

Article

Milk Coagulation Properties: A Study on Milk Protein Profile of Native and Improved Cattle Breeds/Types in Sri Lanka

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Abstract: This study was conducted to assess the variations of milk coagulation properties (MCP) among two native cattle types, e.g., Thamankaduwa White (TW), Lankan cattle (LC) and two improved cattle breeds, e.g., Friesian (FR) and Jersey (JS), in relation to distinctive milk protein compositions. MCP traits, including rennet coagulation time (RCT), curd firmness, meltability and yield, were measured. The milk protein profile of each breed/type was analyzed using capillary zone electrophoresis. Significant differences ($p < 0.05$) were observed among two native and improved cattle breeds/types in relation to RCT. Friesian and TW milk had the longest and shortest ($p < 0.05$) RCT, respectively. There was no significant difference in firmness among the four breeds/types. The highest ($p < 0.05$) coagulum yield was recorded for TW milk, followed by LC, JS and FR. TW milk had the highest ($p < 0.05$) meltability values. As revealed by the protein profiles, κ -casein concentration was significantly higher in TW milk compared to the other three breeds/types. None of the other milk protein fractions showed significant differences among the four breeds/types. The overall results indicate the superior MCP of TW milk, emphasizing the value of native breeds which could be exploited in the development of niche dairy products while supporting the conservation effort of the native cattle gene pool.

Keywords: coagulum yield; curd firmness; native cattle; milk protein profile



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1. Introduction

Milk coagulation is a key aspect of processing fermented dairy products. The technological aspects of dairy products are largely governed by the coagulation capacity of raw milk [1]. Various factors influence milk coagulation properties (MCP), including casein (CN), calcium (Ca) and phosphorous (P) concentration, titratable acidity, milk protein genetic variants, somatic cell count, feed and stage of lactation [2]. Among all milk components, protein acts as one of the most important factors in determining milk coagulation. In particular, the CN fraction is of great concern as it highly affects MCP such as coagulation time, curd firmness and cheese yield [3]. According to previous studies conducted over the past decades, more reliance has been given to assessing the impact of the milk protein profile and genetic variants on MCP and other technological aspects [4–6]. Moreover, a wide variation of MCP has been identified among different cattle breeds as the breed is the main genetic aspect that defines the milk quality [7].

Even though the production potential of dairy cattle has been improved extensively through selection and breeding over the years, the MCP of most high-producing dairy cattle breeds has considerably decreased. In particular, the high incidence of non-coagulating milk has become one of the most common issues associated with cheese production [8]. Superior MCP of milk obtained from native/indigenous cattle breeds has previously been reported in Italy, Sweden, Poland and many other regions compared to the commonly reared improved dairy cattle breeds [9–12]. The detection of improved MCP and the associated genetic traits of native breeds may be highly beneficial for the dairy industry, particularly for the processing of dairy products for niche markets. Furthermore, such approaches support the conservation of the valuable native cattle gene pool, which is currently at risk of extinction [13]. The detailed milk protein profiles of different cattle breeds may provide insights into the improvement of quality traits of milk through the genetic progression of dairy cattle. Therefore, the identification of variations in milk protein polymorphisms among native and improved cattle breeds could support avoiding the loss of economically valuable genetic characteristics through effective utilisation. The aim of the current study was to identify the differences in MCP in relation to detailed protein profiles of two popular native cattle types, Thamankaduwa White (TW) and Lankan cattle (LC), and two improved cattle breeds, Jersey (JS) and Friesian (FR) reared in Sri Lanka.

2. Materials and Methods

2.1. Experimental Design

A total of sixty (60) fresh milk samples from cows belonging to four different breeds/types ($n = 15$ from each), namely TW, LC, JS and FR, were collected during the period of April to June 2020. TW and LC are breeds of the indicine subspecies (zebu), whereas FR and JS are breeds of the taurine subspecies. The phenotypic views of the cattle breeds/types are illustrated in Supplementary Figure S1. All the cows sampled were in similar physiological status (i.e., second parity, mid-lactation stage) and were reared in the Dry Zone (annual rainfall of <1750 mm, average temperature of 28 °C) of Sri Lanka. JS and FR cattle included in this study were raised in a semi-intensive system where both cut and fed and free grazing were practiced. LC and TW cattle were raised under an extensive management system where only free grazing was practiced. Around 500 mL of milk was collected from each animal, and sampling was done three times during the period with four-day time intervals. The milk coagulation property traits were analysed within 6 h of milk collection, without the addition of preservatives. Representative milk samples were prepared into 1.5 mL Eppendorf tubes after vortexing the collected milk, and the milk samples were stored in -80 °C for further analysis of the milk protein profile. Milk composition was evaluated using the Lactoscan SP milk analyser (Lactoscan SP, Bulgari) in previous study conducted by the authors [14]. The results of the compositional analysis were used to interpret the observations of the current study.

2.2. Analysis of Milk Coagulation Properties

Milk coagulation was measured by employing both enzymatic and acid-induced coagulation.

2.2.1. Enzymatic Coagulation

Milk pH was adjusted to pH 6.5 using 0.1 M HCl before the enzymatic coagulation if required. Milk samples were allowed to coagulate according to the previously described procedure by Kübarsepp et al. (2005) [15] with modifications. Each milk sample (50 mL) was preheated to 35 °C with 1 mL of 1.6% (w/v) rennet solution, which was obtained by the fermentation-produced chymosin (chymosin 100%; 0.665 IMCU mL^{-1} , CHY-Max, Chr Hansen, Denmark).

2.2.2. Acid-Induced Coagulation Using Lactic Acid Bacteria (LAB)

Milk samples were coagulated with the addition of commercial starter culture (YFL812, Chr, Hansen Standard, Denmark) consisting of *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*. The inoculation level of the starter culture was 0.004% w/v and samples were incubated at 42 ± 2 °C for 3 h.

2.2.3. Analysis of Milk Coagulation Properties

Different properties of milk coagulum were measured in both coagulation processes. Rennet coagulation time (RCT), curd firmness, coagulum yield, and meltability parameters were evaluated. An average of three replicates was obtained for each measurement. Rennet coagulation time and firmness were only employed for enzyme induced coagulation. Coagulation time was determined by the Berridge method as described by Loopez et al. [16]. The milk coagulum yield was determined by dividing the weight of the milk coagulum by the initial weight of the milk sample and multiplying by 100 [17]. Curd firmness was evaluated subjectively after 30 min of rennet addition. The sample was identified as firm if the curd was firm enough to form cubes upon cutting, otherwise it was identified as a weak curd [18]. Meltability values were determined using Schreiber's test method [19] and expressed as meltability ratio between melted and unmelted volume of the curd.

2.3. Analysis of Milk Protein Profile

The Capillary Zone Electrophoresis (CZE) method was used to determine protein composition and its variation in milk samples. Milk samples were defatted by centrifugation in 10,000 rpm for 10 min at 4 °C in the centrifuge (Himac CT 15RE, Hitachi Koki Co., Ltd., Tokyo, Japan). The small remaining amount of the milk fat was removed from the surface and discarded. All samples were then filtered through a 13 mm 0.45 µL econofilter nylon membrane (Agilent Technologies, Agilent Captiva Econofilter, Lexington, MA, USA). The Capillary Electrophoresis system (Agilent Technologies 7100, Agilent Technologies Co., Santa Clara, CA, USA), controlled by Chemstation software (Agilent 7100 CE, program version Rev. C01.08, Agilent Technologies, Palo Alto, CA, USA [20]), was used for the analysis. The detector was based on UV-vis absorbance at a wavelength of 214 nm. The protein profile was determined by comparing the migration times for the different peaks on the electropherograms to the reference migration times according to the standard procedure. The relative concentrations were based on the peak area and expressed as a percentage of the total area recorded for all peaks in the electropherogram [20]. Identification of the milk protein profile, including all six main protein variants and their relative concentrations, was done using a standard electropherogram.

2.4. Analysis of Ca Content of Milk

Milk Ca content was determined according to the procedure described by Kira and Maihara (2007) [21] with a few modifications. An acid digestion procedure was applied to eliminate the organic matter in milk samples. One gram of milk was mixed with 5 mL of concentrated HNO₃ and refluxed for 2 h at 92–95 °C followed by cooling. Two millilitres (2 mL) of deionized water and 3 mL of trace grade H₂O₂ were added to the cooled sample. Then, the sample was heated until the effervescence subsided, and gravity filtration was performed as required. Digested samples were analysed for Ca concentration using an inductively coupled plasma-optical emission spectrometer (ICP-OES, iCAP 7000, Version 1.01, Thermo Scientific, Waltham, MA, USA).

2.5. Analysis of Somatic Cell Score (SCS)

The somatic cell count (SCC) was determined using the Delaval Cell Counter (Delaval International AB, Tumba, Sweden). Animals were tested for mastitis disease before the analysis. The SCC values were log transformed to somatic cell score (SCS) to achieve the normality and homogeneity of the variances using the following Equation (1).

$$SCS = 3 \log_2 \left(\frac{SCC}{100,000} \right) \quad (1)$$

2.6. Statistical Analysis

The milk protein profile and coagulation properties were analysed using one-way ANOVA at $p < 0.05$ level of significance, followed by the Tukey-Kramer post hoc test. The Pearson's correlation coefficients between milk proteins, SCS, Ca content and coagulation

properties were evaluated. Curd firmness was evaluated using Fisher's exact test and point-biserial correlation was employed to analyse the correlation between gel firmness and milk proteins. Principal component analysis (PCA) was used to analyse the tested variables and coagulation properties using Minitab 18.1 software (Minitab Inc., State College, PA, USA).

3. Results and Discussion

3.1. Milk Coagulation Property (MCP) Analysis

The processability of milk and functional quality aspects of dairy products are highly influenced by the detailed protein composition of milk. According to the relative concentrations of individual milk proteins, only the κ -CN concentration of TW milk was significantly higher than that of the other three breeds/types (Table 1). Since milk with higher κ -CN content is positively related to κ -CN B genotype and negatively related with κ -CN E genotype, the TW cattle type may possibly carry a high frequency of κ -CN B allele and a low frequency of κ -CN E allele [22]. The relative contents of milk protein components tend to vary among different cattle breeds as shown in many previous studies [23,24]. Wedholm et al. (2006) [25] revealed significant differences in β -CN and κ -CN concentrations among Swedish Red/White cows and Swedish Holstein cows. In another study, Joudu et al. (2008) [3] reported significantly higher α S1-CN and κ -CN content in total milk CN from the Estonian Red breed than the Estonian Holstein breed. According to a study conducted in Bangladesh, significantly higher β -CN concentrations in native cow milk have been reported compared to Holstein crossbreed [23].

The type of breed has been shown as an important source of variation for the MCP traits [26,27]. Table 2 shows the variations of MCP traits among the four breeds/types used in the current study. The milk of all four breeds/types included in the study had good coagulation properties, and none of the milk samples was non-coagulating. Significant differences ($p < 0.05$) were observed among the breeds/types in relation to RCT. Friesian cows had a longer RCT ($p < 0.05$) compared to two native cattle types, while TW cows had the shortest ($p < 0.05$) RCT. Descriptive statistics revealed that TW milk coagulum had the highest firmness (64.3%) followed by LC (61.5%). However, Fisher's exact test confirmed that there was no significant difference in the curd firmness of the four breeds/types.

An increased level of κ -CN content in TW milk could have led to a shorter RCT compared to the other three breeds. The κ -CN acts as the most important milk protein in rennet coagulation as it plays an important role during the milk coagulation process [28]. The hydrolysis of κ -CN facilitates the destabilisation of CN micelles through the formation of para- κ -CN and caseinomacropetides [29]. Relatively higher κ -CN content in total milk CN is associated with shorter milk coagulation time as it favours the bridging of proteins by calcium [30]. Milk Ca content has been identified as one of the major factors affecting both milk coagulation time and curd firmness, since Ca and P act as the essential components in CN micelles. As revealed in the present study, the Ca content of milk was significantly different among four breeds/types where LC milk had the highest Ca content ($p < 0.05$) followed respectively by TW, JS and FR milk (Figure 1A). The breed, stage of lactation and environmental factors make significant differences in milk Ca content, while dietary regimes have little influence on the mineral composition of bovine milk [31]. The observed Ca values were very similar to those reported by Chen et al. (2020) [32] for bovine milk. However, the values of the present study were lower than those observed by Soyeurt et al. (2009) [33] and Toffanin et al. (2015) [34], who reported average values of 1051 and 1156.33 mg kg⁻¹, respectively. According to a study conducted on JS and Holstein milk coagulation, Jensen et al. (2012) [35] reported that high colloidal Ca, P and Mg contents in milk were associated with enhanced rennet coagulation properties. The lower levels of Ca, P and Mg in milk have been identified as a common issue with poor or non-coagulating milk where milk that had higher levels of these minerals showed better coagulation than those with lower levels [36]. Hence, it is possible that high κ -CN content in combination with high Ca content in TW milk may have contributed to better coagulation properties in TW milk than in the milk from other breeds/types.

Table 1. The relative concentration of milk proteins as a percentage of the total protein detected in improved cattle breeds (Jersey and Friesian) and native cattle types (Lankan Cattle and Thamankaduwa White).

Breed/Type	Milk Protein Profile (as % of the Total Protein)										
	α -LA	β -LG	α S2-CN	α S1-CN	κ -CN	β -CN B	β -CN A1	β -CN A2	Total β -CN	Total Whey Protein	Total CN
Jersey	0.98 \pm 0.4 ^a	6.35 \pm 2.6 ^a	5.44 \pm 1.0 ^a	32.02 \pm 3.8 ^a	3.47 \pm 1.7 ^b	5.07 \pm 1.3 ^a	18.59 \pm 5.8 ^a	36.25 \pm 8.9 ^a	48.75 \pm 5.4 ^a	7.26 \pm 2.8 ^a	89.68 \pm 4.2 ^a
Friesian	0.87 \pm 0.4 ^a	5.15 \pm 1.8 ^a	5.68 \pm 1.7 ^a	33.63 \pm 3.8 ^a	4.88 \pm 1.3 ^{ab}	4.43 \pm 0.8 ^a	20.87 \pm 2.4 ^a	37.18 \pm 9.8 ^a	46.58 \pm 3.9 ^a	6.01 \pm 2.0 ^a	90.78 \pm 2.6 ^a
Lankan Cattle	0.95 \pm 0.4 ^a	5.53 \pm 0.9 ^a	5.61 \pm 1.6 ^a	34.02 \pm 2.2 ^a	3.89 \pm 1.3 ^b	3.93 \pm 1.3 ^a	17.71 \pm 5.7 ^a	38.86 \pm 7.1 ^a	46.33 \pm 2.9 ^a	6.48 \pm 1.2 ^a	89.85 \pm 2.3 ^a
Thamankaduwa White	1.04 \pm 0.3 ^a	6.57 \pm 1.3 ^a	5.12 \pm 1.4 ^a	33.36 \pm 1.7 ^a	6.03 \pm 1.8 ^a	4.84 \pm 1.1 ^a	21.73 \pm 0.0 ^a	40.54 \pm 4.9 ^a	45.22 \pm 2.9 ^a	7.61 \pm 1.3 ^a	89.73 \pm 2.1 ^a

The values (average \pm SD; n = 15) followed by different superscripts within the column for respective milk protein are significantly different ($p < 0.05$). LA: Lactalbumin, LG: Lactoglobulin; α S2-CN: α S2-Casein; α S1-CN: α S1 casein; κ -CN: κ casein; β -CN B: β -casein B; β -CN A1: β casein A1; β -CN A2: β casein A2; Total β -CN: Total β -casein, Total CN: Total casein.

Table 2. Milk coagulation property traits of improved cattle breeds (Jersey and Friesian) and native cattle types (Lankan Cattle and Thamankaduwa White).

Animal Breed/Type	Milk Coagulation Properties					
	RCT (min)	Firmness (%)	Coagulation Yield (%)		Meltability Ratio	
			Rennet	LAB	Rennet	LAB
Jersey	3.79 \pm 0.9 ^{ab}	56.3 ^a	64.9 \pm 7.3 ^{bc}	66.6 \pm 2.6 ^c	1.69 \pm 0.2 ^b	1.79 \pm 0.4 ^b
Friesian	4.14 \pm 0.2 ^a	53.8 ^a	63.5 \pm 4.5 ^c	65.2 \pm 2.3 ^b	1.10 \pm 0.0 ^c	1.08 \pm 0.0 ^c
Lankan Cattle	3.37 \pm 0.3 ^{bc}	61.5 ^a	69.7 \pm 4.4 ^b	70.2 \pm 3.8 ^a	1.20 \pm 0.0 ^c	1.20 \pm 0.0 ^c
Thamankaduwa White	3.24 \pm 0.3 ^c	64.3 ^a	78.9 \pm 3.2 ^b	80.0 \pm 2.6 ^a	5.26 \pm 0.3 ^a	5.19 \pm 0.3 ^a

The values (average \pm SD; n = 15) followed by different superscripts within a particular column for respective coagulation property is significantly different ($p < 0.05$). RCT: Rennet coagulation time; LAB: Lactic acid bacteria (*Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*).

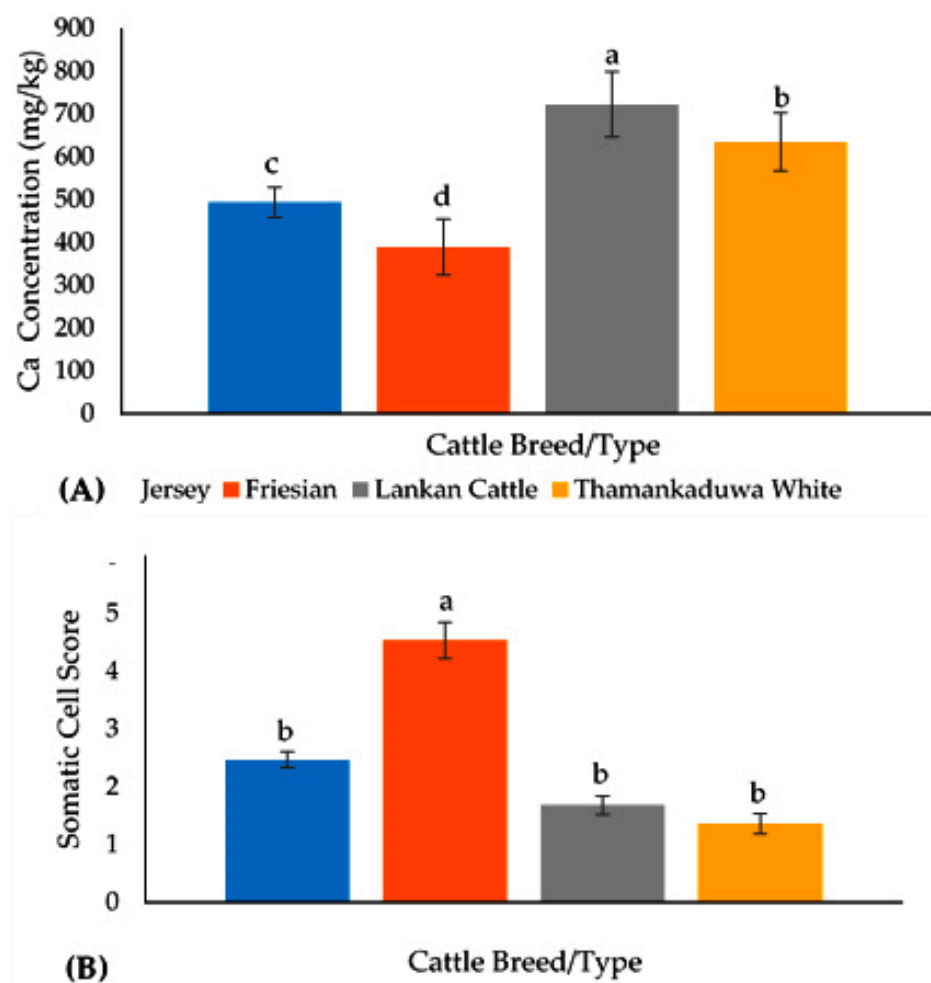


Figure 1. Ca concentration (A) and somatic cell score (B) in the raw milk of improved cattle breeds (Jersey and Friesian) and native cattle types (Lankan Cattle and Thamankaduwa White). The values (average \pm SD; n = 15) followed by different superscripts are significantly different ($p < 0.05$).

The highest ($p < 0.05$) coagulum yield was recorded for TW milk, followed by LC, JS and FR in both rennet and LAB coagulation. There were significant differences in coagulum yield among native and improved breeds. These observations confirm the findings of a previous study done by Abeykoon et al. (2016) [37] who reported the highest coagulum yield for TW milk than LC, JS and FR in rennet coagulation. Milk with a shorter coagulation time is associated with a greater cheese yield [38,39]. High κ -CN content positively affects coagulum yield as high κ -CN content is responsible for small CN micelles, which are associated with good gelation properties of milk [40]. Consequently, the high κ -CN content of TW milk and short coagulation time may have contributed to the highest coagulum yield of TW milk. According to Wedholm et al. (2006) [6], concentrations of α s1-CN, β -CN, κ -CN and β -LG had a significant effect on the cheese yield. Moreover, the milk coagulum yield is positively correlated with the fat and total CN content of the milk [41]. Therefore, the high-fat content in native cattle milk compared to two improved breeds (Table 3) may also have positively contributed to the high coagulum yield [14,37]. Meltability is one of the most important aspects that reflects the functional quality attributes of cheese. The meltability determines the suitability of cheese in some specific food product applications, such as processed and ready-to-eat foods. According to the meltability ratio values observed in both rennet and LAB coagulation, TW had the highest ($p < 0.05$) meltability compared to the other three breeds/types. As reported by Abeykoon et al. (2016) [37], the meltability values of the rennet milk coagulum had a significant correlation with milk fat content. Moreover,

Van Hekken et al. (2007) [42] observed the high meltability of cheese with increased fat content in milk. Similarly, the highest fat content in TW milk (Table 3) could have led to the highest meltability values of the milk coagulum.

Table 3. Composition of raw cow milk from improved cattle breeds (Jersey and Friesian) and native cattle types (Lankan Cattle and Thamankaduwa White).

Breed/Cattle Type	Fat (%)	Protein (%)	Lactose (%)	Solids Non-Fat (%)
Thamankaduwa White	4.56 ± 0.50 ^a	3.20 ± 0.32 ^a	4.28 ± 0.18 ^a	7.89 ± 0.15 ^a
Lankan	4.32 ± 1.32 ^a	3.14 ± 0.26 ^a	4.29 ± 0.25 ^a	7.80 ± 0.46 ^a
Jersey	4.36 ± 0.82 ^b	3.18 ± 0.28 ^a	4.11 ± 0.79 ^a	7.37 ± 1.47 ^b
Friesian	3.15 ± 1.21 ^c	3.06 ± 0.18 ^a	4.35 ± 0.39 ^a	7.29 ± 0.25 ^b

^{abc} Means indicate the significant difference ($p < 0.05$) separately among each milk composition parameter due to the effect of breed type. Extracted from Weerasingha et al., 2021 [14].

Somatic cell count, which is related to milk proteolysis, has been identified as another factor affecting MCP. The highest SCS ($p < 0.05$) was estimated for the FR breed, while there were no significant differences among the other three breeds/types (Figure 1B). This may be due to an underlying reason of poor health status. However, significantly high SCS may have acted as one of the reasons for the poor MCP of FR milk. In general, high MCP is associated with low SCC. Ikonen et al. (2004) [43] reported that selection for low SCC in milk could be a strategy to improve the MCP and reduce the occurrence of non-coagulating milk.

3.2. Correlation Analysis

As shown in Table 4, total protein and fat contents were positively correlated with coagulum yield in rennet and LAB coagulation. The total CN content was positively correlated with curd firmness and had increased coagulum yield in both coagulation methods in the current study. In accordance with the present results, Cecchinato et al. (2012) [44] reported an association of short coagulation time with high total protein and fat percentage in milk. However, a positive correlation between short coagulation time and low protein content has been reported in previous studies [43,45]. In addition, Cassandro et al. (2008) [46] reported that there were no considerable genetic correlations between RCT and fat or protein. However, many previous studies have reported that high cheese yield is correlated with increased levels of fat and total CN in milk [6,47]. High total protein and CN contents are associated with the good coagulation ability of milk. Increasing relative levels of the CN proteins could increase the CN to whey protein ratio, which may, in turn, positively affect the MCP.

Of the other traits measured, the SCS showed a strong positive correlation with RCT and moderately negative correlations with coagulation yield and meltability. SCS was associated with MCP, as reported by Ikonen et al. (2004) [43], where low SCS was correlated with short coagulation time and good curd firmness. A favourable relationship was observed between milk Ca content and MCP, where an increase in Ca content showed a strong positive correlation with curd firmness and coagulation yield. A negative correlation was observed between Ca content and RCT. This could be a positive observation for the cheese making process, as milk having high Ca content could expedite the milk coagulation process. Further, the findings of the present study were consistent with the findings of Toffanin et al. (2015) [34], who reported that an increase in Ca is correlated with an increase in curd firmness after 30 min of enzyme addition (a30), while an increase in Ca content reduces RCT. For instance, the impaired MCP is shown to be improved due to CaCl₂ addition as it reduces RCT while increasing the curd firming rate [47].

Table 4. Correlation analysis of milk coagulation properties and milk protein profile, Ca content, somatic cell score (SCS) in raw cow milk obtained from improved cattle breeds (Jersey and Friesian) and native cattle types (Lankan Cattle and Thamankaduwa White).

Coagulation Property	α -LA	β -LG	α s2 CN	α S1 CN	κ -CN	β -CN B	β -CN A1	β -CN A2	Total β -CN	Total Whey	Total CN	Total Protein	Total Fat	Ca Content	SCS
RCT	−0.19	−0.01	0.03	0.02	−0.45 **	−0.15	−0.40 *	0.02	0.15	0.17	0.20	−0.21	−0.31 *	−0.49 **	0.52 **
Firmness	0.20	0.13	0.17	−0.17	0.24	0.2	0.23	0.16	0.02	0.08	0.35 *	0.33 *	0.16	0.24	−0.15
Coagulation Yield															
Rennet Yield	0.24	0.39	−0.14	0.02	0.69 **	0.51 **	0.37	0.15	−0.22	−0.40 *	0.49 **	0.44 *	0.40 *	0.43 *	−0.43 *
LAB yield	0.27	0.34	−0.21	0.09	0.77 **	0.62 **	0.26	0.27	−0.29	−0.41 *	0.30 *	0.33 *	0.34 *	0.51 **	−0.43 *
Meltability															
Rennet	0.20	0.41	−0.10	0.01	0.46 **	0.16	0.10	0.18	−0.28	0.43	−0.13	0.11	0.50 **	0.35 *	−0.39
LAB	0.21	0.38	−0.10	−0.04	0.43 *	0.18	0.03	0.18	−0.23	0.40	−0.14	0.16	0.41 *	0.34 *	−0.41

* Correlation coefficient is significant at ($p < 0.05$); ** Correlation coefficient is significant at ($p < 0.01$). LG: Lactoglobulin; CN: Casein; SCS: Somatic cell score; RCT: Rennet coagulation time; LAB: Lactic acid bacteria (*Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*).

3.3. Principal Component Analysis

As shown in the score plot, TW and LC milk were different from JS and FR milk. Milk from two native cattle types is located on the same side (right) of the PCA, while milk from two improved breeds is located on the opposite side (left) of the score plot (Figure 2). The TW milk samples were characterised by high coagulum yield and meltability in both coagulation methods, in addition to high fat and Ca contents compared to other samples. Friesian milk samples were characterised by long RCT and high SCS compared to milk from other breeds/types. According to the loading plot, it was observed that the milk samples with higher Ca and fat contents resulted in higher coagulum yields with shorter RCT than those in milk samples from other breeds/types. The RCT was long in those milk samples that had high levels of SCS. High-producing breeds such as FR are highly susceptible to diseases such as bovine mastitis. Thus, the elevated SCS in FR milk may have an indirect impact on decreasing the clotting ability, which may lead to a reduction in the cheese yield and recovery of nutrients in the curd [49].

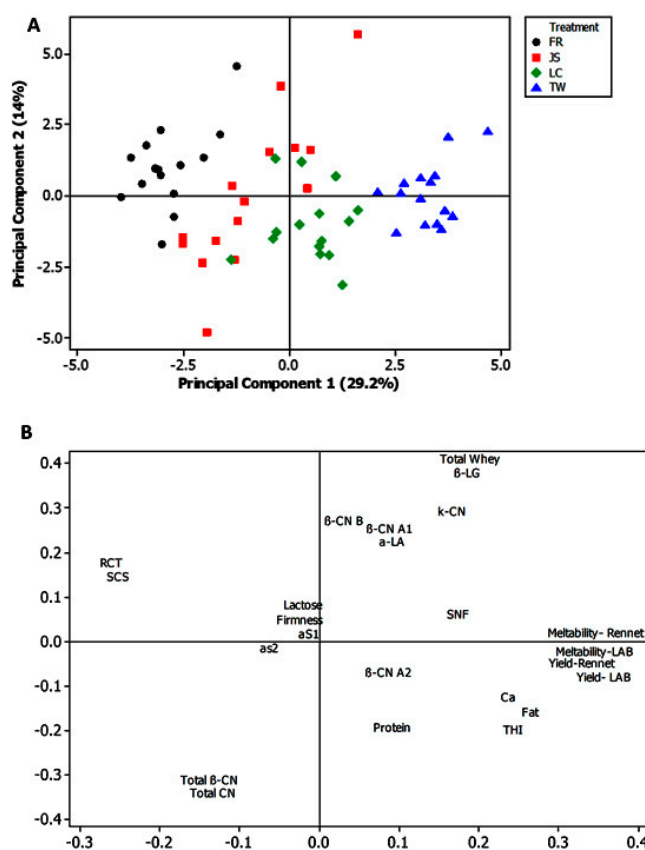


Figure 2. Principal component analysis (PCA) score plot (A) and loading plot (B) of studied parameters and their relationship with four cattle breeds/types: Friesian (FR), Jersey (JS), Lankan cattle (LC) and Thamankaduwa White (TW).

4. Conclusions

Milk of TW showed superior MCP traits than the other three breeds/types in both enzymatic and acid-induced coagulations. Since TW milk had the shortest RCT and the highest coagulum yield, while FR milk had the longest RCT and lowest coagulum yield, the native cattle milk could be used to maximise the yield in cheese production as predicted by the coagulum yield values. According to the present study, higher κ -CN content in TW milk may have a positive influence on the MCP traits of TW milk. Moreover, a higher Ca content in native cattle milk might have contributed to better MCP traits of milk in those cattle types compared to two improved breeds. Native cattle types carrying distinctive milk proteins could be beneficially exploited in the efficient processing of the

dairy product. These findings also provide supporting evidence for the efforts to empower native cattle farming to prevent the extinction of the valuable native cattle populations through effective utilization.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/dairy3040049/s1>, Figure S1: Phenotypic view of the selected animal breeds/types for the experiment,

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