Effect of blending Jersey and Holstein-Friesian milk on Cheddar cheese processing, composition and quality

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Interpretative Summary

Effect of Jersey milk on Cheddar cheese.

By Bland et al.,

Jersey milk is believed to improve cheese yield but to reduce cheese quality. Thus, the effect of Jersey milk used at different inclusion rates on Cheddar cheese production was examined. Jersey milk increased cheese yield, cheese fat content and decrease the level of moisture in proportion to inclusion rate. Jersey milk also increased the total grading score in winter and the yellowness of the cheeses in summer, however no effect on cheese texture was detected and quality was not decreased. Including Jersey milk is thus a valid way of improving Cheddar cheese yield.

Effect of blending Jersey and Holstein-Friesian milk on Cheddar Cheese Processing, Composition and Quality.

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ABSTRACT

The effect of Jersey milk use solely or at different inclusion rate in Holstein-Friesian milk on Cheddar cheese production was investigated. Cheese was produced every month over a year using non- standardized milk consisting of 0%, 25%, 50%, 75% and 100% Jersey milk in Holstein-Friesian milk in 100L vat. Actual, theoretical and moisture adjusted yield increased linearly with percentage of Jersey milk. This was also associated with increased fat and protein recoveries and lower yield of whey. The composition of whey was also affected by the percentage of Jersey milk with lower whey protein and higher whey lactose and solids. Cutting time was lower when Jersey milk was used but the cutting to milling time was higher due to slower acidity development, hence overall cheese making time was not affected by the use of Jersey milk. Using Jersey milk increased cheese fat content in autumn, winter and spring and decreased cheese moisture in spring and summer. Cheese protein, salt and pH levels were not affected. Cheese was analyzed for texture and color and it was professionally graded at 3 and 8 months. The effect of Jersey on cheese sensory quality was an increase in cheese yellowness during summer and a higher total grading score at 3 month in winter, no other difference in cheese quality was found. The study indicates that using Jersey milk is a valid method of improving Cheddar cheese yield.

Key Words: Jersey, Cheddar, cheese yield, cheese quality.

INTRODUCTION

Milk composition has an important influence on the technical and economic efficiency of cheese making (Storry et al., 1983; Sundekilde et al., 2011). Milk suitability is modified by many factors such as diet, breed, protein genetic variant, health, season and rearing condition. The effects of breed and protein genetic variants, which are inter-related, have been subject to increased interest (Barowska et al., 2006). The Jersey, Brown Swiss, Montbéliarde and other high milk solids yielding breeds have been shown to have a positive impact on cheese-making (Lucey and Kelly, 1994).

The Jersey (J) breed is the second most important dairy breed in the world and it has been suggested that using J milk would improve the efficiency of the cheese making sector in Canada (Thompson, 1980), Wales (Hayes, 1983) and the USA (Capper and Cady, 2012) due to improved longevity, superior udder health, higher cheese yield, reduce feed and water requirement, and an overall reduction in the carbon footprint of Cheddar cheese production.

However, the use of J milk for Cheddar cheese production, while common, is still limited both in terms of the quantity used by individual cheese makers and the number of cheese makers using it. This could be linked to the lack of information available to cheese makers on the effects of using J milk on the cheese making process and cheese yield. Estimates of cheese yield from J were based mainly on theoretical cheese yield equations and theoretical increases ranged from 21% to 32% compared to Holstein-Friesian (H-F) (Lundstedt, 1979; Geary et al., 2010; Capper and Cady, 2012). The only practical study measuring the actual improvement in yield did so using standardized milk and showed an increase of only 10% (Auldist et al., 2004).

There also appears to be a presumption in the industry that J milk has a negative impact on cheese quality. Cheese quality can be firstly defined as the compliance to legislation (International Food Standards, 2003) which specifies a minimum level of fat and maximum moisture. Secondly quality can be defined as the cheese having the desirable organoleptic properties at the time of consumption, which is commonly, assessed using grading at the cheese factories. In the case of J cheese, it is believed to have a higher moisture content due to the lower protein to fat ratio, resulting in lower syneresis (Bliss, 1988) and a buttery, weaker texture and rancid taste due to the higher fat content and larger, more fragile fat globules, causing early lipolysis (Cooper et al., 1911). However, these fears of negative impact were not supported by past data. Auldist et al. (2004) found that the moisture content and composition of J and H-F Cheddar cheeses made with standardized milk were not different with the exception of a higher salt concentration and lower pH and ash concentration for J cheese. On the other hand, Whitehead (1948) found that Cheddar cheese from non-standardized J milk had a lower moisture content and the cheese was also firmer. However, the cheese making process also had to be adapted to account for differences in acidity development and syneresis. Unfortunately, no information regarding yield was provided. Thus there is a lack of information on the effect of J milk on Cheddar cheese making, composition and sensory properties limiting its use on a commercial scale.

This study therefore investigated the effect of J milk, and blends of J and H-F, on Cheddar cheese production with the objective of finding the optimal inclusion rate of J milk in H-F milk for improving yield without reducing the quality of the cheese.

MATERIALS AND METHODS

Experimental Design

The experiment was carried out three times each season between September 2012 and November 2013. The seasons were defined as autumn (September, October and November), winter (December, January and February), spring (March, April, May) and summer (June, July, August).

Samples from the combined evening and morning milking were obtained from the University herd of H-F cows (CEDAR, Reading, UK) and two J farms (Brackley and Slough, UK) and transported to the pilot-scale cheese making facility at the University of Reading. J milk was blended with H-F milk at 0%, 25%, 50%, 75% and 100% J in H-F milk. Due to time limits, the ratios 25% and 75% were performed on alternate repeats. Thus, 4 samples were analyzed on each repeat, giving a total of 48 observations.

Milk Composition

Analysis for fat, protein, lactose, casein, urea content and freezing point depression and Somatic Cell Count (SCC) were performed by the National Milk Laboratory (Glasgow, UK) using an infrared milk analyzer. The ratio of protein to fat (P/F) and casein to protein (C/P) were calculated from this data. Size of casein micelles (CMS) and size of fat globules (mean volume D(4.3), mean surface area D(3.2), average size D(0.5) and span) were determined using a Zetasizer 500 (Malvern Instruments Ltd, Worcestershire, UK) and a Mastersizer S 2000 (Malvern Instruments Ltd, Worcestershire, UK) respectively. Calcium ion concentration (Ca^{2+}) was determined using a Ciba Corning 634 ISE Ca^{2+}/pH Analyzer (Bayer Ltd, Newbury, UK) using the method of Lin (2002). Milk pH was measured using a FE20 desktop pH meter (Mettler-Toledo Ltd., Leicester, UK) and titratable acidity was measured using an acid-base titration with a Titralab automatic titrator (Radiometer Analytical, Villeurbanne, France) titrated with 0.1 M NaOH until pH 8.70 was reached, and expressed as Dornic acid (°D). All analyses were performed within 24 h of milk collection.

Cheese making process

On each occasion four vats of cheese were made over two days. Bulk milk was pasteurized, but not standardized, as standardization was not carried out by the large commercial cheese plant on which the cheese making process is based. Approximately 80 kg of milk was placed into each vat and warmed to 33°C. Starter (RSF 638, Chr. Hansen Laboratories A/S, Hørsholm, Denmark) was added at 0.0269 g/kg of milk and left to ripen for 35 min. Coagulant Marzyme 15 PF (Danisco, Dupont Company, Hertfordshire, UK) was then added at 0.2566 ml/ kg after being diluted fivefold with water. Curd was cut at the cheese maker's judgment. The curd and whey was heated to 39°C in 45 min and then left to scald at this temperature for 50 min. Whey was then drained and the cheddaring process started when the TA reached 0.20 ± 0.05 °D. Curd was milled at TA 0.30 ± 0.05 °D and salt added at 24 g/ kg of curd. Salted curds were left to cool and then filled into round moulds of 5 kg and prepressed at 3 Pa up to 7 Pa, and left to press overnight at 7 Pa.

The yield and composition of the whey was determined from the whey collected between drainage until milling (Lactoscope, Advanced Instruments Inc., Drachten, Netherlands). Yield was calculated from the weight of milk placed in the vat, and the weight of cheese after pressing and vacuum packing. Yield was expressed both in actual yield kilo of cheese per 100kg of milk, and adjusted yield using a fixed moisture content of 37%.

Theoretical yield was also calculated using milk composition data and the Van Slyke equation (Van Slyke and Price, 1949). Finally cheese yield efficiency was calculated using the actual yield as percentage of theoretical yield.

Additionally, fat and protein recoveries and losses were calculated using the composition and quantity of milk and whey based on the principle described by Banks et al. (1981). Time of addition of rennet to cutting, cutting to milling and starter to milling was recorded.

Cheese composition

Cheese was analyzed for fat, protein, moisture, pH and salt 1 month after production. Fat content analysis was carried out using the Gerber method as described by Grandison and Ford (1986) and the ISO standard 2446/IDF 226 using an Astell Hearson Gerber centrifuge (Astell Scientific, London, United Kingdom).

Protein content was determined by the Kjeldahl nitrogen method based on the ISO 17837:2008 using the BÜCHI digestion K-424 unit (BÜCHI Labortechnik AG, Postfach, Switzerland) and a BÜCHI distillation unit 323 (BÜCHI Labortechnik AG, Postfach, CH). The moisture content was determined by weighing 10±0.005g of ground cheese into a dish with 20±0.5g of sand, along with lid and rod, which had been previously dried for 1 hour at 105°C and then pre-weighed (±0.0001 g). The sample was then put into an oven to dry for 23h hours at 105°C and the loss in weight recorded. A Titralab automatic titrator (Radiometer Analytical, Villeurbanne, France) was used to assess salt concentration in cheese. A sample (5 ± 0.001 g) of ground cheese was mixed with 100ml of water at 40°C and a 50 ml aliquot was sampled. To this aliquot 5ml of 1M nitric acid was added and then it was titrated using a combined silver / mercurous sulphate metal probe MC609/Ag (Radiometer Analytical, Villeurbanne, FR) with silver nitrate 0.1M to an endpoint of -100Mv. The pH of cheese samples was measured with a Thermo Orion star A111 benchtop pH meter (Thermo Fisher Scientific Ltd, Loughborough, UK) using a specially designed cheese FoodCare pH combination pH probe FC240B (Hanna Instruments Ltd, Leighton Buzzard, UK). All analyzes were carried out in triplicate at room temperature (20 ± 0.5°C).

Sensory analysis

The cheese sensory properties were evaluated after 3 months of ageing. The texture of the cheese was analyzed using Texture Profile Analysis (TPA) as developed by Szczesniak (1963) and Friedman et al. (1963) with a texture analyzer (Model TA-XT2, Stable Micro Systems, Godalming, U.K.). Samples were cut into cylinders of 22 mm diameter and 22 mm height (Halmos et al., 2003) after being tempered to room temperature in a vacuum pack overnight. The TPA parameters recorded were: hardness, cohesiveness, springiness, and resilience. The parameters were 30% compression at a speed of 50mm/s (Shama and Sherman, 1973) and 5 s delay between compressions, this was done in triplicate.

Color was analyzed using a ColorQuest II spectrophotometer (HunterLab, Virgina, US). Cheese samples were prepared into cubes (5x5x3 cm) and analyzed using the Commission on Illumination Standard (CIE) Illuminant D65 lamp. Results are given as a CIE L*a*b color scale and color differences (ΔE^*_{ab}) were calculated (Fernández-Vázquez et al., 2011). Analysis was carried out in triplicate

Cheese grading was carried out at 3 and 8 months according to the standard UK grading scheme (NACEPE) awarding points for flavor and aroma, body and texture, color and appearance with regard to standard Cheddar cheese required by retailers. On each occasion a minimum of three graders were used.

Statistical analysis

Data were subject to ANOVA and Tuckey HSD using SPSS PASW Statistics 21.0 to detect any statistical differences between inclusion rates. Seasonal variation effects were tested the same way. Differences were considered significant at $P < 0.05$.

RESULTS AND DISCUSSION

Milk composition

(**Table 1**)

Means, ranges and SE for each blends are presented in Table 1. The range and differences in composition are in agreement with others studies (Auldist et al., 2004; Barowska et al., 2006; Czerniewicz et al., 2006). The J milk contained significantly higher levels of all components except lactose, urea, calcium ions, D(3.2), fat globule size span and pH which were not significantly different. In addition, the protein to fat and the casein to protein ratio and CMS were higher in H-F milk. This difference in protein to fat and casein to protein ratio would not be representative of all cheese milk due to the increasingly common standardization of milk to a set protein to fat or casein to fat ratio. However, not standardizing enabled the evaluation of the effect of increased fat proportion in the cheese, which is often believed to be the cause of poor cheese quality. In terms of the effect of season on milk composition (Table 1), only the fat and protein content was modified, for both breeds, with the lowest level found of both components in summer and the highest level in winter but no difference in spring and autumn ($P< 0.05$).

Cheese making process

(Table 2)

Table 2 presents the results of the effect of J milk on the cheese making process. The actual, theoretical and moisture adjusted yield of cheese were significantly improved by the inclusion of J milk. Actual yield was increased by up to 34.6% more when using 100% J milk compared to H-F (Table 2). This is consistent with the deterministic model based on a yield equation of Lundstedt (1979) which found an increase of approximately 32%, but was higher than the estimates of Geary et al. (2010) and Capper and Cady (2012) which found respectively increases of 21% and 23%. However, this was due to the J milk composition being lower in protein and fat content than in the previous deterministic model. Auldist et al. (2004) showed an increase in yield of 10% when using standardized J milk. Theoretical yield predicted a smaller increase in yield (17.74%) which is lower than the results of the previously cited research (Lundstedt, 1979; Geary et al., 2010; Capper and Cady, 2012). This could be due to the way casein was measured. In the current study casein level was analyzed whereas in the deterministic model it was calculated from protein level using higher casein to protein ratio (0.8) than what was found in the current study (0.73-0.77). Seasonality variations were found for the theoretical yield, in winter and spring no difference in theoretical yield between inclusion rates were found, while in autumn and summer the theoretical yield increased with increased J milk percentage. This disagrees with actual yield values where the difference between H-F and J was constant throughout the year (Figure 1) due to similar seasonal effect on actual yield for both breeds.

(**Figure 1**)

Differences between actual yield and yield moisture adjusted to 37% were found only for H-F cheese which had lower moisture adjusted yield.

Yield of whey was decreased when J milk was added to H-F milk at rate of 50% or over, with the exception of summer where no difference in whey quantity was found. This is consistent with Whitehead (1948) who found J curd to have improved syneresis compared to H-F. Following the same cheese-making process, J curd retained 25% more whey. This is in accordance with a higher casein content improving syneresis. However, the higher content of fat and bigger globules would be expected to decrease syneresis rate (Guinee et al., 2007). This indicates that protein concentration and size of micelles compensate for the higher fat content and bigger fat globules found for J milk.

Composition of whey was modified by a high inclusion of J milk with protein decreasing and lactose and solid increasing with inclusion of J milk. However, there was some seasonal variation in the phenomenon, in particular, the level of protein was found not to be different in spring and summer, while the level of lactose was not significantly different in autumn and winter and level of solids not different in autumn and summer. The concentration of fat in whey was not affected by inclusion of J milk overall, but was found to be higher in autumn and winter.

The recovery rate of protein and fat was improved when J milk was used solely, but this was highly affected by season, in agreement with the study of Banks et al. (1984a) for fat, but not for protein. This study also found higher recovery value than in the present study which is believed to be due to a lower efficiency on small scale production.. No differences in recoveries were found in autumn and in winter.

The time to cutting was lower when J milk was added at 50% or higher throughout the year. This is in accordance with the shorter coagulation time and higher curd firming rate of J milk reported in several other studies (Okigbo et al. 1985; Barlowska et al. 2006; Kielczewska et al. 2008; Frederiksen et al. 2011; Jensen et al. 2012). The time from cutting to milling was increased for 100% J milk due to a lower acidity development, which was also reported by Whitehead (1948) who advised the use of more starter to overcome this problem. However, this only occurred in the summer, which is in agreement with Banks et al. (1984a). Overall, the total cheese making time was not different between inclusions rates, the faster coagulation time with J milk compensating for the longer acidification time.

Including J milk significantly modified the Cheddar cheese process. The increase in Cheddar cheese yield was linear and was at its maximum when J milk was used solely. The fat and protein recoveries were also improved but no statistical differences were found when more than 25% of J milk was used. Whey quantity and composition was modified by J milk inclusion aswas the cutting and acidification time, but this was not deemed to affect negatively the cheese making process. From these results the use of J milk solely seemed to be the most efficient way of producing Cheddar cheese.

Cheese composition

(Table 3)

The cheeses were analyzed for fat, protein, moisture, salt and pH, and only fat and moisture were modified by the inclusion of J milk (Table 3). This is in agreement with the study of Auldist et al., (2004) which found little difference in cheese composition, however, changes in pH and salt were observed, which were not seen in the current study. All cheeses were above the legal minimum standard for fat content and below the legal maximum standard for moisture content and the fat in dry matter was also always above the recommended 50% for good quality Cheddar cheese (Lawrence and Gilles, 1980). However at 100% J milk, the fat in dry matter (58.21 ± 0.54%) was slightly above the recommended range 50-57%, which could increase the chance of downgrading (O'Riordan and Delahunty, 2003). Fat increased with the inclusion of J milk in autumn, winter and spring (Figure 1). This is consistent with a higher level of casein and larger MFG improving fat retention as well as seasonal effects (Banks et al., 1984b, 1986).

(**Figure 2**)

Moisture was reduced when J milk was used in spring and summer (Figure 2). Whitehead (1948) also found moisture to be decreased when J milk was used, due to higher syneresis, and noted that similar moisture could readily be achieved through the adaptation of the scalding temperature. The moisture in non-fat substance was not found to be different between inclusion rates, but the levels were slightly higher than that considered as optimal for Cheddar cheese (50-56%) by Banks et al. (1984b).

(**Figure 3**)

Cheddar cheese made from J milk complied with current legislation on Cheddar cheese composition.

Cheese sensory properties

From all the sensory properties studied, including texture, color and professional grading, only the color and total grading scores were modified by the inclusion of J milk. This lack of difference in sensory properties is supported by Whitehead (1948), except that the latter study found firmness to be greater in J cheese which was not the case in our study. The lack of effect of J milk on texture is surprising as a the increase in fat in dry matter (Table 3) should have decreased cheese firmness (Martin et al., 2000). Still, as texture was both monitored instrumentally (TPA) and through grading, it can be concluded that in our study this was not the case. Figure 3 presents the b* value in summer, which correspond to the color yellow, and showed when J milk was included the cheese was more yellow. However, the color differences (ΔE^*_{ab}) were not different ($P < 0.05$) and the ranges were lower than the normal eye tolerances, which require a difference of 2.8 to 5.6 (Fernández-Vázquez et al., 2011) to be noticeable by consumer. This was proved by no difference being found in the grading for color.

(**Figure 4**)

The total grading scores in winter increased with the inclusion of J milk (Figure 5), however this difference was not sustained at 8 months and no significant difference in graded flavour, texture, appearance and color was detected at either 3 or 8 months. This is in contradiction with the belief of a negative effect of J milk on cheese quality. Not standardizing, while increasing cheese fat, fat in dry matter and moisture in non-fat substance, did not affect negatively cheese quality, and is thus a viable way of producing Cheddar cheese with J milk. Further research should investigate the effect of J milk on the grading of cheese, after 8 month as the bigger fat globules could still lead to early lipolysis and thus bitter taste (Cooper et al., 1911).

(Figure 5)

CONCLUSIONS

This study showed that including J milk improved the yield of non-standardized Cheddar cheese in direct proportion to the rate of inclusion, and thus, without affecting negatively the sensory quality of the cheese. In addition the change in the cheese making process and cheese composition does not hinder its use. Therefore using J milk is a valid way of improving the yield of Cheddar cheese with the optimal inclusion rate being 100% J milk.

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Table 1. Holstein-Friesian and Jersey milk blends composition (Means ± SED)

		Jersey milk inclusion (%)				*P*	
Milk composition items	H-F n=12	25% n=6	50% n=12	75% n=6	100% n=12	Breed	Season
Fat (g/100g)	3.94 ± 0.07	4.19 ± 0.09	4.70 ± 0.05	5.12 ± 0.12	5.43 ± 0.10	***	*
Protein (g/100g)	3.15 ± 0.08	3.26 ± 0.03	3.44 ± 0.03	3.58 ± 0.06	3.74 ± 0.05	***	*
Protein: fat	0.780 ± 0.016	0.769 ± 0.017	0.767 ± 0.007	0.774 ± 0.014	0.767 ± 0.010	***	NS
Casein (g/100g)	2.31 ± 0.02	2.39 ± 0.03	2.55± 0.03	2.66 ± 0.05	2.79 ± 0.04	***	NS
Casein: protein	0.747 ± 0.002	0.747 ± 0.003	0.749 ± 0.003	0.744 ± 0.005	0.745 ± 0.003	***	NS
Lactose (g/100g)	4.44 ± 0.02	4.44 ± 0.03	4.46 ± 0.02	4.47 ± 0.02	4.46 ± 0.02	NS	NS
Urea (mg/100g)	0.031 ± 0.002	0.026 ± 0.002	0.027 ± 0.003	0.029 ± 0.003	0.023 ± 0.003	NS	NS
SCC[1] (1,000 cells/mL)	162 ± 14	153 ± 17	184 ± 9	217 ± 12	191 ± 10	***	NS
Ca^{2+} (mg/100g)	7.52 ± 0.25	7.66 ± 0.24	7.44 ± 0.16	7.16 ± 0.21	7.31 ± 0.21	NS	NS
D(4.3) (μm)	3.39 ± 0.08	3.74 ± 0.05	4.09 ± 0.06	4.31 ± 0.11	4.69 ± 0.11	***	NS
D(3.2) (μm)	1.15 ± 0.09	1.21 ± 0.06	1.24 ± 0.08	1.20 ± 0.12	1.39 ± 0.10	NS	NS
D(0.5) (μm)	3.30 ± 0.08	3.66 ± 0.05	4.02 ± 0.05	4.25 ± 0.09	4.70 ± 0.40	***	NS
Fat globule size Span (μm)	2.01 ± 0.15	2.20 ± 0.33	2.03 ± 0.19	1.83 ± 0.03	1.97 ± 0.25	NS	NS
CMS[2] (d. nm)	176 ± 3	170 ± 4	164 ± 2	167 ± 6	158 ± 3	***	NS
pH	6.82 ± 0.02	6.78 ± 0.04	6.78 ± 0.03	6.78 ± 0.05	6.73 ± 0.02	NS	NS
Titratable acidity (°D)	0.15 ± 0.32	0.15 ± 0.55	0.16 ± 0.32	0.16 ± 0.41	0.17 ± 0.46	**	NS

[1] Somatic Cell Count. [2] Casein Micelle Size.*P< 0.05 **P< 0.01, ***P< 0.001, NS: Non-significant

Table 2. Effect of different inclusion of Jersey in Holstein-Friesian milk on cheese making properties (mean ± SE).

		Jersey milk inclusion (%)			
Cheese making properties [1]	H-F n=12	25% n=6	50% n=12	75% n=6	100% n=12
Actual yield (kg/100 kg of milk)	9.5 ± 0.1^{a}	10.3 ± 0.2^{b}	11.3 ± 0.2^{c}	12.0 ± 0.2^{cd}	12.8 ± 0.2^{d}
Yield increase (%)	0.0 ± 0.0^{a}	9.8 ± 1.4^{b}	19.0 ± 1.3^{c}	25.3 ± 0.8^{d}	34.6 ± 1.9^{e}
Theoretical yield (kg/100 kg of milk)	10.6 ± 0.2^{a}	11.2 ± 0.4^{ab}	11.5 ± 0.3^{ab}	12.2 ± 0.5^{b}	12.4 ± 0.3^{b}
Yield moisture adjusted 37% (kg/100 kg of milk)	9.1 ± 0.2^{a}	9.7 ± 0.4^{a}	11.1 ± 0.2^{b}	12.1 ± 0.2^{bc}	12.8 ± 0.2^{c}
Yield whey (kg/100 kg of milk)	87.6 ± 0.3^{a}	87.5 ± 0.6^{a}	85.9 ± 0.3^{b}	84.9 ± 0.4^{bc}	84.3 ± 0.4^{c}
Fat whey (%)	0.70 ± 0.07^{a}	0.66 ± 0.11^{a}	0.63 ± 0.06^{a}	0.63 ± 0.01^{a}	0.65 ± 0.06^{a}
Protein whey (%)	0.88 ± 0.07^{a}	0.86 ± 0.15^{ab}	0.84 ± 0.08^{ab}	0.79 ± 0.04^{ab}	0.78 ± 0.07^{b}
Lactose whey (%)	4.51 ± 0.38^{a}	4.48 ± 0.75^{a}	4.58 ± 0.42^{ab}	4.61 ± 0.04^{ab}	4.68 ± 0.39^{b}
Solid whey (%)	7.80 ± 0.65^{a}	7.73 ± 1.29^{a}	7.86 ± 0.72^{a}	7.98 ± 0.03^{ab}	8.11 ± 0.68^{b}
Fat recovery (%)	76.60 ± 1.14^{a}	85.14 ± 1.88^{ab}	87.05 ± 2.35^{b}	87.76 ± 4.11^{b}	99.34 ± 4.72^{b}
Protein recovery (%)	71.61 ± 2.32^{a}	77.40 ± 2.39^{ab}	79.12 ± 1.82^{ab}	78.26 ± 3.85^{ab}	81.25 ± 2.32^{b}
Cutting time (min)	48 ± 1.3^{a}	44 ± 1.6^{a}	33 ± 1.1^{b}	30 ± 1.6^{bc}	27 ± 1.6^{c}
Cutting to milling time (min)	190 ± 5.8^{a}	208 ± 7.1^{ab}	208 ± 6.2^{ab}	204 ± 4.9^{ab}	219 ± 6.1^{b}
Rennet to milling time (min)	239 ± 5.1^{a}	252 ± 7.6^{a}	241 ± 6.4^{a}	234 ± 6.0^{a}	243 ± 7.1^{a}

[1] Results are expressed as mean ± standard error.

$^{a-e}$ Means within a row with different superscripts differ ($P<0.05$)

Table 3. Effect of different inclusion of Jersey milk in Holstein-Friesian milks on Cheddar cheese composition (mean ± SE).

		Jersey milk inclusion (%)			
Cheese composition [1]	H-F n=12	25% n=6	50% n=12	75% n=6	100% n=12
Cheese fat (%)	31.41 ± 0.39^{a}	33.45 ± 0.83^{b}	34.47 ± 0.55^{c}	35.32 ± 0.30^{d}	37.15 ± 0.27^{e}
FDM[2] (%)	51.59 ± 0.52^{a}	54.98 ± 1.47^{b}	54.81 ± 0.88^{b}	55.71 ± 0.43^{b}	58.21± 0.54^{c}
Cheese protein (%)	23.48 ± 0.84^{a}	24.10 ± 1.10^{a}	23.58 ± 0.77^{a}	22. 92 ± 1.03^{a}	23.21 ± 0.80^{a}
Cheese moisture (%)	39.12 ± 0.34^{a}	39.14 ± 0.71^{a}	37.11 ± 0.32^{b}	36.61 ± 0.20^{c}	36.17 ± 0.44^{c}
MNFS[3]	57.04±0.40^{a}	58.85±1.25^{a}	56.66±0.64^{a}	56.60±0.33^{a}	57.54±0.70^{a}
Cheese salt (%)	1.80 ± 0.08^{a}	1.90 ± 0.07^{a}	1.74 ± 0.07^{a}	1.90 ± 0.05^{a}	1.86 ± 0.06^{a}
Cheese pH	5.43 ± 0.05^{a}	5.39 ± 0.14^{a}	5.50 ± 0.05^{a}	5.62 ± 0.03^{a}	5.56 ± 0.05^{a}

[1] Results are expressed as mean ± standard error.

[2] Fat in dry matter

[3] Moisture in non-fat substances.

[a-e] Means within a row with different superscripts differ ($P<0.05$)

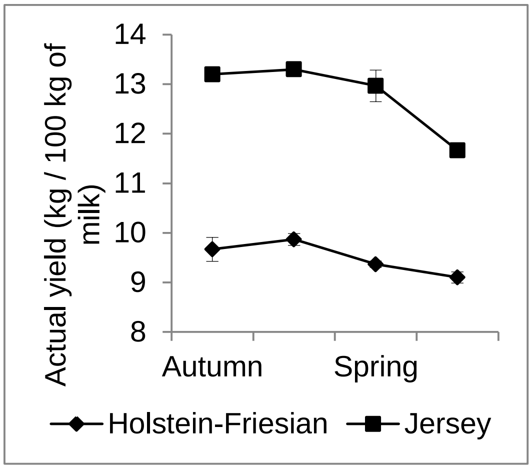

Figure 1: Seasonal variation in actual cheese yield of Holstein-Friesian and Jersey milk.

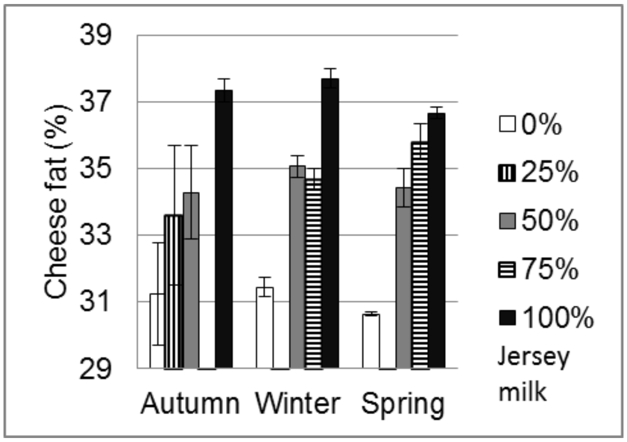

Figure 2: Effect of inclusion of Jersey milk on Cheddar cheese fat at different season.

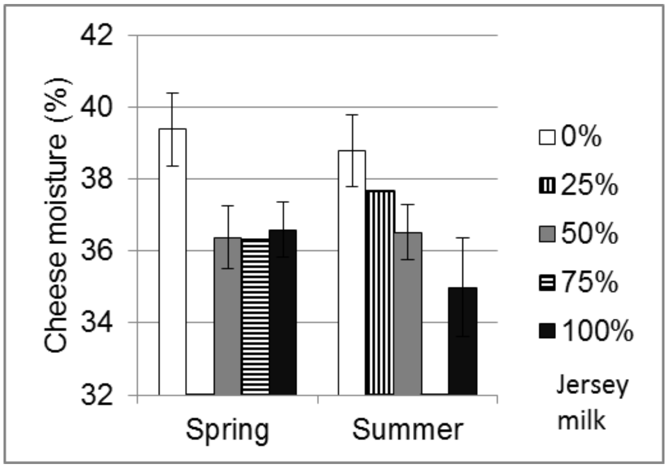

Figure 3: Effect of inclusion of Jersey milk on Cheddar cheese moisture in Spring and Summer.

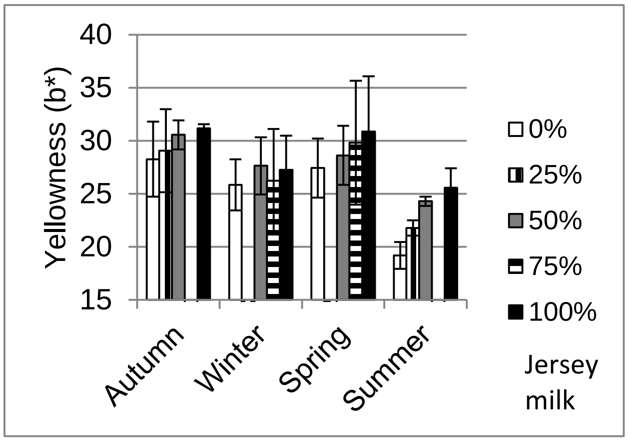

Figure 4: Effect of inclusion of Jersey milk on the yellow color of Cheddar cheese according to season (yellowness expressed in CIELAB).

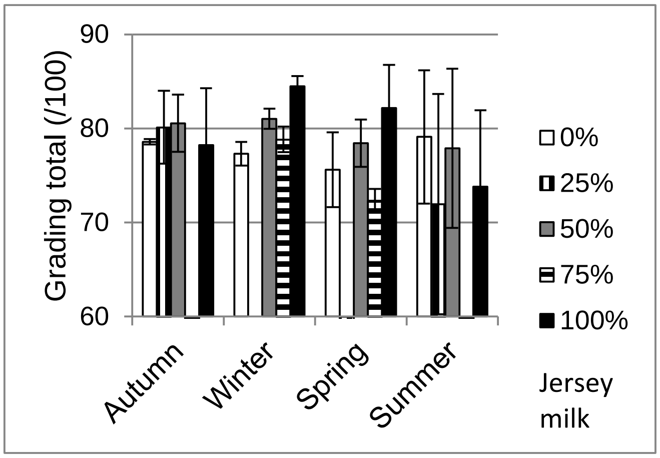

Figure 5: Effect of inclusion of Jersey milk on the total grading score of Cheddar cheese according to season.