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Article

Physicochemical and sensory characterization of 'Molido' fresh cheese made with milk from cows fed sorghum or corn silage

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Abstract:

The diet of cows affects dairy products due to the physicochemical and sensory characteristics of the milk produced. Sorghum silage is an alternative for small-scale milk production systems in the high valleys of Mexico in the face of changes in rainfall and drought periods. Sorghum forage contains tannins that could affect the composition and sensory characteristics of the cheese. The objective was to evaluate 'Molido' fresh cheese made with milk from cows fed based on 80 % sorghum silage – 20 % corn silage for the silage component in the diet (SORGHUM treatment) compared to 100 % corn silage (CORN

treatment). The physicochemical composition was analyzed using a completely randomized design. The sensory evaluation used a Likert scale analyzed with Kruskal-Wallis, and cheese preference used a Chi-square (χ^2) test. There were differences (P<0.05) between cheeses for contents of fat (SORGHUM 25.3 % *vs.* CORN 24.9 %), protein (SORGHUM 17.6 % *vs.* CORN 16.3 %), and ashes (CORN 2.4 % *vs.* SORGHUM 2.9 %). Regarding the sensory analysis, there were differences (P<0.05) for taste (SORGHUM 3.4 *vs.* CORN 4.0), mouthfeel (SORGHUM 3.4 *vs.* CORN 3.7), and aroma persistence (SORGHUM 2.3 *vs.* CORN 2.1). However, in terms of general preference, SORGHUM cheese was preferred (P<0.05) by consumers (53 %). The preference for cheese made with milk from cows fed with a forage base of sorghum silage represents an alternative for small-scale producers whose milk is destined for the artisanal production of 'Molido' fresh cheese.

Keywords: Sensory perception, Consumer preferences, Condensed tannins, Untrained judges, Hedonic test.

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Introduction

Cheese is one of the most consumed foods in the world[1], with a global production of more than 19 million tonnes, with a growing demand in developing countries that favors small-scale producers[2,3], who in turn stimulate economic activity and job creation in their communities[4,5]. Several factors influence the final composition and quality of cheeses, such as the diet of the cows, the initial composition of the milk, and the aging times and processes[6,7].

Milk production in the high valleys of central Mexico is mainly carried out by small-scale systems, which are defined as small farms with herds of between 3 and 35 cows plus their replacements, that base their operation on the family labor force[8]. Most sell their milk to local producers who process it into artisanal dairy products, mainly cheeses, with a typicity linked to the territory and the result of local know-how, culture, and the history of the region[5,9].

The cows' diet is increasingly based on corn silage[10] as a quality forage to maintain milk yields in the dry winter season. Nonetheless, corn crops for silage require adequate rainfall[11]. The availability of irrigation water is increasingly restricted[12] due to both high demand and several years of low rainfall, coupled with possible effects of climate change, with disruption in the rainfall pattern, with longer dry periods; all of this requires the evaluation of better-adapted forage alternatives[13].

An alternative forage is sorghum (*Sorghum bicolor* L.), a tropical cereal native to Africa that adapts to low rainfall and drought[14]. Sorghum for grain and forage is widely used in Mexico in low-altitude zones with tropical warm temperatures[14], but it has not been evaluated in the temperate regions of the high valleys of central Mexico; it may be an alternative since it has been promoted in temperate areas of Italy[15], Galicia[16], and Canada[17] as a valuable source of forage to overcome the problems of water restrictions mentioned.

Likewise, sorghum forage contains secondary metabolites (polyphenols and tannins), which interact with proteins and carbohydrates, affecting its rumen digestibility[18]. Studies show that moderate concentrations (2-4 % dry matter) reduce rumen protein degradation through tannin-protein complexes, increasing the flow of essential amino acids to the intestine[19]. This mechanism can influence the physicochemical composition of milk and cheese[20] and the sensory perception, where tannins modify the fatty acid profile[21,22], which contributes to sensory changes in the cheese[23]. Since cheese production is the main destination for milk in small-scale systems, it is necessary to evaluate the effects it may have on the properties of cheese. Therefore, the work aimed to assess the physicochemical composition and sensory characteristics of fresh cheese made with milk from cows fed diets based on sorghum or corn silage.

Material and methods

Study area

The work was carried out in collaboration with a small-scale cheese factory where typical Mexican cheeses are made in an artisanal way, located in the municipality of Aculco in the State of Mexico, in the region of the High Valleys of central Mexico. Aculco is located between coordinates 20° 00' - 20° 17' N and 99° 40' - 100° 00' W, at an altitude between 2,000 and 3,000 m, with a temperate subhumid climate[24]. The region, the production systems, and the milk-cheese system have been described in other publications[11,12,25].

Research design

Small-scale milk producer, through a completely randomized design lasting 28 d, which agrees with other experiments in periods of 28 d for productive performance[26] and 21 d for sensory evaluation of cheese[27], with eight Holstein dairy cows. The cow selection criteria were daily milk yield, days in milk, and live weight.

The small number of experimental cows is related to the small herd size in small-scale production systems. Nevertheless, the experiment had a statistical power of 0.67, validating the results. In addition, being an on-farm experiment, it allows for the adoption of the results since it is developed in the context in which these systems operate, and allows for their dissemination among producers through direct communication at a distance of up to 30 km[28].

The cows were divided into two groups, evaluating two silage-based diets. One group received the SORGHUM treatment= 7.6 kg dry matter (DM)/cow/d of Caña Dulce sorghum silage + 1.9 kg DM cow^{-1} d^{-1} of corn silage (80 % sorghum silage and 20 % corn silage in DM in terms of the silage component of the diet). The other group received the CORN treatment= 9.5 kg DM cow^{-1} d^{-1} of corn silage in terms of the silage component of the diet.

All cows also received 4.0 kg fresh matter (3.6 kg DM) cow^{-1} d^{-1} of a commercial concentrated feed and 2.4 kg DM/cow/d of alfalfa hay, and 2.4 kg DM cow^{-1} d^{-1} of corn stover, by decision of the collaborating producer, which was respected as a premise of rural participatory research. The results of animal performance and forage and feed composition are reported in another study[28].

On the last day of the experiment, 57 L of milk were collected from each treatment from the morning and afternoon milkings, which were kept refrigerated and were transported to the artisanal cheese factory; this milk was used to make the evaluated cheeses following the procedures described by several authors[29,30,31] regarding the preparation of the evaluated cheeses from the set of milk produced by treatment.

Cheese-making process

Fresh cheeses of the ‘Molido’ type of Aculco were made traditionally. This cheese is the most representative of the study area[5,32]. It is a fresh, unpressed cheese, characterized by a soft granular consistency, with a slightly acidic flavor, and marketed mainly in the form of

rectangular prisms. The name 'Molido' (ground) comes from the processing, where the curd is left to rest for 24 hours to be subsequently ground in a stone mill before being placed in molds[5].

The usual practices for making 'Molido' cheese were followed[29]. The milk is heated to 35 °C, and 3 g L^{-1} of calcium chloride is added, along with 5 ml L^{-1} of synthetic rennet. Thirty minutes later, the curd is cut into cubes of approximately 1 cm^3, and the whey is drained, leaving the curd cubes to drain for 24 h; salt (15 g kg^{-1}) is then added, and the cubes are ground in a stone mill. The ground curd was deposited in rectangular stainless-steel molds with an approximate capacity of 500 g. The cheeses were coded, vacuum-packed, and kept refrigerated for laboratory and sensory analysis. Eleven cheeses were made in a rectangular prism format of approximately 500 g for each treatment.

Physicochemical composition

Physicochemical analyses were performed from samples of 150 g of each cheese in triplicate for moisture, pH, ash, protein, and fat, following Mexican standards: NOM-116-SSA1[33] for moisture; NMX-F-099[34] for pH; NMX-F-066-S[35] for ashes. Protein content was determined by the Kjeldahl method[36], and fat content by the Soxhlet method[37]. The cheese yield was expressed as kilograms of cheese 10 kg^{-1} of milk.

Sensory evaluation

The sensory evaluation was carried out with 132 young university students who consumed cheese (untrained judges), and the number of judges was adequate for this Drake[38] test.

Each cheese was cut into cubes of approximately 20 g and placed on white cardboard plates, and each sample was coded with three random digits. Each participant had white bread and water to cleanse the palate between evaluations. Two tests were conducted, one for acceptance (sensory attributes) and one for general preference. Acceptance was evaluated with a five-point Likert scale, where the values corresponded to: 1= I do not like it; 2= I do not like it much; 3= I neither like nor dislike it; 4= I like it; and 5= I like it very much[39]. The attributes evaluated were visual appreciation, hand-feel, smell, taste, mouthfeel, aromas, and aftertaste[29]. Preference was determined by asking participants which sample of cheese they preferred the most.

In sensory evaluation, the panelists were not informed about the type of cheese they were evaluating until after the exercise ended. This strategy was used precisely to avoid biases related to previous perceptions, familiarity, or cultural associations, and to ensure an assessment based solely on the organoleptic characteristics of the product.

Statistical analysis

An analysis of variance was applied to the physicochemical variables under a completely randomized design[40] with the following model:

Yij = μi + tj + eij, where μ= general mean; t= effect of treatments (i= 1, 2), and e= residual variation.

The analysis was carried out by taking the average values of the three determinations per cheese. Sensory attributes were analyzed using the non-parametric Kruskal-Wallis test, which is valid for comparing two or more independent samples[41], and cheese preferences using the Chi-square (χ^2) test[39].

Results

Physicochemical composition

Table 1 shows the results of the physicochemical composition of the cheeses by treatment, with significant differences (P<0.05) for protein, fat, and ash contents, and non-significant differences (P>0.05) for moisture content and pH. The protein and fat contents were higher in the SORGHUM treatment; in contrast, the ash content was higher in the CORN treatment. The cheese yield was 1.14 kg 10 kg^{-1} milk for the CORN treatment and 1.12 kg cheese 10 kg^{-1} milk for the SORGHUM treatment.

Table 1: Physicochemical composition of 'Molido' cheese by feed treatment

	Treatments			
Variable	**CORN**	**SORGHUM**	**SEM**	***P*-value**
Protein, %	16.3	17.6	0.193	0.000
Fat, %	24.9	25.3	0.0650	0.027
Moisture, %	46.1	46.6	0.304	0.246
Ashes, %	2.9	2.4	1.187	0.004
pH	4.7	4.7	0.025	0.235

CORN= treatment with corn silage; SORGHUM= treatment with sorghum silage; SEM: standard error of the mean.

Sensory evaluation

Table 2 presents the scores for the sensory attributes evaluated, where significant differences ($P<0.05$) were detected in taste, mouthfeel, and aroma persistence, with higher values for the CORN treatment. While the medians and interquartile ranges appear to be similar between treatments, the differences identified by the Kruskal-Wallis test reflect variations in the distribution of responses given by consumers. This occurs because, in non-parametric data, similar central values do not imply equal distributions; there may be variations in how responses are concentrated along the Likert scale, reflecting different sensory perceptions between treatments. Likewise, a trend ($P=0.06$) was observed towards a more favorable assessment in the smell attribute for the CORN treatment, without statistically significant differences ($P>0.05$).

Table 2: Scores of the sensory attributes of 'Molido' Cheese on the five-point Likert scale

Attribute	**Treatments**				**H-value**	***P*-value**
	CORN		**SORGHUM**			
	Median	**IQR**	**Median**	**IQR**		
Color	4.0	0	4.0	0	0.99	0.321
Visual appreciation	4.0	1	4.0	1	0.05	0.831
Hand-feel	4.0	1	4.0	1	0.04	0.843
Smell	4.0	2	3.5	1	3.43	0.064
Taste	4.0	2	4.0	2	4.50	0.034*
Mouthfeel	4.0	1	4.0	1	7.75	0.005*
Aromas	4.0	1	4.0	1	1.41	0.235
Aftertaste	4.0	1	4.0	1	0.65	0.420
Aroma persistence	2.0	1	2.0	1	9.64	0.002*

H-value= Kruskal-Wallis test statistic. IQR= interquartile range. CORN= treatment with corn silage; SORGHUM= treatment with sorghum silage.

* Significant differences ($P<0.05$).

Nonetheless, in terms of general preference, cheese from the SORGHUM treatment was significantly preferred by 53 % of the participants, while cheese from the CORN treatment was chosen by 47 % (χ^2= 3.84, P<0.01).

Discussion

The higher fat and protein contents in the cheese from the SORGHUM treatment can be attributed to the effects of the differences between the two types of forages (sorghum or corn silage). Some studies[42] attribute these modifications to the dietary tannin content present in sorghum, which can influence rumen metabolism and milk composition. In Brazil, Dos Santos *et al*[23] reported that adding tannins to the goats' diet significantly modified the ash content of Coalho cheese, results that can be compared with the findings of the present study. These results also coincide with what was reported in an analysis of fresh cheese marketed in the Toluca Valley, 110 km away from Aculco in central Mexico[43], where the ash content was in a range between 2.65 and 5.24 %.

Regarding the composition of cheese fat, other authors[44] demonstrated that a diet with added tannins increases the amount of fat in cheese, going from 17.8 g to 18.4 g, a quantitative difference similar to that observed between the treatments in this study. In addition, a study on Caciocavallo cheese[45] showed that sorghum silage as a feed base generated a higher fat content (50.2 %) compared to that produced from milk from cows fed with sorghum hay (48.9 %). Similarly, it has been shown that the tannins and polyphenols present in forages, such as *Leucaena leucocephala* (a tannic forage shrub), are not only transferred to milk and cheese but also significantly increase their antioxidant capacity and substantially modify their lipid profile[42].

The integration of all these elements suggests that the tannins present in sorghum silage, through their multiple mechanisms of action, including the protection of rumen proteins[18,46], the increase in available amino acids[18,47,48], and the modulation of oxidative processes, could explain the compositional and sensory differences observed between cheeses made with milk from cows under the SORGHUM and CORN treatments in the present study.

As it was not possible to determine the tannin contents in silages or diets, it is not possible to say that the differences in the physicochemical composition or consumer preference for cheeses were due to the tannin content in the SORGHUM treatment. Nevertheless, based on reports in the literature regarding the effects of tannins in the diet of ruminants on the composition of milk and cheeses, this effect may be considered in the present experiment[20].

Sensory evaluation

Some studies[45,49,50] have shown that the type of forage and its preservation method influence the sensory and compositional properties of cheese. Uzun *et al*[49] observed that fresh sorghum in the buffalo cows' diet modified the texture of Mozzarella cheese, reducing its softness compared to corn-based diets, results consistent with those of this study.

Regarding the taste profile, Serrapica *et al*[45] reported that sorghum silage in the diet of cows increased the presence of ketones and acids in Caciocavallo cheese, compounds associated with bitter flavors[45]. This effect could explain the lower sensory ratings obtained in the cheeses from the SORGHUM treatment, since the condensed tannins and other phenols present in the sorghum can generate astringency and bitterness[48]. Additionally, it was found that the method of preservation (silage *vs* hay) and the type of forage alter the taste profile of the cheese; however, its impact varies according to the dairy raw material used[43].

On the other hand, Manzocchi *et al*[50] demonstrated that a properly preserved silage does not generate unpleasant flavors in Cantal cheese, which coincides with the results of this work in certain specific sensory attributes. Also, some researchers[23] agree that including tannins in the diet of goats modified the ash content in Coalho cheese.

The lower texture score observed in the cheeses from the SORGHUM treatment could be attributed to the presence of secondary metabolites of sorghum, particularly tannins, since it has been reported that tannin-rich diets generate harder and less adherent cheeses[51]. This is consistent with what was reported in Tepeque cheese[20], where phenolic compounds from tropical plants were associated with increased product hardness.

On the other hand, the cheeses from the CORN treatment stood out for their greater aromatic persistence, maintaining the perception of aromas for longer after consumption[52], a result aligned with previous studies that favor corn in sensory evaluations.

Preference test

The results on the general preference of the panelists suggest that there are particular consumers for each type of cheese, as, although the cheeses from the CORN treatment were better rated for individual sensory attributes, most of the panelists preferred the cheese from the SORGHUM treatment.

Similarly, a study conducted in Brazil[27] reported high values of global preference for goat cheese obtained from the diet with different levels of inclusion of sorghum silage in the diet of goats, with results in line with those reported here. This phenomenon, far from being contradictory, reflects the complexity of consumer behavior, where food choices do not depend solely on technical evaluations, but also on psychological, cultural, and experiential factors[53]. As mentioned, consumers tend to base their decisions on specific attributes of personal interest, leaving aside other aspects evaluated separately[54].

This finding is consistent with what was reported by Arvola *et al*[55] in their study on familiar and unknown cheeses, where they demonstrated that, although a cheese may have lower sensory scores in specific attributes, its association with positive experiences (such as Western foods or nostalgia) may influence its overall preference. In the present study, panelists may have prioritized characteristics such as aftertaste, juiciness, or familiarity of the cheese from the SORGHUM treatment, even when other attributes were better evaluated in the cheese from the CORN treatment.

Likewise, the preference for SORGHUM cheese can be explained from the concept of familiarity, understood as the connection with previous experiences of the consumer. Studies such as that by Torrico *et al*[53] have shown that consumers tend to prefer foods that are aligned with their previous experiences, cultural references, or consumption habits, even if they are not the most prominent sensorily.

Conclusions and implications

The results showed that the physicochemical composition of the 'Molido' fresh cheese presented significant variations depending on the type of silage used in the diet of cattle. Specifically, cheeses made with milk from cows fed sorghum silage showed higher fat and protein contents. These compositional differences were accompanied by modifications in sensory attributes. The cheese from the SORGHUM treatment reached a higher level of general acceptance, so including sorghum silage in the dairy cattle diet represents a viable alternative for small-scale producers oriented to the artisanal production of 'Molido' fresh cheese, where the specific characteristics of the final product are decisive for its acceptance in the market.

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Conflict of interest

The authors declare that they have no conflict of interest.

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