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Effects of goat milk addition on physicochemical characteristics and conditioning performance of shampoo

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ABSTRACT
Goat milk, *per se*, has very interesting technological and nutritive features, and could be used in shampoo formulations and improve their properties. The aim of this study was to compare the physicochemical characteristics and conditioning performance of shampoo made with 0, 10, 20 and 30% content of goat milk. pH, surface tension, solids content, wetting time, foaming ability and foam stability, dirt dispersion, viscosity, instrumental colour, and conditioning performance were evaluated during 60 days of storage. pH ranged between 5.55 and 6.73. Goat milk addition decreased the surface tension and viscosity, as well as provided good conditioning performance, good cleaning capacity, foaming stability, wetting time, luminosity and blueish to the shampoos. The best shampoos were those that used 10–20% of goat milk, because they kept their features and did not present flocculation of milk proteins or acidification. The stability of the product with goat milk was established at one month.

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Conditioning performance; dirt dispersion; foaming ability; goat milk; shampoo

1. Introduction

Goat milk production ranks third in the world, after cow and buffalo milk, with a production of 20.6 million tons in 2020, representing 2.32% of total world milk production, according to semi-official data obtained up to 2020 (FAOSTAT 2022). In Mediterranean countries and Latin America, goat milk is mainly considered for cheese production, while in Africa and South Asia, goat milk is consumed as raw or acidified milk. Goat milk has been widely known for its nutritional, health and therapeutic benefits, which has the possibility of potentially being used to transform or be used as ingredients in non-food products, thus gaining special recognition in the cosmetic industry (Ribeiro and Ribeiro 2010).

Goat milk is a balanced mixture of proteins, fats, carbohydrates, probiotics, cells, salts and other components (Sánchez-Macías et al. 2014), at the same time presenting very different properties from cow or sheep milk, such as better digestibility, alkalinity, buffering capacity and therapeutic values in medicine and nutrition (Park et al. 2007; Bidot-Fernández 2017). In addition, goat casein micelles contain more calcium and inorganic phosphorus than cow's milk casein, and goat milk components help to reduce its allergenic potential (Verruck et al. 2019). Several studies have been published on the physicochemical, antimicrobiological and functional properties of bioactive components and somatic cells in goat milk-based products and their implications on human health and skin, including cosmetic products (Sánchez-Macías et al. 2013a; Jaya et al. 2019; Sánchez-Macías et al. 2019; Verruck et al. 2019). Other relevant components in goat milk are α-hydroxy acids, vitamins and minerals, which would potentially aid cellular nutrition. An important role would be played by lipoproteins, providing natural characteristics to certain products, in addition they also provide defense against type O enteropathogens, which have crucial impacts on metabolism and human health (Park and Nam 2015). The physical form of the fat globules, which are naturally homogenized in the goat milk and rich in phospholipids (Sánchez-Macías et al. 2013b) makes it an ideal ingredient for the cosmetic industry. On the other hand, Zakirul Islam et al. (2021) isolated, characterized and evaluated the probiotic properties of lactic acid bacteria from raw goat milk. Of a total of 50 lactic acid bacteria, they found the existence of 6 genera where *Lactobacillus* was found as dominant, and more than 80% inhibited the growth of tested pathogenic microorganisms. Also, their study, most of the tested strains exhibited good survivability under digestive juices and salts, as well in low pH conditions, and also resistance against some antibiotics (such as tetracycline, neomycin, ampicillin, gentamycin, chloramphenicol, and penicillin, among others). Cosmetic products containing goat's milk as an ingredient could act differently on the skin than products that do not contain it, as they could offer greater benefits and do not cause allergies.

Shampoo is considered one of the most used cosmetic products for daily cleansing of the hair and scalp, its usage is intended for both men and women of all ages. The function of shampoo is to remove dust, excessive sebum, or other grease effectively and completely. On the other hand, it should have good foaming ability and foam stability, be easily removed on rinsing with water, and to leave the hair

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soft, shiny, and manageable. There are shampoos on the market that contain special and natural ingredients as rosemary, aloe vera, anti-dandruff medication, or vitamins, to provide the hair and scalp with extra nourishment and an anti-dandruff effect, among others.

Currently, consumers prefer shampoos that are totally organic, i.e. free of parabens (which are considered by consumers to be harmful to health), with natural ingredients, as goat milk. There is not enough scientific bibliography regarding the effects of using goat milk in cosmetic formulations on their physicochemical and technological characteristics, as well on the conditioning performance. For our study, we previously analyzed the formulation of 13 different shampoos from the market as well as formulations found in databases and standard operating procedures, among others. Thus, it was established that the ideal is to use a shampoo formulation free of parabens and other components that are potentially harmful to our health. It was also avoided to use components that together produce carcinogenic compounds such as benzene, as occurs when mixing sodium benzoate with vitamin C.

Some indicators that determine if a shampoo is out of date or in poor condition are the presence of strange odours or consistency, colour change, low foaming capacity, separated into phases, does not clean effectively, or leaves residues. The recommended usage time for commercial shampoo is about 12–18 months after opening. In our study we started with a time of 2 months after opening, in order to evaluate the usefulness and characteristics of the product in the short term, and then, in new studies, change the formulation if necessary and extend the study times. Evaluating the presence of goat milk in different concentrations in the shampoo base formulation could help to understand its effect little by little, so that in the future also these formulations could become more complex according to the results of the studies. According to this background, the objective of this work was to evaluate the use of goat milk in a shampoo base formulation on the physicochemical, technological characteristics and conditioning performance for 60 days after opening the container.

Table 1. Formula for production of 2 L of shampoo with 0, 10, 20 y 30% of goat milk.

Component	Function	Goat milk percentage in formulation			
		0%	10%	20%	30%
Texapon ® (g), sodium lauryl sulphate	Anionic surfactant	240	240	240	240
Comperland ® (g), Cocodiethanolamide	Thickener/foam booster	100	100	100	100
NaCl (g)	Thickener	20	20	20	20
Glycerine (g)	Humectant	20	20	20	20
Cetiol ® (g), ethylhexil stearate	Emollient	20	20	20	20
Sodium benzoate (g)	Antimicrobial agent	10	10	10	10
Citric acid (g)	pH adjuster	6	6	6	6
Distilled water (mL)	Diluent	2000	1800	1600	1400
Goat milk (mL)	Added value ingredient	0	200	400	600

2. Material and methods

2.1. Goat milk, ingredients, and experimental design

Milk was obtained from an experimental dairy farm of early lactation and healthy Saanen goats in the province of Chimborazo (Ecuador). It was obtained daily under hygienic conditions and transported at 4°C in sterilized glass containers and pasteurized at 83 °C for 10 min prior to use. The ingredients for shampoo base formulation were obtained from a store specializing in raw materials for cosmetics (chemical grade) in the province of Chimborazo.

Two litres of shampoo were made with 0, 10, 20 and 30% of goat milk, coded as **G0**, **G10**, **G20** and **G30**, respectively. G0 was considered as control in this study. The experiments were carried out in triplicate, for which three batches of shampoo were worked on different days. Physicochemical, technological, and sensory analyses were performed at 0, 30 and 60 days of storage after opening the containers.

Both the preparation and analysis of the shampoo were carried out in the laboratories of the Animal Production and Industrialization Research Group (Universidad Nacional de Chimborazo, Riobamba, Ecuador).

2.2. Shampoo formulations and production

A base formulation was made depending on the levels of goat milk used to prepare the product, according to the ingredients and quantities summarized in Table 1. The treatments were made by duplicate in three baths.

Briefly explained, to prepare the shampoo, first the sodium lauryl sulphate was mixed with the cocodiethanolamine until a lump-free mixture was obtained. Sodium chloride was dissolved in 100 mL of distilled water and added to the previous mixture. Then the rest of the distilled water was added and mixed until a homogeneous, lump-free and thick consistency was observed. Glycerine and cetiol (ethylhexil stearate) were added, stirring until a texture and viscosity characteristic of shampoo was obtained. On the other hand, sodium benzoate and citric acid were dissolved in the milk and added to the shampoo base.

The whole mixture was left to stand for one day under ambient conditions (20–23 °C), in order to allow the interaction of all the components and the elimination of the foam produced during the shampoo preparation. Subsequently, the shampoos were packaged in sterile 2-L containers and labelled according to treatment. Samples of the shampoo were taken from the same container at 0, 30 and 60 days, simulating the analysis from the time the product was first used until 60 days after opening.

All physicochemical and conditioning analyses were performed in triplicate and at 0, 30 and 60 days of shampoo storage.

2.3. Physicochemical analysis of the shampoo

The pH was analyzed in samples of 50 mL pure shampoo, in triplicate at 0, 30 and 60 days, using a digital potentiometer

(Milwaukee, model MI 150, United States) according to the method proposed by Abu-Jdayil and Mohameed (2004).

To evaluate foaming formation and foam stability, the cylinder shaking method, proposed by Kumar and Mali (2010), was used. A dilution of 1% shampoo in 50 mL of distilled water was prepared at room temperature (20–23 °C) in a 250 mL graduated cylinder. It was covered by hand and shaken 10 times. The volume of foam formed was recorded after 1 min. To evaluate the stability of the foam, the final volume was recorded after 20 min.

The wetting time was measured with the velvet test, proposed by Krunali et al. (2013) to evaluate wettability. Discs of velvet of 2.54 cm in diameter and weighing approximately 0.30 g were cut. In a 500 mL graduated cylinder, 100 mL of a 1% solution of shampoo was prepared. The disc was placed in the prepared solution and the time required for the disc to sink was noted as the wetting time.

To quantify the percentage of solids, the procedure described by Fazlolahzadeh and Masoudi (2015) was carried out, in which the evaporated amount of the liquid part of the shampoo is measured. Four g of shampoo was used in the evaporation dish at 150°C on the heater. The sample was allowed to evaporate all the liquid part, about 10 min. The sample was weighed again, and the percentage of solids was calculated.

To measure the surface tension, measured in dynes/cm, the protocol proposed by Kumar and Mali (2010) was followed. An empty beaker was weighed, and 10 drops of distilled water were weighed with a dropper. A 10% solution of shampoo was prepared, and 10 drops of the solution were weighed into the beaker with the help of an eyedropper. The surface tension of the shampoo solution (R2) was calculated as the following equation 1.

$$\mathrm{R2} = \frac{(W3 - W1)N1}{(W2 - W1)N2} \times R1 \quad (1)$$

Where: W1 is the weight of the empty glass. W2 is the weight of the beaker with distilled water. W3 is the weight of the beaker with shampoo solution. N1 is the number of drops of the distilled water and N2 is the number of drops of the shampoo solution. R1 is the surface tension of distilled water at room temperature (20–23 °C). R2 is the surface tension of the shampoo solution.

The dirt dispersing ability of the shampoos was performed through the India ink method proposed by Kumar and Mali (2010), a qualitative test in which the amount of ink in the foam was observed and scored with the parameters of none, light, moderate, or heavy, compared with a grey scale. A 1% solution of shampoo (1 g in 100 mL of distilled water) was prepared, a drop of India ink was added with the help of an eyedropper and shaken 10 times before evaluating with the grey scale.

2.4. Viscosity and colour evaluation

Viscosity analysis was performed following the protocol proposed by Kumar and Mali (2010) using the viscometer (SHP NDJ 8S Viscosimeter, China) with rotor #3. The viscosity of the shampoos was measured at 3 speeds: 12, 30 and 60 rpm in triplicate.

In addition, the colour of the shampoos was measured with a portable colorimeter (CR-400, Konika Minolta) and based on the CIE Lab* and CIE LCh* colour space, where L* indicates lightness, a* indicates red-green index, b* indicates yellow–blue index, C* indicates chroma or saturation and h* indicates hue angle.

2.5. Conditioning performance test

The sensory or conditioning test performed on the shampoo was described by Boonme et al. (2011), in which the softness of the hair after shampooing is evaluated. Nine full tails of hair were obtained from mestizo women, between 25 and 35 years of age, with healthy, straight, brown, uncoloured hair, in a beauty salon located in the city of Quito (Ecuador). Each strand of hair was divided into 16 tufts of 10 cm in length and weighing 5 g. Each tuft of hair was washed with the same shampoo: four locks were used as control and washed with treatment G0. The remaining locks were distributed with 4 tufts for each shampoo treatment containing goat milk. To perform the washing, the tuft was placed in a beaker with 10 g of shampoo and 15 g of distilled water. The tuft was then shaken in the mixture for 2 min and rinsed with 50 mL of distilled water. This was repeated for each of the tresses and shampoo treatments. Once the samples were washed, they were left to dry at room temperature for one day.

The shampoo conditioning performance was evaluated by means of a blind touch test, which was performed with 270 volunteers between 19 and 53 years of age, who participated randomly. To rate hair softness, before performing the test it was explained to them how they should rate each sample using a scale from 1 to −1, where 1) very soft, 0.5) soft, 0) equal to control, −0.5) rough −1) very rough. Participants were asked to close their eyes, touch the three samples washed with the 10, 20 and 30% goat milk shampoo treatments and compare their softness with the control sample (0% goat milk).

2.6. Statistical analysis

The statistical program SAS version 9.2 (SAS Institute, 2008) was used. An ANOVA of Repeated Measures procedure was performed to evaluate the effect of goat milk concentration (4 levels: 0, 10, 20 and 30%) and shampoo opening time (3 levels: 0, 30 and 60 days) on the physicochemical and sensory characteristics of the product. The Tukey test ($P < 0.05$) was applied to analyze statistical differences between pairs of means of the variables analyzed.

3. Results

3.1. Physicochemical characteristics of the shampoo and dirty dispersion

Table 2 shows the mean values obtained from the physicochemical analyses of the shampoo prepared with different percentages of goat milk, during 60 days after container opening. The pH of the shampoo increased significantly as the

Table 2. Mean values of physicochemical parameters and qualitative assessment of dirt dispersion capacity of shampoo with 0, 10, 20 and 30% goat milk in its formula, during 60 days of storage.

		Goat milk percentage in shampoo								
Parameter	Days	0%		10%		20%		30%		SEM
pH	0	5.59	c	5.66	bcy	5.81	by	6.27	ay	0.08
	30	5.65	c	6.27	bz	6.40	bz	6.73	az	0.11
	60	5.55	c	6.24	az	6.23	az	5.96	bx	0.09
	SEM	0.04		0.10		0.09		0.12		
Foaming ability at 1 min (mL)	0	103.33	ab	107.22	a	105.56	a	91.11	b	2.52
	30	93.33	a	101.67	a	100.00	a	83.33	b	2.42
	60	93.89	ab	100.00	a	101.67	a	86.11	b	2.13
	SEM	2.30		1.66		1.28		2.30		
Foam stability at 20 min (mL)	0	97.78	abz	102.22	az	95.56	ab	86.11	b	2.44
	30	83.33	aby	85.00	aby	90.55	a	76.11	b	2.10
	60	86.67	abzy	82.78	aby	93.33	a	77.78	b	2.27
	SEM	2.87		3.46		1.16		2.90		
Wetting time (s)	0	13.20	bx	13.06	bx	14.00	ax	11.26	cx	0.30
	30	14.06	dy	16.53	cy	18.63	by	22.71	ay	0.96
	60	15.63	dz	21.40	cz	23.98	bz	26.13	az	1.20
	SEM	0.36		1.22		1.45		2.25		
Solid content (%, w/w)	0	20.83	dx	22.44	cx	23.88	bx	27.11	ay	0.70
	30	22.64	dy	24.11	cy	26.10	by	29.13	az	0.74
	60	23.36	dz	25.60	cz	27.40	bz	29.56	az	0.69
	SEM	0.38		0.46		0.53		0.39		
Surface tensión (dyn cm^{-1})	0	51.53	dz	55.50	cz	57.43	bz	60.75	az	1.03
	30	36.14	dy	39.65	cy	42.83	by	48.19	ay	1.35
	60	33.27	dx	35.87	cx	39.46	bx	41.33	ax	0.97
	SEM	2.84		3.02		2.77		2.86		
Indian ink presence (scale)	0	None		None		None		None		
	30	None		None		None		None		
	60	None		Light		Light		Light		

a-d Means in the same row with different letters differ statistically ($P < 0.05$).
z-x Means in the same column with different letters differ statistically ($P < 0.05$).
SEM: Standard Error of the Mean.

concentration of goat milk in the formula increased (5.59 versus 6.27 in shampoo G0 and G30, respectively), and this pattern was maintained until day 30. With respect to the stability of the pH during the experimental time, it was observed that it remained stable in the control (5.59 and 5.55, day 0 and 60, respectively), while it increased slightly in shampoos G10 and G20 (6.23–6.24). In the case of G30, pH increased at 30 days, but decreased drastically after 60 days until a pH value of 5.93.

During the whole experimental time, the G0, G10 and G20 shampoos had practically the same foaming capacity (between 93.33 and 107.22 mL). With the addition of 30% goat milk to the shampoo formulation, this capacity was significantly decreased compared to the other treatments (91.11 mL). The foaming capacity of all the shampoos remained similar during the experimental time. The foam stability measurements showed that G0, G10, G20 and G30 at day 0 lost between 5 and 10 mL of foam after 20 min. At day 30, shampoo lost between 7 and 16 mL, while at day 60, the lost was between 8 and 9 mL of formed foam after 20 min.

Respect to wetting time, at day 0, G20 had the higher wetting time (14 s), followed by G0 and G10 (approx. 13 s), and G30 (11.26 s). At 30 and 60 days after container was opened, the wetting time increased slightly to 15 s in G0. However, as the concentration of goat milk in the formulation and storage time increased, the wetting time value of the shampoos were higher (up to 26 s).

The solids percentage values of the shampoos were within the established range to be considered as easy to clean (20–

Table 3. Mean values of viscosity (mPa s^{-1}) of shampoo with 0, 10, 20 and 30% goat milk in its formula, during 60 days of storage.

		Goat milk percentage in shampoo								
	Days	0%		10%		20%		30%		SEM
Viscosity at 12 rpm	0	11633.00	az	1590.00	bz	862.22	cz	663.33	dz	1389.62
	30	10656.00	ay	1054.44	by	837.78	czy	235.56	dy	1300.75
	60	9450.00	ax	1043.33	by	810.00	cy	248.61	dy	1144.6
	SEM	316.96		90.46		9.70		70.27		
Viscosity at 30 rpm	0	11420.00	az	1580.44	bz	772.00	cz	611.56	cz	1367.7
	30	9880.00	ay	1017.33	by	583.11	cy	186.56	dy	1219.27
	60	8804.44	ax	910.22	bx	456.67	cx	190.00	dy	1080.88
	SEM	387.74		104.01		45.86		70.55		
Viscosity at 60 rpm	0	7673.33	az	1515.33	bz	732.22	cz	627.11	dz	882.80
	30	7470.00	ay	985.11	by	602.44	cy	198.28	dy	904.22
	60	7151.11	ax	905.11	bx	423.56	cx	160.50	dx	870.16
	SEM	79.89		95.82		44.79		74.82		

a-d Means in the same row with different letters differ statistically ($P < 0.05$).
z-x Means in the same column with different letters differ statistically ($P < 0.05$).
SEM: Standard Error of the Mean.

30%, according to Bushra et al. 2018). As the concentration of goat milk in the formula increased, as well as the storage time, the solids concentration also increased in the products.

Regarding the surface tension parameter, the values varied between 51.53 and 60.75 dyn cm^{-1} in the shampoos at day 0, increasing as goat milk presence was higher in the shampoo. As the storage time passed, the surface tension decreased, ranged from 33.27 dyn cm^{-1} in G0 to 41.33 dyn cm^{-1} in G30.

Table 2 also shows the mean values obtained in the dirt dispersion analysis of the shampoo made with different percentages of goat milk during 60 days of storage. The visual test showed that on days 0 and 30, both in the control shampoo and with different concentrations of goat milk, a completely white foam was obtained, i.e. there were no traces of Indian Ink in the foam, which indicates good dirt dispersion. After 60 days, a light residual of India ink was observed in the foam in the four treatments. Therefore, it was obtained as a result that the shampoo dragged the dirt more efficiently from 0 to 30 days, regardless of the amount of milk added, while it loses a little of that efficiency at 60 days.

3.2. Viscosity of the shampoo

Table 3 shows the mean values of the viscosity of shampoo made with goat milk during 60 days after opening. The viscosity of the control shampoo, whether measured with the rotor at 12, 30 or 60 rpm, and during the whole experimental time, was significantly higher than in the rest of the shampoos made with goat milk. With the addition of 10% goat milk in the formulation, the viscosity of the shampoo decreased considerably, up to seven times less viscous. As the concentration of goat milk in the shampoo increased, the viscosity decreased significantly. On the other hand, a decreasing trend in viscosity was observed in all shampoos as the 60 days after opening the container passed.

With respect to the rotor speed used for the analysis, a slight decrease in viscosity values was also observed as the speed increased, but only in the control shampoo. In the G10, G20 and G30 shampoos, the increase from 12 to 60 rpm of the rotor on the rheometer did not have much impact on the viscosity results. The drastic decrease in viscosity in the G30 shampoo after 30–60 days of storage is striking, which is related to the formation of two phases in the shampoo and will be discussed later.

3.3. Instrumental colour of shampoo

Table 4 presents the mean values of colour parameter in CIELab* system of shampoo made with different concentration of goat milk during 60 days after container opening. The lightness values of the base shampoo, without goat milk, ranged between 28 and 31 on the first day. The addition of 10% goat milk did not significantly modify the shampoo's brightness, while the addition of 20 or 30% goat milk increased the values considerably (up to 45.58). The opening of the container and the passage of time up to 60 days produced a greater decrease in brightness in the G20 and G30 shampoos.

As for the colour parameter a*, it was very close to the 0 value, but with negative values (greenish). As goat milk concentration increased, a* values increased significantly (−0.50 vs −2.29 in G0 and G30, respectively). Over time, values decreased in all treatments.

Regarding the colour parameter b*, positive values (yellow) were obtained in the control shampoo, while when goat milk was included in the formula, the values became negative, towards a certain bluish hue. After 30 and 60 days, the values of this parameter b* increased, both in the control (yellow) and in the shampoos with goat milk (blue).

In relation to the C* saturation parameter, both as the concentration of goat milk in the formula increases, as well as the storage time increases, the colour saturation values of the shampoos also increased. Respect to the Hue angle data, the control shampoo was in the second quadrant (approximately 97°), but with the inclusion of goat milk in the formula, the angle values moved dramatically to the third quadrant (240–265°). Regarding the stability during storage time, the hue angle tends to increase over time in the shampoos with goat milk, while it decreases in the control shampoo.

3.4. Sensory analysis and shampoo conditioning test

Table 5 shows the mean values obtained in the sensory analysis with respect to the conditioning of the control shampoo and shampoos made with different percentages of goatmilk during 60 days of storage. Freshly prepared, in the conditioning test the untrained judges reported that all 4 shampoos, regardless of the amount of goat milk in their formulation, had the same level of softness. After 30 and 60 days of storage, the G10 and G20 shampoos resulted in a softer and more conditioned coat than the control, while the inclusion of 30% goat milk in the formulation did not differ from the control.

4. Discussion

4.1. Physicochemical characteristics

The pH level of the shampoo is responsible for improving hair quality, minimizing eye irritation, and stabilizing the ecological balance of the scalp. Mild acidity prevents swelling and promotes scale setting, which induces hair shine and minimizes hair damage (Bushra et al. 2018). The stable pH in a shampoo to prevent scalp damage is 5–7, which is close to the pH of the skin. In other words, hair shampoo should have a neutral or slightly acidic pH. In formulations, what allows giving the right pH to the shampoo is citric acid (Abu-Jdayil and Mohameed 2004; Krunali et al. 2013).

In this study, the pH of G0 was lower than the other treatments and remains stable over time, and as the concentration of goat milk in the formulation increases, the pH rises. All shampoos were presented within the optimal pH range of a shampoo, which is between 5 and 7, similar to the results obtained by other authors.

Bushra et al. (2018) analyzed different shampoo brands from the Saudi Arabian market and reported pH variations from 4.99–6.55. On the other hand, Khaloud and Shah (2014) reported a pH of 7.2 in samples of an herbal shampoo. In the study conducted by Seema et al. (2017) the pH of a polyherbal shampoo was 5.5 which was considered slightly acidic.

Table 4. Mean values of colour parameters of shampoo with 0, 10, 20 and 30% goat milk in its formula, during 60 days of storage.

		Goat milk percentage in shampoo				
Parameter	Days	0%	10%	20%	30%	SEM
Luminosity, L*	0	31.45^{bz}	28.66^{b}	43.34^{az}	45.58^{az}	2.23
	30	27.92^{cy}	27.38^{c}	34.64^{by}	39.44^{ay}	1.52
	60	26.39^{cy}	26.32^{c}	34.92^{by}	36.62^{ax}	1.20
	SEM	0.62	0.60	1.44	1.34	
Green index, a*	0	−0.50^{ay}	−0.52^{ay}	−1.73^{by}	−2.29^{cy}	0.24
	30	−0.48^{ay}	−0.35^{az}	−1.02^{bz}	−1.13^{bz}	0.10
	60	−0.25^{az}	−0.26^{az}	−0.82^{bz}	−1.01^{cz}	0.10
	SEM	0.04	0.04	0.12	0.23	
Yellow–blue index, b*	0	3.76^{az}	−4.94^{bz}	−4.44^{bz}	−4.10^{bz}	1.09
	30	3.52^{az}	−5.41^{by}	−6.49^{cy}	−6.44^{cy}	1.27
	60	4.17^{ay}	−5.22^{by}	−6.67^{cy}	−6.34^{cy}	1.35
	SEM	0.13	0.09	0.36	0.40	
Chroma, C*	0	3.80^{b}	4.96^{a}	4.75^{ay}	4.73^{ay}	0.16
	30	3.54^{c}	5.41^{b}	6.58^{az}	6.57^{az}	0.38
	60	4.19^{c}	5.23^{b}	6.70^{az}	6.40^{az}	0.30
	SEM	0.13	0.09	0.32	0.31	
Hue angle, h	0	96.92^{dz}	265.18^{a}	251.96^{by}	240.68^{cy}	20.53
	30	98.90^{cz}	267.76^{a}	259.85^{bz}	259.15^{bz}	21.36
	60	93.21^{cy}	270.70^{a}	261.07^{bz}	262.33^{bz}	22.42
	SEM	0.89	1.00	1.69	3.66	

$^{a-d}$Means in the same row with different letters differ statistically ($P < 0.05$).
$^{z-x}$Means in the same column with different letters differ statistically ($P < 0.05$).
SEM: Standard Error of the Mean.

However, in our study a drastic drop in pH as well as the formation of 2 phases was observed at day 60 in the G30 shampoo. It is presumed that a high concentration of milk and caseins, as well as the acidification of the product, caused the denaturation of the milk proteins and caused them to flocculate over time.

Although foam generation has no correlation with the cleaning ability of shampoos, it is of utmost importance to the consumer. To consider that the shampoo has a good foaming capacity it should be 100 mL or more and should remain as stable as possible during the evaluation time (Sarath et al. 2013), 20 min in this case. In the case of the shampoo with 10 and 20% goat milk, a volume of 105–107.22 mL of foam was formed and after 20 min it remained at approximately in the range of 100–101 mL. In the case of G30 less foam was formed, which may indicate that the presence of the milk components at that ratio may have a negative impact in terms of foam formation.

In the study conducted by Bushra et al. (2018), in which they compared different brands of shampoo in the Saudi Arabian market, a foam formation of between 107 mL to 78 mL was obtained and at 20 min approximately 6 mL was lost. Khaloud and Shah (2014) in tests conducted on their herbal shampoo obtains a foam formation of 115 mL to 92 mL. Seema et al. (2017) in a polyherbal shampoo obtains a foam formation of between 110 mL to 115 mL and reported it as a good foam formation. In the study conducted by Kumar and Mali (2010) to an herbal shampoo they obtained between 180–134 mL of foam formation and in their case after 5 min they lose 3 mL of foam. Thus, it is observed that the use of 30% goat milk in the shampoo formulation decreases the foaming capacity in comparison to the control, while at a concentration of 10 and 20%, the foaming capacity increases.

Table 5. Mean values of sensory scores of softening in conditioning test of shampoo with 0, 10, 20 and 30% goat milk in its formula, during 60 days of storage.

		Goat milk percentage in shampoo				
	Days	0%	10%	20%	30%	SEM
Softening, (−1/1)	0	0.00	−0.02^{y}	−0.01^{y}	0.06	0.03
	30	0.00^{b}	0.31^{az}	0.29^{az}	0.08^{b}	0.03
	60	0.00^{b}	0.32^{az}	0.23^{az}	0.14^{b}	0.03
	EEM	0.00	0.04	0.04	0.04	

$^{a-b}$Means in the same row with different letters differ statistically ($P < 0.05$).
$^{z-y}$Means in the same column with different letters differ statistically ($P < 0.05$).
SEM: Standard Error of the Mean.

Wetting capacity depends on the amount of detergent applied in the shampoo. Wetting phenomena are complex and depend on several processes and factors such as diffusion, surface tension, concentration and the nature of the surface being wetted (Manikar and Jolly 2001). Bushra et al. (2018) in their study conducted on different brands of shampoos concludes that Syoss brand contains the maximum detergent concentration because it had less wetting time (12.67 ± 5.03 s) in contrast to Sunsilk brand, which exhibited the maximum wetting time (23.00 ± 8.19 s), and therefore, the amount of detergent present in its formulation is less. Khaloud and Shah (2014) reported the wetting time of three shampoos in the order 141 < 157 < 187 s for Dove, Herbal Essences and their shampoo formulated with reetha, amla, shikakai and cider extract, respectively. They conclude that Dove brand contains the maximum concentration of detergents because it had the least wetting time. In contrast, their formulated shampoo that exhibited the maximum wetting time is the one that contained the least concentration of detergents. Gholamreza et al. (2011), when evaluating a shampoo based on fenugreek seeds, obtain a wetting time of 150 s so their shampoo does not contain a large amount of detergent.

When compared with the control and the results obtained by other authors, our study showed that the wetting time increased with the concentration of goat milk added to the formula and with the passing of days. The longest wetting time was in the G30 shampoo, most probably because it contains more fat globules which, being small, allow easy entry and absorption into the skin, promoting greater wetting (Ferreira et al. 2003).

Good shampoos generally have 20–30% solid content, while allowing it to be easily applied and rinsed from the hair. Without enough solids, the shampoo will be too watery and will wash out quickly (Bushra et al. 2018). Evaluation made by Bushra et al. (2018) of several shampoos of different brands in the Saudi Arabian market were reported to be between 17.8% to 25.1% in terms of solids content, while Khaloud and Shah (2014) reported their shampoos to be within the range of 22% to 25% and expected to wash out easily. Seema et al. (2017) found that herbal shampoo formulated with polyherbal extract had a solids content of 26.42% and suggests that it can be easily washed out. And lastly, the study conducted by Kumar and Mali (2010) to an herbal shampoo, showed that its solids percentage was between 22 and 29%. As a result, they were easy to wash. In our study, by including and increasing the concentration of goat milk and over time, the percentage of solids increased, always remaining within the proposed ranges to be considered easy to wash shampoos.

Surface tension can be measured by the amount of surfactant present in shampoos to reduce surface tension. The lower the surface tension, the higher the shampoo's cleaning ability. A shampoo is considered to be of good quality if it decreases the surface tension of pure water from 72.28 dyn cm^{-1} to approximately 40 dyn cm^{-1} (Ireland et al. 2007). For shampoos based on goat milk, values between 55 and 60 dyn cm^{-1} were obtained at day 0 and values between 35 and 41 dyn cm^{-1} were obtained at day 60.

Khaloud and Shah (2014) indicate that the shampoo formulated with reetha, amla, shikakai and cider extract reduced the surface tension to 38.72 dyn cm^{-1}, which is comparable to Herbal Essences brand (38.36 dyn cm^{-1}). However, among all shampoos, the Dove brand had the lowest surface tension (31.68 dyn cm^{-1}), indicating that it has the strongest cleansing ability. Bushra et al. (2018) reported that the surface tensions of the tested shampoos ranged from 32.20 340 $\pm$ 0.69 to 34.73 $\pm$ 2.57 dyn cm^{-1}, which were acceptable results. Kumar and Mali (2010) mentioned that the reduction in water surface tension from 72.8 dyn cm^{-1} to 35.37 dyn cm^{-1}, so the herbal shampoos have good cleaning action.

When compared to the control, the inclusion of goat milk in the formula resulted in an increase in surface tension as the amount of goat milk increased. But as the storage time passed, the surface tension decreased in all four treatments. The goat milk shampoo starts with a surface tension above 40 dyn cm^{-1}. However, at day 30 and 60 for all goat milk concentrations the surface tension decreased, so that in this time the efficiency of the detergent is stronger especially in the G10 shampoo since it presents lower surface tension than the other three treatments.

4.2. Dirt dispersion

Dirt dispersion is an important criterion for evaluating the cleaning action of shampoos. Shampoos that cause the ink to concentrate in the foam are considered to be of low quality because the ink or dirt remaining in the foam is difficult to rinse out and is re-deposited on the hair (Saad and Kadhim 2011). In the studies conducted by Kumar and Mali (2010), Khaloud and Shah (2014) and Bushra et al. (2018) observed that the shampoo samples analyzed showed good results as there was no ink distribution in their foam. However, Seema et al. (2017) indicated that in their polyherbal shampoo there is presence of ink in the foam, but it is light, so it is considered a medium quality result. In our case we have good results in the control and goat milk shampoo treatments up to day 30 since there is no presence of ink in the foam formed by the shampoo. But on day 60 in the 4 treatments, both control and shampoo with goat's milk, there was a slight presence of ink in the foam, so the shampoo decreased its cleaning quality.

4.3. Viscosity and instrumental colour of the shampoo

The viscosity of a shampoo is related, at least in part, to the amount of solids that are present. Product viscosity plays an important role in defining and controlling many attributes, such as shelf-life stability (Bushra et al. 2018). Several authors (Kumar and Mali 2010; Rihan et al. 2014; Bushra et al. 2018) have observed that with increasing rotor analysis speed, the viscometer gives lower viscosity values.

In the case of the goat milk shampoo, when compared with the control, it was observed that the control is much more viscous than the goat milk treatments and that, with increasing of the analysis velocity, the viscosity of shampoos decreases and likewise with storage time. In the case of G30, a greater decrease was observed due to the phase separation of the shampoo. When compared with the other authors, the same trend was observed in the viscosity values, so the shampoo is considered to be pseudoplastic in nature, since the viscosity varies depending on the speed applied and the concentration of goat's milk. Furthermore, the viscosity of a shampoo is not constant and if the right pressure is applied it tends to behave like a solid.

Generally, the colour of shampoo is evaluated in the analysis of physical appearance by means of a visual examination, using volunteers who indicate the colour of the shampoo. Thus, different authors (Kumar and Mali 2010; Khaloud and Shah 2014; Seema et al. 2017; Bushra et al. 2018) have carried out visual evaluations obtaining diverse results regarding the colour of shampoo, some being brown, light brown, white, yellow, among others. Likewise, the colour of the shampoo will depend on the colorants or ingredients included in its formulation.

The colorimeter allows us to observe the colours that the human eye cannot see, and also gives us more precise results about the real colour of the shampoo. In our study, it was obtained that as the concentration of goat milk in the shampoo increases, the luminosity increases. The shampoo takes on a more greenish and bluish tone, but as the storage time elapses the luminosity of the shampoo decreases, the intensity of the green tone decreases, and the intensity of the yellow–blue tone increases. These changes may be due to the characteristic colour of the goat's milk and the colour obtained in the shampoo base. Furthermore, these different shades obtained by including goat's milk in the formulation may be due to some kind of reaction between the compounds in the shampoo base and those in the goat's milk.

4.4. Sensory analysis and shampoo conditioning test

The conditioning performance of shampoos, i.e. their mildness, is one of the most sought-after requirements by the consumer, as the shampoo is expected to provide softness to the hair after shampooing. Evaluating conditioning allows the consumer to know the quality of the shampoo to be used (Boonme et al. 2011).

In the results obtained by Seema et al. (2017) on a polyherbal shampoo, it was observed that washed tresses were slightly thicker than unwashed ones, and the results obtained by people's evaluation yielded that the shampoo has a satisfactory conditioning performance. Igwebike-Ossi et al. (2017), evaluating a triclosan-based medicated shampoo, obtained increased hair silkiness and shine. This is due to the incorporation of an alkanolamine, which has a conditioning effect on the hair, as well as additional benefits of increasing the foamability and increasing the viscosity of the shampoo. On the other hand, in studies conducted by Khaloud and Shah (2014) to their herbal shampoo and compare it with commercial ones, they obtain that the braid that was washed with Dove brand provided the best conditioning performance and as expected the control (unwashed) braid scored the lowest. In addition, their shampoo has good conditioning performance.

In our case, when comparing the G10, G20 and G30 shampoos with the control shampoo, it was observed that softness improved after 30 days of storage, and hair shine increased when washed with the different treatments containing goat's milk. But the best hair conditioning performance was obtained in treatment G10 by obtaining slightly higher smoothness results than the other treatments. The G30 shampoo at day 60 presented two phases, in addition to the fact that from day 60 the G20 shampoo presented a slight bad odour, while the G30 shampoo presented a strong unpleasant odour.

5. Conclusions

The physicochemical characteristics of the shampoo improve slightly with the addition of 10–20% goat milk. The addition of 30% goat's milk produces an acidification and a decrease in foaming capacity, as well as in the flocculation of milk proteins during the time analyzed, which is not acceptable in the product. Likewise, the dirt dispersion capacity is kept within proper standards in all the shampoos, but only during the first month of storage.

The presence of goat milk in the formulation results in shampoos that are less viscous, more luminous and with a greener and bluer shade, but over time, these characteristics are slightly lost. The addition of goat milk also results in greater hair softness with respect to the control, with the best results obtained in the G10 treatment, which gives greater conditioning performance.

Due to the fact that after 30 days of storage a deficient dispersion of dirt was observed, a phase separation in shampoo G30 and the presence of a slight rancid milk odour in shampoo G20 and a strong rancid odour in shampoo G30, it is concluded that the use of 10 and 20% goat milk in the shampoo formulation is viable and favourable, as long as the stability time of the product is 30 days, since the best sensory and physicochemical characteristics are obtained along this period.

It is recommended that microbiological and skin and eye irritation tests be carried out on the goat milk-based shampoo. It is also recommended to carry out studies to evaluate shampoo with other goat milk products or by adding preservatives permitted in the cosmetic industry, in order to improve the shelf life and conservation of the product.

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