2v'sP3 s.e.d.
RCT, min					
Spring	25.6	21.7	33.3	2.58	3.08
Autumn		18.5	19.5		3.20
Spring/autumn		18.4	22.8		2.13
K20, min					
Spring	11.8	8.2	15.2	1.12	1.34
Autumn		8.3	10.5		1.73
Spring/autumn		7.1	9.8		0.78
A60, mm					
Spring	37.3	43.8	30.7	3.41	4.08
Autumn		38.6	44.7		3.20
Spring/autumn		46.8	46.1		3.05
FFA, mmol/kg fat					
Spring	10.43	9.96	11.1	1.225	1.464
Autumn		7.39	6.31		0.676
Spring/autumn		6.98	6.47		0.396
Calcium,mg/l					
Spring	1129	1308	1222	57.5	63.0
Autumn		1251	1216		36.3
Spring/autumn		1295	1287		34.1
Phosphorus, mg/l					
Spring	515	649	599	88.8	97.3
Autumn		667	709		53.5
Spring/autumn		671	680		37.7
SCC, x 10^3/ml					
Spring	333	411	329	27.5	32.9
Autumn		237	351		50.5
Spring/autumn		332	373		48.1

*DIM=Days in milk

In general, the processability of spring milk deteriorated from 275 DIM onwards. This deterioration (which was not observed in the previous study) may be due to the lower daily herbage allowance (18 kg DM/cow/day), the later concentrate supplementation (11 October) and housing of cows (19 November). Changes in total protein and casein were closely associated with changes in renneting properties. However, autumn milk had similar total protein and casein levels to spring milk in period 3 but had superior renneting characteristics. This may be due to a deterioration in casein quality in late lactation spring milk which may occur as a consequence of increased proteolytic activity. This is indicated by the increased PMN and reduced plasminogen levels observed in spring milk during the latter part of the previous study. In conclusion, compositional and processing quality of spring milk was maintained up to 275 DIM and deteriorated thereafter. The autumn milk had superior processing characteristics than spring milk and combining autumn milk with spring milk resulted in a milk with processing characteristics similar to autumn milk.

5. Effect of blending milks from cows with different calving patterns on milk processability (October to December)

The previous study has indicated that milk from a mixed herd of 50 % spring and 50 % autumn calving cows maintains good milk processing characteristics and allows the manufacture of quality Mozzarella cheese during late November/early December, due to the superior processing quality of the early lactation milk. The present study was undertaken to compare the effect of mixing early and late lactation milk in the laboratory (simulating mixing at the processing plant) with mixing at farm level and to establish the volume of early lactation milk required to maintain milk processability as the end of the spring calvers lactation is approached.

The spring, autumn and spring/autumn herds having MCD of 22 February, 28 September were used. The experimental period extended from 14 October to 22 December (10 weeks). The herds were managed as outlined in the previous study. Each week, an

'artificial' bulk of spring and autumn milk was formed from equivalent volumes to those constituting the spring/autumn herd bulk milk. Spring and autumn milks were also bulked in proportions of 70:30, 50:50 and 30:70, respectively. The spring, autumn and spring/autumn herd milks, the 'artificial' bulk and the 3 spring:autumn bulks were analysed for gross and detailed composition and measurement of processing characteristics.

The effect of blending spring and autumn milks on composition and processability is shown in Tables 4 and 5. Fat, lactose, total protein and casein concentrations were lower ($p<0.05$) in the 'artificial' bulk milk than in the mixed herd bulk milk. Casein number, FFA content, formagraph properties and SCC levels were similar in both bulk milks (Table 4). Fat and lactose concentrations of spring milk were lower ($p<0.001$) than those of autumn milk; the addition of 50 and 30 % autumn milk increased ($p<0.05$) fat and lactose concentrations of spring milk, respectively (Table 5). The RCT, K20 and A60 values for spring milk were poorer that those of autumn milk ($p<0.001$); the addition of 30, 30 and 50 %, respectively, of autumn milk improved ($p<0.01$) the renneting properties of spring milk. Similarly the addition of 30 and 50 %, respectively, of autumn milk to the spring milk improved FFA ($p<0.01$) and SCC ($p<0.05$) levels in spring milk.

The compositional differences between the bulks mixed at farm and laboratory level were probably due to different cows in the herds forming the bulks. Good processing characteristics of late lactation spring milk can be maintained up to 275 days of lactation by good management, subsequently the addition of 30 or 50 % of autumn milk will improve the processability of the mix but 70 % autumn milk is required to maintain milk processability at pre-275 DIM level. In conclusion, mixing of late lactation spring milk with early lactation autumn milk at the factory from separate herds would result in similar processing characteristics to a mixed spring and autumn calving herd, and 70 % autumn milk would be required for mixing with late lactation spring milk (which has deteriorated in processability) in order to improve that milk sufficiently for cheesemaking.

Table 4. Blending spring and autumn milks at farm and laboratory

	Bulk (Farm)	Bulk (Artificial)	s.e.d.
Fat, g/kg	46.6	44.3	0.497
Lactose, g/kg	46.9	45.7	0.531
Total protein, g/kg	35.3	33.5	0.485
Casein, g/kg	27.4	25.9	0.465
Casein no., %	77.4	77.2	0.50
Whey protein, g/kg	6.3	6.0	0.15
RCT, min	22.9	23.0	2.54
K20, min	9.8	10.1	0.83
A60, mm	46.1	42.1	3.15
FFA, mmol/kg fat	6.47	6.62	0.764
SCC x 10^3/ml	373	348	34.7

Table 5. Blending varying proportions of spring and autumn milks

	Spring	Autumn	70S:30A	50S:50A	30S:70A	s.e.d.
Fat, g/kg	42.7	44.3	43.4	43.8	44.0	0.50
T. protein, g/kg	33.8	33.2	33.8	33.9	33.5	0.49
Lactose, g/kg	42.0	47.2	43.4	44.4	45.6	0.53
Casein, g/kg	25.9	25.8	26.0	26.2	26.6	0.47
Casein no., %	76.8	77.7	76.9	77.2	77.5	0.50
Whey protein, g/kg	6.2	6.0	6.1	6.1	5.9	0.15
RCT, min	33.3	19.5	24.5	23.2	21.3	2.55
K20, min	15.2	10.5	13.2	10.8	10.6	0.83
A60, mm	30.8	44.7	37.2	42.8	44.6	3.15
FFA,mmol/kg fat	11.11	6.31	8.13	7.76	6.48	0.764
SCC x 10^3/ml	411	237	380	344	300	30.6

6. Chemical composition and processing characteristics of milk from spring and autumn calved herds in the May to August period

The two previous studies have indicated that mixing early lactation autumn milk with good quality late lactation milk reduced the compositional variation of the total supply and improved its processing characteristics. At present, a number of processing outlets are contracting autumn milk from their suppliers for Mozzarella cheese, fresh cheese, etc. However, the quality of late lactation autumn milk produced during the summer months has not been investigated. This study was undertaken to establish the chemical composition and renneting properties of late lactation autumn milk and of a mixed spring and autumn herd milk in mid to late summer.

The autumn calved herd (MCD of 28 September), the spring calved herd (MCD of 16 February) and the autumn/spring herd were used. The experimental period extended from 26 May to 24 August (13 weeks). Stocking rate was 2.48 cows/ha. Grass was not limiting. Autumn calved cows were dried-off 7 weeks prior to calving or at a milk yield of ~6-7 kg milk/day. The bulk milks (consisting of 1 pm and 1 am milking) were sampled once weekly after the am milking and analysed for gross and detailed composition and measurement of processing characteristics. Bulk milk from the individual herds was also collected for Mozzarella cheese manufacture. The duration of the experiment was divided into two periods for statistical analysis: period 1, 26 May-13 July and period 2, 14 July-24 August. There were seven and six values for the various characteristics during periods 1 and 2, respectively.

Variation in milk composition and processability over time

The composition and processability of late lactation autumn and mid lactation spring milks are shown in Tables 6, 7 and 8. A reduction in casein number ($p<0.01$) and an increase in SCC level ($p<0.05$) in autumn milk was observed in period 2 compared to period 1. PMN levels and plasmin concentration were also increased ($p<0.05$) in autumn milk in period 2.

Variation in composition and processability between milks
Casein number and SCC level were lower ($p<0.001$) and higher ($p<0.001$), respectively, in autumn compared to spring milk in period 2. These values were increased ($p<0.001$) and reduced ($p<0.001$) by mixing with spring milk. PMN level and plasmin concentration were higher ($p<0.01$) in autumn compared to spring milk in period 2. These values were reduced ($p<0.01$) by mixing with spring milk.

Cheesemaking characteristics
The late lactation autumn milk had higher levels of milk fat, protein, casein and whey protein and these compositional differences appeared to be reflected in non-significantly higher actual Mozzarella cheese yield. The Mozzarella cheese manufactured from the autumn milk had higher levels of proteolysis, was softer and had a lower apparent viscosity (chewiness) on melting at most ripening times throughout most of the investigation period. However, the differences were small and probably would not markedly impact on quality.

In general there were no notable adverse effects of stage of lactation during the lactation period 240-330 DIM on composition or processing characteristics of autumn milk, except for casein number, SCC and PMN levels and plasmin concentration. Where differences in these characteristics were observed between autumn and spring milks, the spring/autumn mix milk had superior processing characteristics compared to the 50:50 mix of spring and autumn milks. Because of a later MCD in their subsequent lactation, the autumn herd were milked for longer than would be desired. However, they maintained a relatively high milk yield up to the end of the lactation.

In conclusion, the compositional and processing quality of late lactation autumn milk was maintained to the end of lactation and did not adversely affect cheesemaking characteristics. The functional differences between cheeses manufactured from spring, autumn and spring/autumn milks were small and not likely to impact on quality. Blending of autumn milk with spring milk generally improved the processing quality of the autumn milk further.

Table 6 Composition of milk from spring and autumn-calved cows (May to August)

Spring, DIM* / Autumn, DIM	Period 1 99-147 240-288	Period 2 148-189 289-330	s.e.d.
Milk yield, kg/c/d			
Spring	25.0	20.6	0.41
Autumn	17.5	14.0	0.62
Spring/autumn	21.9	17.7	0.59
Fat, g/kg			
Spring	36.3	38.4	0.06
Autumn	42.2	44.0	0.14
Spring/autumn	40.4	41.8	1.12
Protein, g/kg			
Spring	34.3	34.4	0.45
Autumn	36.4	36.9	0.33
Spring/autumn	35.5	35.8	0.33
Lactose, g/kg			
Spring	46.7	45.3	0.39
Autumn	45.4	45.5	0.27
Spring/autumn	46.8	45.9	0.61
Total protein,g/kg			
Spring	33.7	34.0	0.47
Autumn	35.8	36.4	0.38
Spring/autumn	34.8	35.3	0.49
Casein, g/kg			
Spring	26.1	26.3	0.34
Autumn	27.5	27.4	0.27
Spring/autumn	27.3	27.2	0.33
Casein no., %			
Spring	77.6	77.3	0.49
Autumn	76.8	75.5	0.39
Spring/autumn	78.3	77.1	0.54

*DIM=Days in milk

Table 7 Processing characteristics of milk from spring and autumn-calved cows (May to August)

Spring, DIM* / Autumn, DIM	Period 1 99-147 / 240-288	Period 2 148-189 / 289-330	s.e.d.
RCT, min			
Spring	23.8	22.5	1.22
Autumn	23.9	20.7	1.02
Spring/autumn	25.0	21.8	1.40
K20, min			
Spring	11.4	11.9	1.17
Autumn	10.1	9.0	0.74
Spring/autumn	13.1	11.8	1.04
A60, mm			
Spring	36.3	36.5	2.77
Autumn	40.0	38.8	3.30
Spring/autumn	37.5	35.7	2.36
FFA, mmol/kg fat			
Spring	9.46	6.73	0.868
Autumn	11.44	8.01	1.265
Spring/autumn	8.92	7.76	0.727
SCC $\log_{10}$/ml			
Spring	5.48	5.47	0.050
Autumn	5.60	5.74	0.049
Spring/autumn	5.60	5.45	0.060
PMN x 10^3/ml			
Spring	226	177	42.1
Autumn	230	380	59.1
Spring/autumn	300	203	31.1
Plasmin, AMC units/ml			
Spring	0.129	0.173	0.0255
Autumn	0.199	0.295	0.0361
Spring/autumn	0.142	0.238	0.0325
Plasminogen, AMC units/ml			
Spring	2.74	3.16	0.340
Autumn	2.84	3.09	0.269
Spring/autumn	2.70	3.15	0.345
Ratio (Plasminogen:Plasmin)			
Spring	21.69	19.13	1.876
Autumn	14.74	10.86	1.354
Spring/autumn	19.7	16.8	2.960

*DIM=Days in milk

Table 8. Blending spring (mid lactation) and autumn (late lactation) milks (May to August)

	Autumn	Spring	Autumn/Spring	50A:50S	s.e.d.
Fat, g/kg	44.0	38.4	41.8	40.7	0.87
Protein, g/kg	36.9	34.4	35.8	35.8	0.28
Lactose, g/kg	45.5	45.3	45.9	45.5	0.37
Casein, g/kg	27.4	26.3	27.2	26.8	0.24
RCT, min	20.7	22.5	21.8	21.0	1.08
K20, min	9.0	11.9	11.8	9.9	0.92
A60, mm	38.8	36.5	35.7	37.1	1.37
FFA, mmol/kg fat	8.01	6.73	7.76	7.32	0.398
SCC $\log_{10}$/ml	5.74	5.47	5.45	5.60	0.049
PMN x 10^3/ml	380	177	203	307	52.3
Plasmin, AMC units/ml	0.295	0.173	0.203	0.238	0.0150

7. Conclusions

1. By maintaining spring-calved cows on a good plane of nutrition in late lactation milk yield, composition and processing characteristics and quality Mozzarella cheese can be sustained until late November (275 DIM).

2. Changes in total protein and casein were closely associated with changes in renneting properties. There may be evidence of a deterioration in casein quality which may occur as a consequence of increased proteolytic activity in late lactation spring milk.

3. Early lactation autumn milk had better processing characteristics than late lactation spring milk. Combining autumn milk with spring milk resulted in a milk with processing characteristics similar to autumn herd milk.

4. Casein concentration was closely associated with cheese yield. There were no notable effects of stage of lactation up to 275 DIM on the composition or functionality of low-moisture Mozzarella manufactured from spring milk but cheese quality deteriorated subsequently. Blending of autumn milk with spring milk during this period overcame the problems associated with cheesemaking from the spring milk.

5. Mixing of late lactation spring milk with early lactation autumn milk at the factory from separate herds would result in similar processing characteristics to a mixed spring and autumn calving herd. The addition of 30 % of early lactation autumn milk improved the processability of the late lactation spring milk but 70 % autumn milk was required to maintain milk processability at pre-275 DIM level and to improve the milk sufficiently for cheesemaking.

6. In general there were no notable adverse effects of stage of lactation during the lactation period 240-330 DIM on composition or processing characteristics of autumn milk.

7. The quality of Mozzarella cheese manufactured from late lactation autumn milk deteriorated slightly but the differences were small and probably would not markedly impact on quality.

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