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EFFECT OF CAMEL AND COW MILK POWDER ADDITION ON ACIDIFICATION, PHYSICOCHEMICAL PROPERTIES, YIELD, AND SENSORY QUALITY OF CAMEL SOFT WHITE CHEESE

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ABSTRACT

Camel milk is a nutritionally valuable resource with considerable potential for dairy processing; however, its transformation into cheese remains limited due to its specific physicochemical characteristics, particularly its low content of coagulable caseins and atypical micellar structure, which impair coagulation efficiency and cheese yield. This study was aimed to evaluate the effect of enriching camel milk with different levels of cow milk powder (CWMP) and camel milk powder (CMP) on the manufacture, composition and sensory quality of fresh soft white cheese. Camel milk was supplemented with CWMP or CMP at 2%, 5% and 10% (w/v), alongside a non-enriched control. The acidification kinetics, coagulation behaviour, physicochemical composition, cheese yield and sensory properties of the resulting cheeses were analysed. Enrichment with CWMP, particularly at 5% and 10%, resulted in a faster acidification rate, lower final pH values, improved curd firmness and significantly higher cheese yields compared with CMP-enriched and control samples. Cheeses enriched with CMP exhibited slower acidification and weaker curd structure, reflecting the intrinsic compositional properties of camel milk. Sensory evaluation revealed that moderate enrichment levels were critical for consumer acceptance. Cheeses supplemented with 2% and 5% CWMP achieved the highest scores for colour, appearance, taste and overall acceptability, while preserving the characteristic camel milk flavour. In contrast, high incorporation levels, especially 10% CMP, negatively affected sensory perception and overall acceptance. Overall, the results indicate that moderate supplementation of camel milk with cow milk powder, particularly at a level of 5%, represents an optimal strategy to improve the technological performance and yield of camel milk fresh soft white cheese while maintaining its desirable sensory attributes. This approach offers a promising pathway for the valorisation of camel milk in arid and semi-arid regions through the development of acceptable and high-quality dairy products.

Key words: Acidification, camel milk, camel milk powder, cheese yield, fresh soft cheese, sensory quality

In arid and semi-arid regions, camel milk represents a strategically important resource due to its high nutritional value and its potential for valorisation within local agri-food systems. Despite these advantages, the conversion of camel milk into cheese remains technically challenging and is still poorly developed. These limitations are primarily associated with the specific physicochemical characteristics of camel milk, notably its low content of coagulable caseins, reduced κ-casein proportion and atypical casein micelle structure, all of which impair enzymatic coagulation efficiency and result in low cheese yields.

In this context, the enrichment of camel milk with milk powder may constitute a relevant technological approach to improve its cheese making performance. The incorporation of either cow milk powder or camel milk powder has the potential to increase the total solids and functional protein content of the milk, to modify its buffering capacity and, consequently, to enhance acidification kinetics, curd formation and cheese yield. However, such enrichment strategies must be carefully controlled to ensure that the characteristic sensory attributes of camel milk cheese, particularly its distinctive flavour profile, are preserved, as these features play a crucial role in consumer acceptance.

The present study was aimed to evaluate the effect of enriching raw camel milk with different concentrations of cow milk powder (CWMP) and

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camel milk powder (CMP) on the production of a camel soft white cheese, in comparison with a non-enriched control. Particular attention was given to assessing the impact of these enrichments on the evolution of acidification during fermentation, on coagulation behaviour and cheese yield, as well as on the sensory quality and consumer preference of the resulting cheeses. In addition, this work sought to identify an optimal enrichment level capable of improving technological performance while maintaining the typical sensory characteristics associated with camel milk cheese.

Materials and Methods

Materials

Samples of camel milk were collected from eight she-camels in their 2nd to 4th lactation, reared by a local producer located on the outskirts of the city of Aïn El Aouda, in the Rabat–Salé–Zemmour–Zaer region of Morocco. Milk was obtained directly during milking and transported to the laboratory within one hour, where it was stored at 4±1°C until use. Three independent batches of 5 L of camel milk were collected for the purposes of this study.

The camel milk powder used in this study was obtained from the commercial brand Golden Camel (carbohydrates: 3.12 g/100 g, fat: 3.16 g/100 g, protein: 2.40 g/100 g), while the cow milk powder was supplied by the brand NIDO (carbohydrates: 3.65 g/100 g, fat: 2.82 g/100 g, protein: 2.57 g/100 g).

The camel chymosin used, supplied by the company Chr. Hansen, had a clotting activity of 1000 IMCU/g. Appropriate dilutions were prepared by adding distilled water to the rennet in order to obtain the required concentrations. The starter cultures used consisted of selected and mixed mesophilic strains capable of producing aroma compounds and CO_2. The reference starter culture was FD-DVS-CHN-11 (Chr. Hansen), composed of *Lactococcus lactis subsp. cremoris, Leuconostoc* spp., *Lactococcus lactis* subsp. *lactis,* and *Lactococcus lactis subsp. lactis biovar diacetylactis.*

Milk Composition

Milk pH was measured using the potentiometric method described by Kaur *et al* (2020) employing a pH meter (Eutech pH 700). Titratable acidity was determined by acid–base titration using a magnetic stirrer (Fisherbrand) and an analytical balance (OHAUS Pioneer). Milk density was measured at 20°C using a portable densitometer (Density2Go, Mettler Toledo).

Total solids content was determined by drying 10 g of milk in a drying oven (Thermo Fisher Scientific, Model 5160) at 103±2°C. Ash content was measured by incineration of the dried milk sample in a muffle furnace at 525±25°C, according to the standard method NF V04-208. (NF V04-208 s. d.). Milk fat content was determined using the Gerber acid–butyrometric method.

Lactose content was determined according to the Bertrand method (Bourdon and Gielfrich, 1972). Protein content was measured using the Kjeldahl method (Pointurier *et al,* 2003), based on the determination of total nitrogen and applying a conventional conversion factor of 6.39 for milk. Vitamin C content was quantified using a calibration curve prepared with standard ascorbic acid solutions of known concentration (Tomovska *et al,* 2018). Analyses were performed in triplicate.

The composition of the raw camel milk used in this study was as follows: pH 6.67±0.07, titratable acidity 16.70±0.22, protein content 3.34±0.21 g/100 mL, fat content 4.56±0.43 g/100 mL, total solids 13.62±0.79 g/100 g, ash content 0.74±0.08 g/100 mL, density 1.030±0.002, and lactose content 3.71±0.38 g/100 mL. These values are consistent with those previously reported for camel milk (Konuspayeva *et al,* 2009; Badidja and Djellabi, 2014; Learoussy *et al,* 2020).

Manufacture of soft white cheese

Soft white cheese was produced from camel milk following a method adapted from that described by Bekele *et al* (2019). A total volume of 24 L of camel milk was used and divided into three batches of 8 L each. For each batch, seven cheese making trials were conducted by varying the level and type of milk powder addition: three concentrations of camel milk powder (2%, 5% and 10%), three concentrations of cow milk powder (2%, 5% and 10%), and a control without milk powder addition.

Whole milk was first filtered through a muslin cloth and then pasteurised at 65°C for 30 min in a stainless-steel vessel equipped with a thermostatically controlled water bath, under continuous stirring provided by an electric agitator. Cooling was achieved by immersing the pasteurisation vessel in a larger container filled with water and ice cubes (approximately 70% by volume), with continuous agitation to accelerate temperature reduction to 32°C. The milk was then distributed into seven 1-L containers. Calcium chloride was added to each container at a concentration of 0.3 mL/L (33%

anhydrous $CaCl_2$ solution). The average pH of the milk at the time of calcium chloride addition was 6.6±0.13, a value considered favourable for optimal coagulation, in agreement with the observations of Hailu *et al* (2016).

After an initial stirring period of 5 min, the starter culture was added at a temperature of 29°C. For inoculation, one sachet of commercial starter culture containing 50 units (U) was dissolved in 200 mL of fresh camel milk previously heat-treated at 100°C for 35 min. This preparation was stored at –22°C until use. The amount of starter culture added corresponded to the manufacturer's recommended dose, namely 10 U per 100 L of milk. Following a moderate acidification phase of 42 min at 27°C, the control milk reached an average titratable acidity of 17.2±0.2 °D, corresponding to a mean pH of 6.58±0.03. At this stage, camel-specific chymosin was added at a concentration of 80 international milk-clotting units per litre, as reported by Bekele *et al* (2019) and Hailu *et al* (2016).

Milk from each container was subsequently divided into two 500 mL portions, one used for cheese making and the other for monitoring acidification kinetics. The containers were then placed in an incubator set at 27°C for 3.5 h to allow complete coagulation and to reach a target pH for the control between 6.0 and 5.9. During fermentation, pH and titratable acidity were measured every 30 min.

After coagulation, the curd was cut vertically using a stainless-steel curd cutter into cubes of 1.2 cm in width and length, followed by a horizontal cut at mid-height (3 cm). Gentle stirring was applied, followed by a resting period of 10 min to promote whey expulsion. Moulding was carried out by transferring the curd into plastic moulds previously lined with a filtration cloth. The moulded curd was then held for 18 h at 22°C to allow further drainage. After this period, cheese samples were collected in sterile, airtight glass containers, weighed, and stored at 4°C for subsequent analyses.

Cheese yield and compositional analysis

Cheese yield was calculated according to the following formula: Cheese yield (%) = (Weight of cheese / Weight of milk) × 100.

The chemical composition of the cheese, including pH, titratable acidity, fat, protein, total solids (TS) and ash content, was determined using standard methods as described by Feldsine *et al* (2002).

A representative cheese sample was taken, sliced and homogenised in accordance with the sampling protocol proposed by d'Ardö and Polychroniadou (1999). Fat content was determined using the Gerber method, protein content by the Kjeldahl method, while total solids and ash contents were quantified using gravimetric methods. All analyses, with the exception of protein determination, which was carried out on the following day, were performed within 24 h after completion of cheese drainage. Each measurement was conducted in triplicate.

Sensory analysis

To evaluate the impact of milk powder enrichment on the sensory properties of the cheeses obtained, a delayed hedonic test was conducted by a trained panel of 10 assessors, including six assessors familiar with the consumption of camel milk cheese. In order to avoid any interference between the results of the different sensory evaluations, the tests were carried out on two separate days. Sensory assessment was performed 72 h after cheese manufacture.

Several sensory attributes were evaluated, including colour, appearance, aroma, taste and overall acceptability. Textural perception was not evaluated as a separate sensory attribute, however, its perception during mastication likely influenced taste and overall acceptability scores, as texture–flavour interactions are known to play a key role in consumer appreciation of fresh cheeses (Walstra *et al,* 2006). An additional criterion i.e., typicity of camel milk flavour, was introduced and clearly explained to the assessors to be taken into account during the overall evaluation. This criterion was used to assess the extent to which the addition of milk powders altered or preserved the distinctive sensory profile of camel milk cheese. Although, this parameter is not commonly reported in the literature, it is considered relevant in the context of valorising products with a strong identity, such as camel milk.

For each attribute, a 7-point hedonic scale was used, defined as follows: 1 = extreme dislike, 2 = moderate dislike, 3 = slight dislike, 4 = neither like nor dislike, 5 = slight like, 6 = moderate like, 7 = extreme like.

Samples were handonly coded and presented to the assessors at 3-min intervals. Tasting sessions were conducted in a sensory analysis laboratory equipped with individual booths, allowing easy sample handling by the operator and independent evaluation by each assessor, thereby avoiding interaction between panellists. Each booth was also equipped with an individual sink to allow mouth rinsing between samples.

Statistical analysis

Results obtained from physicochemical analyses, cheese yield determination and consumer preference tests were analysed using analysis of variance (ANOVA) according to a completely randomised design with seven treatments. Treatment means were initially evaluated using the F-test at a significance level of $\alpha = 0.05$. When a significant treatment effect was observed ($p < 0.05$), mean comparisons were performed using Tukey's honestly significant difference (HSD) test for multiple comparisons.

Results and Discussion

Monitoring of pH and titratable acidity of the samples

The acidification kinetics of the milk, expressed in terms of pH and titratable acidity, until reaching a pH of approximately 5.9 and a titratable acidity of 24.7°D, are presented in tables 1 and 2.

The results showed that camel milk supplemented with cow milk powder, particularly at inclusion levels of 5% and 10%, exhibited a faster acidification rate, characterised by a more pronounced decrease in pH compared with samples fortified with camel milk powder and the control. In contrast, formulations containing camel milk powder displayed a slower development of titratable acidity, indicating a less intense acidification over time (Fig 1).

The differences observed in acidification profiles can be attributed to compositional variations induced by milk powder supplementation, particularly in terms of fermentable lactose, protein content and mineral composition. Cow milk powder, which is richer in caseins and readily available substrates for lactic acid bacteria, promotes faster lactic acid production and consequently a more rapid decrease in pH. Conversely, camel milk powder, characterised by a low κ-casein content and the presence of natural antimicrobial components, leads to a more gradual acidification process (Konuspayeva *et al,* 2009; Seifu, 2023).

Similar behaviour was reported by Desouky *et al* (2019), who observed consistently higher pH values in systems supplemented with camel milk powder compared with control samples, particularly at higher incorporation levels. The authors attributed these differences to compositional modifications, including changes in lactose content, soluble nitrogen fractions and salt balance, which collectively affect the acid–base equilibrium of cheese systems. Comparable effects of formulation on pH and acidity have also

Table 1. Evolution of milk pH following the addition of two types of milk powder at different inclusion levels.

Time (min)	2% CMP	5% CMP	10% CMP	2% CWMP	5% CWMP	10% CWMP	Control	P-Value
0	6.58 ± 0.00^{a}	6.57 ± 0.01^{a}	6.59 ± 0.01^{a}	6.51 ± 0.02^{a}	6.53 ± 0.01^{a}	6.47 ± 0.00^{a}	6.58 ± 0.03^{a}	NS
30	6.54 ± 0.01^{a}	6.53 ± 0.00^{a}	6.54 ± 0.02^{a}	6.49 ± 0.02^{a}	6.48 ± 0.03^{a}	6.39 ± 0.01^{b}	6.54 ± 0.01^{a}	*
60	6.48 ± 0.00^{a}	6.50 ± 0.00^{a}	6.51 ± 0.00^{a}	6.41 ± 0.01^{b}	6.38 ± 0.00^{b}	6.31 ± 0.01^{b}	6.49 ± 0.01^{a}	**
90	6.45 ± 0.01^{a}	6.44 ± 0.02^{a}	6.36 ± 0.00^{b}	6.33 ± 0.04^{b}	6.27 ± 0.01^{c}	6.24 ± 0.02^{c}	6.48 ± 0.01^{a}	**
120	6.32 ± 0.01^{b}	6.34 ± 0.02^{ab}	6.29 ± 0.01^{c}	6.22 ± 0.03^{c}	6.18 ± 0.01^{d}	6.16 ± 0.00^{d}	6.38 ± 0.01^{a}	***
150	6.22 ± 0.02^{b}	6.29 ± 0.02^{a}	6.16 ± 0.00^{c}	6.15 ± 0.03^{c}	6.07 ± 0.02^{d}	6.04 ± 0.00^{d}	6.28 ± 0.02^{a}	***
180	6.15 ± 0.02^{a}	6.12 ± 0.02^{a}	6.04 ± 0.01^{b}	6.03 ± 0.02^{b}	5.92 ± 0.03^{c}	5.88 ± 0.03^{c}	6.19 ± 0.02^{a}	***

Values are expressed as mean±standard deviation (n = 2).

a–d: Means within the same row bearing different superscript letters differ significantly ($p < 0.05$). *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

Table 2. Evolution of titratable acidity of milk supplemented with two types of milk powder at different inclusion levels.

Time (min)	2% CMP	5% CMP	10% CMP	2% CWMP	5% CWMP	10% CWMP	Control	P-Value
0	18.35 ± 0.21^{a}	18.50 ± 0.42^{a}	18.35 ± 0.07^{a}	18.85 ± 0.49^{a}	18.55 ± 0.21^{a}	19.40 ± 0.28^{a}	18.30 ± 0.10^{a}	NS
30	18.55 ± 0.21^{b}	18.50 ± 0.00^{b}	18.75 ± 0.07^{b}	19.20 ± 0.71^{b}	19.05 ± 0.35^{b}	20.70 ± 0.00^{a}	18.70 ± 0.00^{b}	*
60	19.60 ± 0.14^{b}	19.55 ± 0.07^{b}	20.45 ± 0.07^{b}	20.60 ± 0.14^{b}	21.10 ± 0.42^{a}	21.50 ± 0.14^{a}	19.60 ± 0.26^{b}	**
90	20.45 ± 0.21^{b}	20.70 ± 0.28^{b}	21.70 ± 0.28^{a}	21.35 ± 0.21^{a}	22.30 ± 0.57^{a}	22.45 ± 0.35^{a}	20.50 ± 0.20^{b}	**
120	21.45 ± 0.64^{b}	21.40 ± 0.28^{b}	22.45 ± 0.07^{a}	22.60 ± 0.14^{a}	23.00 ± 0.28^{a}	23.30 ± 0.14^{a}	20.93 ± 0.46^{b}	***
150	21.70 ± 0.14^{d}	21.55 ± 0.35^{d}	22.70 ± 0.28^{c}	22.85 ± 0.35^{c}	23.80 ± 0.14^{b}	24.70 ± 0.14^{a}	21.50 ± 0.26^{d}	*

Values are expressed as mean±standard deviation (n = 2).

a–d: Means within the same row bearing different superscript letters differ significantly ($p < 0.05$). *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

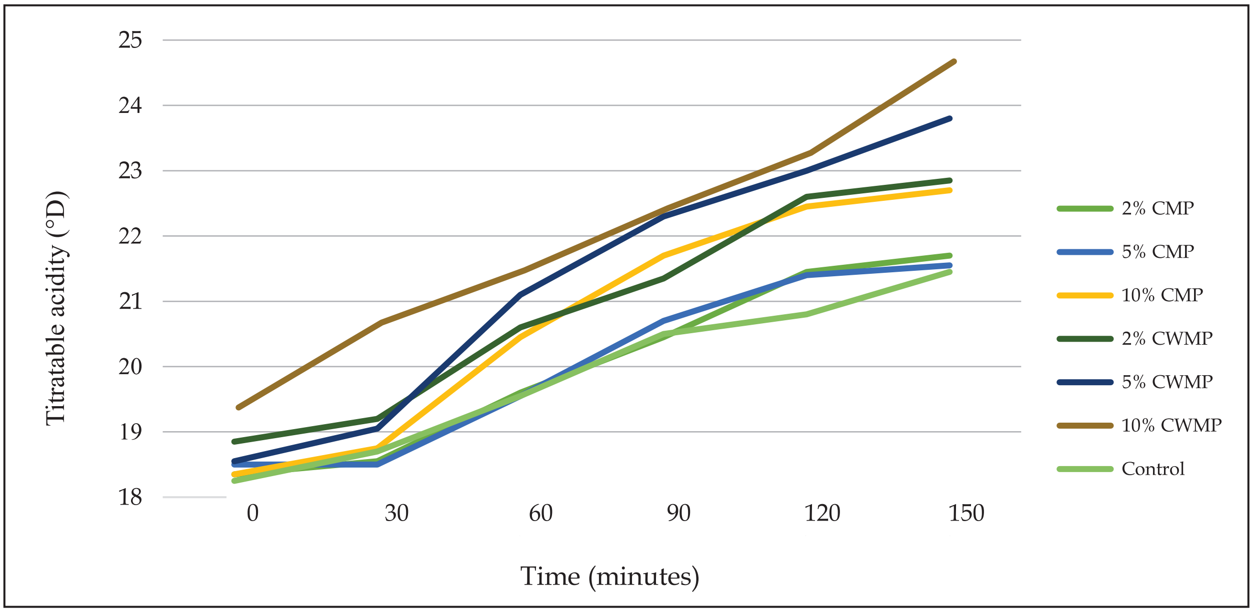

Fig 1. Evolution of milk titratable acidity following supplementation with two types of milk powder at different inclusion levels.

been described in dairy matrices by Aly *et al* (1995), Awad (2003) and Hassan *et al* (2007), emphasising the critical role of milk composition in regulating pH behaviour during cheese manufacture and storage.

These differences in acidification kinetics had a direct impact on coagulation properties. Formulations exhibiting a rapid pH decrease, particularly those enriched with cow milk powder, resulted in firmer and more cohesive curds, whereas samples with slower acidification produced weaker curds, accompanied by greater losses of fine particles into the whey. These observations confirm that, in cheese manufacture, the rate and intensity of acidification play a decisive role in gel structuring and curd quality, even when the same starter culture is used across treatments (Kongo, 2013).

Cheese analyses

The cheeses were analysed for pH, titratable acidity, fat content, protein content, total solids (TS) and ash, with all determinations performed in duplicate.

The physicochemical and technological analyses of fresh cheese produced from camel milk supplemented with different milk powders revealed significant differences among formulation, reflecting the pronounced influence of milk composition on most key cheese-making parameters. Variations observed in pH and titratable acidity confirmed that the addition of cow milk powder promote more intense acidification compared with camel milk powder and the control non supplemented. Similar trends have been reported in several studies, indicating that milk acidification kinetics strongly depend on the nature of the substrates available to lactic acid bacteria and on the buffering capacity of the medium (Walstra *et al*, 2006; Fox and McSweeney, 2004).

Lower pH values and higher titratable acidity observed in cheese enriched with cow milk powder are consistent with previous findings showing that enrichment of dairy matrices with bovine components stimulates fermentative activity and accelerates lactic acid production (Ho *et al*, 2022; Abo-Amer, 2021). In contrast, cheese supplemented with camel milk powder exhibited a more moderate acidification profile, which is in line with the intrinsic characteristics of camel milk, notably its low κ-casein content and the presence of natural antimicrobial compounds that may partially inhibit the growth of lactic acid bacteria (Al Haj and Al Kanhal, 2010; Konuspayeva *et al*, 2009).

Cheese yield was significantly higher in formulations enriched with cow milk powder, particularly at higher inclusion levels. This increase in yield can be explained by improved curd formation and greater curd firmness, which limited the loss of fine protein and fat particles into the whey during drainage. Similar observations have been reported for fresh camel milk cheeses that were enriched or subjected to faster acidification, where effective acidification favoured the retention of solid

Table 3. Charactérisation of the cheese obtained.

Parameter	2% CMP	5% CMP	10% CMP	2% CWMP	5% CWMP	10% CWMP	Control	P-Value
pH	5,61±0,12^{a}	5,41±0,21^{a}	5,53±0,19^{a}	5,41±0,22^{a}	4,52±0,16^{b}	4,31±0,18^{c}	5,42±0,13^{a}	***
Titrable acidity (°D)	75,2±0,8^{c}	86,0±1,5^{b}	86,5±2,0^{b}	97,6± 0,7^{b}	112,3±2,0^{a}	126,5±1,7^{a}	85,6±3,3^{b}	***
Fat (%)	23,53 ±0,09^{a}	22,86±0,86^{a}	22,81±0,86^{a}	23,37±0,38^{a}	22,33±0,45^{ab}	20,24±0,27^{b}	22,67 ±0,31^{a}	*
Ash (%)	13,59±0,36^{c}	12,68±0,13^{c}	13,41±0,66^{c}	14,65±0,87^{b}	14,18±0,58^{b}	15,78 ±0,10^{a}	13,62±0,11^{c}	*
Total Solids (%)	44,01±2,09^{a}	39,65±2,64^{b}	43,47±0,63^{a}	39,08±0,91^{b}	39,99±1,72^{b}	41,85±0,91^{ab}	44,46±0,82^{a}	**
Protein (%)	1,62±0,18^{c}	1,69±0,06^{c}	2,23±0,14^{b}	1,53±0,10^{c}	1,87±0,23^{b}	1,76±0,17^{b}	2,44±0,32^{a}	***
Yield (%)	10,61±0,18^{c}	10,58±0,36^{c}	11,51±0,35^{b}	12,65±0,40^{b}	13,63±0,06^{a}	14,48±0,20^{a}	10,79±0,51^{c}	**

Values are expressed as mean±standard deviation (n = 3).

a–d: Means within the same row bearing different superscript letters differ significantly ($p < 0.05$). *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

constituents within the curd (Siddig *et al,* 2016; Khan *et al,* 2004). Conversely, formulations associated with slower acidification resulted in lower yields, probably due to a more fragile gel structure and less controlled syneresis.

Variations in fat content among formulations can be related to the microstructural properties of the gels formed. Firmer and more cohesive gels, resulting from faster acidification, promote the retention of fat globules within the protein network, whereas weaker gels lead to increased fat losses into the whey (Castillo, 2006). The values obtained in the present study are comparable to those reported for fresh camel milk cheeses in some previous studies (Khan *et al,* 2004), but higher than those reported by Siddig *et al* (2016) and Mehaia (2006), highlighting the influence of formulation and processing conditions on lipid retention.

Protein content was also significantly affected by formulation, with cheese enriched with cow milk powder exhibiting higher values. This trend may be attributed to improved coagulation of bovine proteins and their greater ability to form dense protein networks, thereby enhancing their retention in the curd. Although, the protein contents measured were lower than those reported by Khan *et al* (2004), they remain comparable to values observed for fresh camel milk cheeses produced using similar processing approaches (Mehaia, 2006).

Total solids (TS) contents followed a trend consistent with that observed for yield and syneresis. Higher TS values were recorded in cheeses from formulations exhibiting faster acidification, confirming that acidification plays a key role in the solubilisation of colloidal minerals, gel contraction and whey expulsion (Lucey *et al,* 2003; Fox and McSweeney, 2004). The values obtained fall within the ranges reported for fresh camel milk cheeses at the end of drainage (Ramet, 2001; Hailu *et al,* 2014).

Finally, variations in ash content reflected differences in the mineral composition of the powders used and their impact on mineral retention in the curd. Higher ash contents were associated with formulations enriched with cow milk powder, in agreement with their higher calcium and phosphorus contents, whereas formulations characterised by slower acidification exhibited lower ash values. Comparable observations have been reported by Hailu *et al* (2014) and Siddig *et al* (2016), who emphasised the combined influence of milk composition, acidification mode and processing conditions on the mineral content of cheese.

Sensory analysis

The sensory evaluation results of soft white cheese supplemented with different milk powders are presented in table 4 ????ed on 7-point hedonic scale:1 = extreme dislike, 2 = moderate dislike, 3 = slight dislike, 4 = neither like nor dislike, 5 = slight like, 6 = moderate like, 7 = extreme like.

Overall acceptance included the panelists' evaluation of the presence and perception of the typical camel milk flavour in the cheese as a positive criterion.

Highly significant differences ($p < 0.01$ to $p < 0.001$) were observed among formulations for all the sensory attributes evaluated, namely colour, appearance, aroma, taste and overall acceptability (Table 4). These results indicate that the nature of the milk powder added as well as its level of incorporation have a marked influence on the sensory perception of soft white cheese. Colour scores showed that cheeses enriched with 2% CWMP (6.75) and 5% CMP (6.50) obtained the highest values ($p < 0.001$), reflecting better visual appreciation by consumers.

Table 4. Sensory evaluation and consumer preference scores of soft white cheeses supplemented with milk powders.

Parameter	2% CMP	5% CMP	10% CMP	2% CWMP	5% CWMP	10% CWMP	Non-supplemented control	P-Value
Colour	4,50±0,58^{bc}	6,50±0,58^{a}	3,25±0,50^{d}	6,75 ±0,50^{a}	5,00±0,82^{b}	4,00±1,83^{cd}	4,00±0,82^{cd}	***
Appearance	3,00±0,82^{c}	6,00 ±0,82^{a}	4,00±0,82^{b}	6,00±0,82^{a}	5,75±0,96^{a}	4,00±1,41^{b}	2,50±0,58^{c}	***
Aroma	5,25±0,50^{bc}	6,50 ±0,58^{a}	4,00±0,82^{d}	6,00±0,82^{ab}	5,50±1,29^{bc}	3,75±1,26^{d}	5,00±0,82^{c}	**
Taste	6,00± 0,00^{ab}	5,50±1,29^{bc}	4,25±0,96^{cd}	6,75± 0,50^{a}	5,50 ±0,58^{bc}	4,00±0,82^{d}	4,00±0,82^{d}	***
Overall acceptance	5,50±0,58^{bc}	6,00 ±0,82^{ab}	2,75±0,96^{d}	6,75±0,50^{a}	6,00±1,15^{ab}	3,75±1,26^{cd}	5,75±0,50^{b}	***

Values are expressed as mean±standard deviation.

a–d: Means within the same row bearing different superscript letters differ significantly ($p < 0.05$). **$p < 0.01$; ***$p < 0.001$.

In contrast, cheese enriched with 10% CMP (3.25) received the lowest colour score, suggesting a less favourable perception related to visual appearance. The control and the formulations 2% CMP and 10% CWMP showed intermediate scores, without reaching the level of acceptance of the highest-rated formulations.

Regarding appearance, highly significant differences ($p < 0.001$) were also observed. Cheeses enriched with 5% CMP (6.00) and 2% CWMP (6.00) obtained the highest scores, indicating a better perception of product structure and homogeneity. Conversely, the control (2.50) and cheese enriched with 2% CMP (3.00) showed the lowest scores, suggesting an appearance considered less attractive by consumers.

Aroma scores highlighted a significantly higher preference ($p < 0.01$) for cheeses enriched with 5% CMP (6.50) and 2% CWMP (6.00) compared with formulations containing 10% CMP (4.00) and 10% CWMP (3.75), which obtained the lowest scores. These results indicate that moderate enrichment levels favour the development of a more appreciated aromatic profile, whereas higher levels may lead to aroma notes perceived as less pleasant.

Concerning taste, the differences observed was highly significant ($p < 0.001$). Cheese enriched with 2% CWMP obtained the highest score (6.75), followed by 2% CMP (6.00) and 5% CMP (5.50). In contrast, cheese enriched with 10% CMP (4.25) and 10% CWMP (4.00) showed significantly lower taste scores, indicating reduced gustatory acceptability at higher enrichment levels.

Overall acceptability followed a similar trend, with significantly higher scores ($p < 0.001$) for cheeses enriched with 2% CWMP (6.75), 5% CWMP (6.00) and 5% CMP (6.00). Conversely, the 10% CMP formulation obtained the lowest overall acceptability score (2.75), suggesting that high levels of camel milk powder enrichment negatively affect the overall appreciation of the product. The control showed an intermediate score (5.75), indicating acceptable but lower consumer preference compared with some enriched formulations.

It should be noted that overall acceptability included the panellists' assessment of the presence and perception of the typical camel milk flavour, considered as a key identity attribute of camel milk cheese. In this context, moderate enrichment levels appeared to preserve this characteristic flavour while improving textural and visual attributes, whereas higher levels of camel milk powder tended to intensify intrinsic camel milk notes that were perceived as less pleasant by some consumers.

The variations observed in sensory scores can be attributed to changes in cheese composition and structure induced by milk powder supplementation. Moderate incorporation levels appear to promote a balance between texture, flavour and appearance, whereas high levels, particularly with camel milk powder, may intensify intrinsic sensory characteristics of camel milk that are perceived as less pleasant by consumers. Similar observations have been reported for fresh camel milk cheese, where sensory properties strongly depend on formulation and processing conditions (Bekele *et al,* 2019). Furthermore, differences in aroma and taste may be related to the formation of volatile compounds during fermentation, such as diacetyl, acetaldehyde and other aromatic metabolites produced by lactic acid bacteria. These compounds play a key role in the development of the aromatic profile of fresh cheeses, and their concentration depends on substrate composition and fermentative activity (Walstra *et al,* 2006; Papagianni, 2012). Overall, moderate enrichment of camel milk with milk powders, particularly cow milk powder, appears to create a more favourable environment for the development of sensory characteristics appreciated by consumers.

The present study demonstrated that the enrichment of camel milk with milk powders markedly influenced the acidification behaviour, coagulation properties, physicochemical composition, cheese yield and sensory quality of fresh soft white cheese. Significant differences was observed among formulations, highlighting the decisive role of milk composition in determining the technological performance and consumer acceptance of camel milk cheese.

Enrichment with cow milk powder, particularly at inclusion levels of 5% and 10%, resulted in a faster acidification rate, lower final pH values and improved curd firmness compared with camel milk powder supplementation and the control. These effects translated into higher cheese yields, greater retention of proteins and total solids, and more cohesive curd structures, thereby confirming the positive contribution of bovine milk components to the cheese making aptitude of camel milk. In contrast, formulations enriched with camel milk powder exhibited a slower acidification kinetics and weaker curd structure, reflecting the intrinsic compositional characteristics of camel milk, including its low κ-casein content and higher antimicrobial activity. From a sensory perspective, moderate levels of enrichment were found to be critical for balancing technological improvement and sensory quality. Cheese enriched with 2% cow milk powder and 5% cow milk powder achieved the highest scores for colour, appearance, taste and overall acceptability, while maintaining the typical camel milk flavour appreciated by the panellists. Conversely, higher incorporation levels, particularly 10% camel milk powder, negatively affected sensory perception, leading to lower consumer preference scores. These findings indicate that excessive enrichment may intensify certain intrinsic sensory attributes of camel milk that are perceived as less pleasant by consumers. Overall, the results suggest that moderate enrichment of camel milk with cow milk powder, especially at level of 5%, represents the most suitable compromise between technological performance and sensory acceptability. This formulation provided improved acidification, higher cheese yield, enhanced compositional quality and favourable consumer preference scores, while preserving the characteristic sensory identity of camel milk cheese. Controlled supplementation with cow milk powder constitutes a promising technological strategy for improving the manufacture of fresh soft white cheese from camel milk. Such an approach may contribute to the valorisation of camel milk in arid and semi-arid regions by enhancing processing efficiency and product quality without compromising consumer acceptance. Further studies could explore the combined use of different enrichment strategies or starter cultures to optimise both functional and sensory attributes of camel milk cheeses.

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