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Pharmaceutical evaluation of different shampoo brands in local Saudi market



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ABSTRACT

Shampooing is the most common form of hair treatment. Shampoos are primarily products aimed at cleansing the hair and scalp. There are many brands of shampoos in Saudi Arabia, available from different sources, locally and imported from other countries. This study aims to investigate whether such brands comply with the Saudi standard specifications for shampoos, issued by the National Center for Specifications and Standards, and to what extent these specifications are applied. Six shampoo brands were randomly collected from Riyadh market (Pantene[®], Sunsilk[®], Herbal essences[®], Garnier Ultra Doux[®], Syoss[®] and L'Oreal Elvive[®]). The selected shampoos were evaluated according to their physico-chemical properties, including organoleptic characterization, pH measurement, percentage of solid content, rheological measurements, dirt dispersion level, foaming ability and foam stability, and surface tension. All shampoos had a good percentage of solids, excellent foam formation with stable foam and a highly viscous nature. Regarding the pH measurement, all shampoo samples were within the specified range with good wetting ability.

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1. Introduction

Shampoos are probably the most widely used cosmetic products for daily cleansing of the hair and scalp (Ishii, 1997). A shampoo may be described as a cosmetic product for washing of the hair and scalp, leaving the hair soft, lustrous, and manageable. However, there are some specialty shampoos that contain special ingredients with unusual properties, such as anti-dandruff, nutrition, etc. (Mitsui, 1997), packed in a convenient form.

Shampoos can be transparent or opaque and are available as liquids, gels, lotions, pastes, creams, or even dry-powder aerosols. Based on their specific functions, shampoos can be classified into the following major categories: general purpose shampoos, conditioning shampoos, anti-dandruff shampoos, baby shampoos, and dry shampoos (Johnson, 1997).

Most shampoos are formulated as aqueous solutions, emulsions, liquids, lotions, creams, pastes, gels, dry shampoos, etc.

(Siaan, 2014). All shampoo formulations contain a mixture of surfactants (synthetic or natural) as cleansing and foaming agents, excipients (viscosity-controlling agents, emollients, preservatives, etc.), and active ingredients (Breuer, 1981). Shampoo formulations must be medically safe for long-term usage.

Various synthetic, herbal, medicated, and non-medicated shampoos are available in local market and it is necessary to measure their performance, quality, and effectiveness. The evaluation of shampoos comprises quality control tests including visual assessment and measuring physicochemical controls such as pH, density, viscosity, surface tension, foam volume, and wetting ability.

Therefore, this study aimed to evaluate several shampoos for normal hair available in local market in Riyadh, Saudi Arabia, based on scientifically physicochemical measurable properties. To evaluate the formulations, quality control tests including visual assessment and measuring physicochemical controls such as pH, density, etc. were performed. Additionally, to analyze product quality, specific tests were conducted for shampoo formulations including determining dry residue and wetting ability, total surfactant activity, surface tension, and detergency tests.

2. Materials and methods

Various shampoos of different brands, slightly different from same brands available in other countries, were procured from the

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Table 1
Listed ingredients of the selected shampoos.

Generic name	Ingredients	Manufacturer	Batch no.	Expiration date
 Pantene	Aqua, Sodium Laureth Sulfate, Sodium Lauryl Sulfate, Dimethicone, Glycol Distearate, Cocamidopropyl Betaine, Sodium Citrate Cocamide MEA, sodium xylenesulfonate, Parfum, Citric Acid, Sodium chloride, Sodium Benzoate, Polyquaternium-6, Glycerin, Tetra-sodium EDTA, Trisodium Ethylenediamine Disuccinate Hexyl Cinnamal, Panthenol, Panthenyl Ethyl Ether, Benzyl Salicylate, Limonene, Alpha-isomethyl Ionone, Magnesium Nitrate, Methylchloroisothiazolinone, Magnesium Chloride, Methylisothiazolinone	Modern Industries Co., Dammam, KSA	B.8.13.34	March 2019
 Sunsilk	Water, Sodium Laureth sulfate, Dimethiconol, cocamidopropyl Betaine, Glycerin, Sodium Chloride, Perfume Carbomer, Hydroxypropyl methylcellulose, TEA-dodecylbenzenesulfonate, Tetrasodium EDTA, Citric Acid, Guar Hydroxypropyltrimonium chloride, Sodium hydroxide, Amodimethicone, Tea-Sulfate, Mica, triethanolamine, DMDM Hydantoin, Sodium benzoate, PEG-45 M, PPG9, Magnesium Nitrate, Paraffinum Liquidum, Cetrimonium chloride, Lysine HCl, Trideceth-12 Argania Spinosa Kernel Oil, Panthenol, Orbignya Speciosa Kernel Oil, TBHQ, Methylchloroisothiazolinone, Silica, BHT, Magnesium chloride, Methylisothiazolinone, Acetic Acid, Astrocaryum Murumuru Seed Butter, Pantolactone, Butylphenyl Methylpropional, Linalool, Citronellol, Hexyl Cinnomol, Benzyl Salicylate, Alpha-Isomethyl-ionone, CI 77891, CI 17200, CI 42090, CI 19140	Binzagr Unilever Ltd., KSA		June 2019
 Herbal Essences	Aqua, Sodium Laureth Sulfate, Sodium Lauryl Sulfate, Glycol Distearate, Sodium Citrate, Cocamide MEA, Sodium Xylenesulfonate, Dimethicone, Cocamidopropyl, Betaine, Parfum, Citric Acid, Sodium Benzoate, Guar Hydroxypropyltrimonium Chloride, Sodium Chloride, Glycerin, Tetrasodium EDTA, Hexyl Cinnamal, Sodium Oxide, Benzyl Salicylate Propylene Glycol, Limonene, Linalool, Magnesium Nitrate, Zea Mays Silk Extract, Orchis Masculina Flower Extract, Cocos Nucifera Fruit Extract, CI42090, Methylchloroi-sothiazolinone, Magnesium Chloride, Methylisothia-zolinone, Potassium Sorbate	Modern Industries Co, Dammam, KSA		October 2019
 Garnier Ultra Doux	Aqua/Water, Sodium Laureth Sulfate, Cocamidopropyl Betaine, Sodium Lauryl Sulfate, Glycol Distearate, Sodium Chloride, Amodimethicone, CI 19140/Yellow 5, CI 15985/Yellow 6, Guar, Hydroxypropyl Trimonium Chloride, Sodium Benzoate, Sodium Hydroxide, PPG-5-CETETH-20, Trideceth-6, Salicylic Acid, Mel/Honey, Limonene, Benzyl Alcohol, Benzyl Salicylate, 2-Oleamido-1,3-Octadecanediol, Propolis Extract, Carbomer, Cetrimonium Chloride, Citric Acid, Coumarin, Royal Jelly, Parfum/Fragrance. (C164290/2)	L'Oreal Cosmetics, Industrial Zone A7, Pyramids Industrial park, 10 Ramadan city, Egypt		
 Syoss	Aqua (Water, Eau). Sodium Laureth Sulfate Cocamid-opropyl Betaine, Sodium Chloride, Malus Domestica Fruit Cell Culture Extract, Panthenol, Hydrolyzed Keratin, Prunus Armeniaca (Apricot) Kernel Oil, Disodium Cocoamphodiacetate, Glycol Distearate, Citric Acid, Sodium Benzoate, Cocamide MEA, Dimethicone, PEG-7 Glyceryl Cocoate, Parfum Laur-eth-4, PEG-40 Hydrogenated Castor Oil, Linalool, Guar Hydroxypropyltrimonium Chloride, Hydrogenated Castor Oil. Linalool, Mica, Laureth-23, Glycerin, Geraniol, Butylphenyl Methylpropional, Benzyl Alcohol, Hexyl Cinnamal, Propylene Glycol, CI 77891 (Titanium Dioxide), CI 17200 (Red 33), CI 42090 (Blue 1)	Tunis by Henkel Tunisia	P7217	July 2018
 L'Oreal Elvive	Aqua/Water, Sodium Laureth Sulfate, Dimethicone, Disodium Cocoamphodiacetate, Sodium Chloride, Cetyl Alcohol, Hydroxystearyl Cetyl Ether, Guar Hydroxypropyltrimonium Chloride, Cocamide Mipa, Sodium Benzoate, Sodium Glycolate, Sodium Cocoate, Sodium Hydroxide, PPG-5-CETETH-20, Salicylic Acid, Limonene, Linalool, Benzyl Salicylate, Propylene Glycol, 2-Oleamido-1,3-Octadecanediol, Carbomer, Citronellol Butylphenyl, Methylpropional, Methyl Cocoate, Citric Acid, Hexyl Cinnamal Glyceryl Linoleate, Glyceryl Oleate, Glyceryl Linolenate, Parfum/Fragrance (F.I.L. C46917/2)	L'Oreal Cosmetics, Industrial Zone A7, Pyramids Industrial park, 10 Ramadan city, Egypt	68In00	November 2017

Note: After 8 weeks, we determined that the shampoo formulations were stable.

local Saudi supermarket. The ingredients of each shampoo are listed in Table 1.

3. Evaluation of the selected shampoos

3.1. Physical appearance/visual inspection

The formulations were evaluated based on their clarity, color, odor, and texture.

3.2. Determination of pH

The pH levels of the different shampoos tested in 1% and 10% water solutions were evaluated using a pH meter (pH/ORP meter, HI 2211 Hanna instrument, Michigan, USA) at a room temperature of 25 ± 2 °C, based on the work of several authors (Abu-Jdayil and Mohameed, 2004; Kumar and Mali, 2010; Sharma et al., 2011; Krunali et al., 2013; Nirmala Halligudi, 2013a,b; Al Badi and Khan, 2014; Siaan, 2014; Fazlolahzadeh and Masoudi, 2015). Most shampoos are neutral or slightly acidic. Acidic solutions cause the cuticle (outer layer) of the hair to shrink and lie flatter on the hair shaft. Basic solutions cause the cuticle to swell and open up. Acidic solutions make the hair smoother, while basic solutions make the hair frizzier.

3.3. Rheological evaluation (Viscosity)

The viscosity of the tested shampoos was determined using the Brookfield Viscometer (R/S plus rheometer model, LV, USA) set at different spindle speeds of 1–5, 10, and 20 rpm (Sharma et al., 2011; Nirmala Halligudi, 2013a,b; Fazlolahzadeh and Masoudi, 2015). The shampoos' viscosities were measured using spindle C50-1. The temperature and the sample containers' sizes were kept constant during this study.

3.4. Foaming ability and foam stability

The cylinder shake method is the most widely used method for determining foaming ability (Kumar and Mali, 2010; Sharma et al., 2011; Krunali et al., 2013; Nirmala Halligudi, 2013a,b; Fazlolahzadeh and Masoudi, 2015). At room temperature, 1% of 50 mL of the shampoo solution was put into a 250-mL graduated cylinder, which was then covered by hand and shaken ten times. The total volume of the foam content after 1.0 min of shaking was recorded. The height of the foam generated was measured immediately. To evaluate foam stability, the same procedure was performed and the foam volume after 20 min was measured.

3.5. Dirt dispersion

A one percentage (1%) solution of each shampoo (1 g of sample in 100 mL of water) was taken and one drop of India ink was added; the test tube was stoppered and shaken ten times. The amount of ink in the foam was estimated as none, light, moderate, or heavy. Shampoos that cause the ink to concentrate in the foam are considered poor quality. The dirt should remain in the water portion. Dirt that remains in the foam will be difficult to rinse away and will be redeposited on the hair (Kumar and Mali, 2010; Sharma et al., 2011; Krunali et al., 2013; Nirmala Halligudi, 2013a,b; Fazlolahzadeh and Masoudi, 2015).

3.6. Wetting time

Wetting time was measured using Drave's test, wherein some kind of weighed skein (velvet) was allowed to sink through a

wetting solution in a 500-mL graduated cylinder, and the time taken for sinking was considered as the wetting efficiency (Krunali et al., 2013; Fazlolahzadeh and Masoudi, 2015). Velvet cut into 1-in. diameter discs, having an average weight of 0.30 g, was chosen for the wetting test of the shampoos. The lower the time required for sinking, the greater the wetting efficiency. The disc was floated on the surface of 1% (w/v) shampoo solution and the stopwatch was started. The time taken by the disc to begin to sink was measured accurately and noted as the wetting time.

3.7. Percentage of solid content

A clean dry evaporating dish was weighed and 4 g of shampoo was added to it. The dish and the shampoo were weighed together. The exact weight of the shampoo was calculated and the evaporating dish with the shampoo was placed on a hot plate until the liquid portion evaporated. The weight of the shampoo (solids) after drying was calculated (Fazlolahzadeh and Masoudi, 2015; Kumar and Mali, 2010; Sharma et al., 2011; Krunali et al., 2013).

If a shampoo has too many solids, it will be difficult to work it into the hair or to wash out. If it does not have enough solids, it will be too watery and will wash away quickly. A good shampoo has 20–30% of solids.

3.8. Surface tension

Surface tension measurements were carried out using a solution of 10% shampoo diluted in distilled water at room temperature using a dropper (Kumar and Mali 2010; Sharma et al., 2011; Krunali et al., 2013; Preethi, Padmini et al., 2013; Moldovan and Părăuan, 2014; Fazlolahzadeh and Masoudi, 2015; Nirmala Halligudi, 2013a,b). The dropper was thoroughly cleaned using chronic acid and purified water since surface tension is highly affected by grease or other lubricants. Surface tension was calculated by the following equation:

$$R^2 = \frac{(W_3 - W_1)n_1}{(W_2 - W_1)n_2} \times R_1$$

where W_1 is the weight of the empty beaker and W_2 is weight of the beaker with distilled water; W_3 is the weight of the beaker with the shampoo solution; n_1 is the number of drops of distilled water and n_2 is number of drops of the shampoo solution. R_1 is the surface tension of distilled water at room temperature while R_2 is the surface tension of the shampoo solution.

3.9. Stability studies

The thermal stability of the shampoos was studied by placing them in glass tubes in a humidity chamber at 45 °C with 75% relative humidity as well as in a refrigerator at 4 °C, and comparing them to the same shampoos kept at a room temperature of 25 °C. The thermal stabilities were observed after storage periods of zero, four, and eight weeks. Their appearances and physical stabilities were inspected for a period of two months (Deshmukh, Kaushal et al., 2012).

4. Results and discussions

4.1. Physical appearance and determination of pH

Table 2 presents the results of the visual inspection of the tested shampoos, which are brands available in local Saudi Supermarket having different organoleptic properties. The color and odor of the tested shampoos were found to be acceptable by all volunteers.

Table 2
Evaluation for physical appearance and pH (mean \pm SD, n = 3).

Physical appearance	Time for sample	PH concentration	Pantene	Sunsilk	Herbal essences	Ultra Doux	Syoss	L'Oreal Elvive
			White, shiny	Faint yellow, shiny	Sky blue, shiny	Faint yellow, shine	Faint pink, shiny	Faint yellow, shiny
At 25 °C	At zero time	1%	6.34 \pm 0.2	6.72 \pm 0.6	6.04 \pm 0.3	5.34 \pm 0.5	4.99 \pm 0.4	6.03 \pm 0.3
		10%	6.13 \pm 0.3	6.57 \pm 0.3	5.92 \pm 0.4	5.06 \pm 0.2	4.82 \pm 0.3	5.87 \pm 0.4
	After four weeks	1%	6.23 \pm 0.2	6.57 \pm 0.6	5.97 \pm 0.5	5.21 \pm 0.5	4.87 \pm 0.6	6.03 \pm 0.10
		10%	6.03 \pm 0.3	6.45 \pm 0.5	5.79 \pm 0.4	5.16 \pm 0.2	4.68 \pm 0.3	5.67 \pm 0.7
	After eight weeks	1%	6.25 \pm 0.3	6.61 \pm 0.5	5.97 \pm 0.5	5.21 \pm 0.5	4.87 \pm 0.6	6.03 \pm 0.10
		10%	6.05 \pm 0.4	6.52 \pm 0.5	5.82 \pm 0.5	5.24 \pm 0.4	4.73 \pm 0.4	5.74 \pm 0.6
At 4 °C	At zero time	1%	6.34 \pm 0.2	6.72 \pm 0.6	6.04 \pm 0.3	5.34 \pm 0.5	4.99 \pm 0.4	6.03 \pm 0.3
		10%	6.13 \pm 0.3	6.57 \pm 0.3	5.92 \pm 0.4	5.06 \pm 0.2	4.82 \pm 0.3	5.87 \pm 0.4
	After four weeks	1%	6.34 \pm 0.4	6.64 \pm 0.4	5.85 \pm 0.4	5.18 \pm 0.4	4.94 \pm 0.4	5.96 \pm 0.3
		10%	6.12 \pm 0.4	6.52 \pm 0.4	5.86 \pm 0.5	5.26 \pm 0.4	4.77 \pm 0.4	5.74 \pm 0.3
	After eight weeks	1%	6.14 \pm 0.4	6.55 \pm 0.4	5.86 \pm 0.4	5.31 \pm 0.4	4.69 \pm 0.4	5.93 \pm 0.4
		10%	6.15 \pm 0.4	6.59 \pm 0.4	5.79 \pm 0.4	5.35 \pm 0.5	4.63 \pm 0.5	5.66 \pm 0.4
At 45 °C and 75% humidity	At zero time	1%	6.34 \pm 0.2	6.72 \pm 0.6	6.04 \pm 0.3	5.34 \pm 0.5	4.99 \pm 0.4	6.03 \pm 0.3
		10%	6.13 \pm 0.3	6.57 \pm 0.3	5.92 \pm 0.4	5.06 \pm 0.2	4.82 \pm 0.3	5.87 \pm 0.4
	After four weeks	1%	6.41 \pm 0.3	6.77 \pm 0.4	6.55 \pm 0.4	6.44 \pm 0.3	5.55 \pm 0.4	6.87 \pm 0.3
		10%	6.33 \pm 0.3	6.42 \pm 0.3	6.22 \pm 0.4	5.58 \pm 0.4	5.513 \pm 0.4	6.56 \pm 0.3
	After eight weeks	1%	6.23 \pm 0.3	6.74 \pm 0.3	6.52 \pm 0.3	6.44 \pm 0.3	5.56 \pm 0.5	6.42 \pm 0.3
		10%	6.18 \pm 0.4	6.65 \pm 0.4	6.14 \pm 0.4	5.37 \pm 0.4	5.33 \pm 0.4	6.23 \pm 0.4

Shampoo pH level is responsible for improving and enhancing hair quality, minimizing eye irritation, and stabilizing the scalp's ecological balance. Mild acidity prevents swelling and promotes tightening of the scales, thereby inducing shine. Thus, the current trend is to promote shampoos with lower pH as a way to minimize hair damage. Table 1 presents the pH level of the 10% tested shampoos, which were acid-balanced and whose pH between ranged 4.82 \pm 0.03 to 6.13 \pm 0.03. The acceptable pH-range for hair shampoo is 5.0–7.0, which is close to the skin's pH, i.e., hair shampoo should be neutral or slightly acidic (Abu-Jdayil and Mohameed, 2004; Krunali et al., 2013). The pH of the 1% tested shampoos showed similar results with no significant differences from the 10% tested shampoos.

The acceptability of the organoleptic properties and stability of the selected shampoos at different storage temperatures (4 °C, 25 °C, and 45 °C) for storage periods of 0, 4, and 8 weeks are also listed in Table 2. The results show that the pH level at both concentrations (1 and 10%) showed no significant differences at different storage conditions than at zero time at 25 °C. This indicates that the selected shampoos are physically stable.

4.2. Rheological evaluation

Viscosity is the thickness or stickiness of a liquid. 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, product aesthetics such as clarity and ease of flow of the product package, spreading ability of shampoo on the hair, and product consistency in the package.

The results of rheological evaluation (Table 3) showed that the viscosity of the tested shampoos change gradually with the increase in revolution per minute (rpm); therefore, the shampoo formulations were time-dependent. Next, the data shows that shampoo viscosity decreases with increase in rpm; therefore, the shampoo formulations were pseudo-plastic in nature. Pseudo-plastic behavior is a desirable attribute in shampoos. At low rpm, the shampoos showed high viscosity and an increase in the shear rate results in a drop in the viscosity of the shampoos. This favorable property eases the spreading of the shampoos on hair. The results obtained from the rheological studies were fitted into different flow behaviors, using linear or non-linear regression. Table 2

shows the goodness-of-fit indices for Newtonian, plastic, and pseudo-plastic flow behaviors. All the formulations shown in Table 2 followed a pseudo-plastic rheogram. Fig. 1 shows that the graphical lines are not linear lines; hence, the formulations are non-Newtonian in nature.

Viscosity changes ranging from 9593.67 to 910 cps are acceptable; however, L'Oreal Elvive® has a higher viscosity.

The viscosity profile of the selected shampoos at different storage temperatures (4 °C, 25 °C, and 45 °C) for storage periods of 0, 4, and 8 weeks were listed in Table 3. The outcomes were indicated that the viscosity exhibited no significant differences among the different storage condition than the results obtained at zero time at 25 °C. This is proven that the selected shampoos are physically stable.

4.3. Foaming ability and foam stability

Although foam generation (lathering) has no correlation with the cleansing ability of shampoos, it is of paramount importance to the consumer and is therefore an important criterion in evaluating shampoos. Table 4, showed the mean \pm SD, n = 3 of tested shampoos in distilled water, they have accepted foam formation. All tested shampoos had the same foam volume for 5 min showing that their foam has good stability (should be 100 mL or more) as shown in Fig. 2.

The effect of the storage conditions (4 °C, 25 °C, and 45 °C) on the foam retention profile (Figs. 2 and 3) of the selected shampoos during storage periods of 0, 4, and 8 weeks showed no significant differences among the different storage conditions compared to the results obtained at zero time at 25 °C. This verifies that the selected shampoos are physically stable.

4.4. Dirt dispersion

Dirt dispersion is an important criterion for evaluation the cleansing action of shampoos. Shampoos that cause the ink to concentrate in the foam are considered of poor quality because ink or dirt that stays in foam is difficult to rinse away and gets redeposited on the hair (Saad and Kadhim, 2011). Therefore, dirt should remain in the water portion to achieve better cleansing action. All tested shampoos (Table 5) showed good results in the dirt dispersion test because there was no ink distribution in their foam.

Table 3
Viscosity measurements (mean \pm SD, n = 3) for the tested shampoo brands.

	Time for sample		Pantene	Sunsilk	Herbal essences	Ultra Doux	Syoss	L'Oreal Elvive	
At 25 °C	At zero time	1	10131.67 \pm 874.53	6213.67 \pm 1544.62	9226.67 \pm 797.26	5297.33 \pm 473.66	3457 \pm 435.57	9593.67 \pm 1209.75	
		5	3566.0 \pm 159.35	3304.67 \pm 360.98	3551 \pm 187.58	3447.67 \pm 352.46	2668 \pm 370.526	4792.67 \pm 605.74	
		10	1762.67 \pm 146.18	2022 \pm 134.1801	1823.33 \pm 150.01	2414.67 \pm 109.16	1863 \pm 167.57	2493.67 \pm 317.23	
	After four weeks	20	938.80 \pm 185.04	1130 \pm 134.59	910.71 \pm 142.02	1227.67 \pm 145.24	1033.33 \pm 137.82	1245.33 \pm 113.77	
		1	9990.45 \pm 654.53	6626.77 \pm 1440.75	9303.45 \pm 810.22	5927.27 \pm 434.34	3554 \pm 455.55	9610.12 \pm 1190.60	
		5	3510.5 \pm 177.55	3298.55 \pm 133.60	3490.51 \pm 182.78	3320.45 \pm 363.36	2611 \pm 366.22	4801.55 \pm 599.22	
	After eight weeks	10	1797.67 \pm 111.46	2199 \pm 123.48	1804.46 \pm 115.45	2390.89 \pm 99.67	1845.63 \pm 154.65	2503.56 \pm 3287.78	
		20	925.88 \pm 108.85	1090 \pm 112.34	899.10 \pm 112.02	1212.55 \pm 105.24	1093.56 \pm 103.37	1124.53 \pm 104.13	
		1	9980.11 \pm 753.74	6187.67 \pm 1505.44	9122.66 \pm 806.77	5310.97 \pm 510.47	3505.57 \pm 405.45	9222.93 \pm 1190.97	
		5	3511.66 \pm 98.10	3285/557 \pm 290.34	3515.11 \pm 101.85	3222.44 \pm 315.24	2466.83 \pm 325.70	4814.67 \pm 590.55	
		10	1715.62 \pm 101.46	2185.15 \pm 112.34	1788.81 \pm 100.11	2388.23 \pm 112.22	1801.37 \pm 144.23	2511.11 \pm 290.20	
		20	925.24 \pm 105.34	1166.67 \pm 107.23	905.34 \pm 113.38	1144.67 \pm 124.45	985.54 \pm 102.37	1331.15 \pm 96.67	
	At 4 °C	After four weeks	1	10000.11 \pm 775.42	6113.34 \pm 1414.44	9393.36 \pm 800.97	5285.14 \pm 510.11	3522.45 \pm 403.55	9622.45 \pm 1185.68
			5	3336.45 \pm 109.36	3270.50 \pm 297.67	3505.17 \pm 113.33	3404.77 \pm 305.52	2560.68 \pm 345.70	4710.09 \pm 450.55
			10	1706.67 \pm 108.11	2191.88 \pm 114.18	1790.45 \pm 100.50	2400.14 \pm 122.96	1786.33 \pm 133.67	2511.22 \pm 333.34
			20	1009.10 \pm 103.22	1206.66 \pm 101.56	955.39 \pm 102.56	1292.77 \pm 124.12	997.67 \pm 103.72	1124.33 \pm 101.43
After eight weeks		1	9944.78 \pm 790.34	6197.45 \pm 1496.44	9226.67 \pm 797.26	5297.33 \pm 473.66	3457 \pm 435.57	9593.67 \pm 1209.75	
		5	3495.57 \pm 113.65	3322.56 \pm 296.56	3499.30 \pm 99.56	3411.47 \pm 311.34	2575.57 \pm 344.45	4811.55 \pm 577.67	
		10	1744.67 \pm 118.46	2111.11 \pm 101.34	1801.33 \pm 100.51	2488.46 \pm 97.67	1805.67 \pm 113.67	2513.67 \pm 288.69	
		20	984.080 \pm 114.08	1090.30 \pm 103.45	955.10 \pm 102.55	1311.22 \pm 111.24	1005.29 \pm 113.78	1194.59.33 \pm 100.13	
At 45 °C and 75% humidity		After four weeks	1	7315.67 \pm 1234.71	6579.0 \pm 70.71	8441.33 \pm 531.53 \pm 780.55	5290.22 \pm 430.67	4542.33 \pm 114.69	8992.5 \pm 13.43
			5	3793.33 \pm 61.81	4110 \pm 141.42	3495 \pm 173.98	5197 \pm 115.96	3522.67 \pm 126.12	5001.5 \pm 13.43
			10	1961.33 \pm 181.09	2382 \pm 165.46	1911 \pm 123.51	4209.33 \pm 106.21	2120.33 \pm 171.23	2583.5 \pm 157.27
			20	953.28 \pm 125.84	1307.5 \pm 108.19	1026 \pm 125.16	2488.5 \pm 177.07	1158.67 \pm 145.78	1240.5 \pm 140.30
	After eight weeks	1	10110.88 \pm 820.88	6499.36 \pm 1510.44	9204.09 \pm 805.55	5303.66 \pm 461.73	3422 \pm 410.33	9550.11. \pm 1195.77	
		5	3551.66 \pm 165.95	3996.30 \pm 355.69	3511 \pm 190.19	3405.57 \pm 343.36	2611 \pm 361.70	4804.34 \pm 595.65	
		10	1712.20 \pm 155.46	2255 \pm 144.44	1888.33 \pm 112.50	2501.44 \pm 111.19	1910 \pm 155.89	2533.67 \pm 290.77	
		20	925.80 \pm 111.34	1190.13 \pm 122.34	989.10 \pm 114.22	2227.67 \pm 122.45	1103.03 \pm 141.78	1277.45 \pm 99.90	

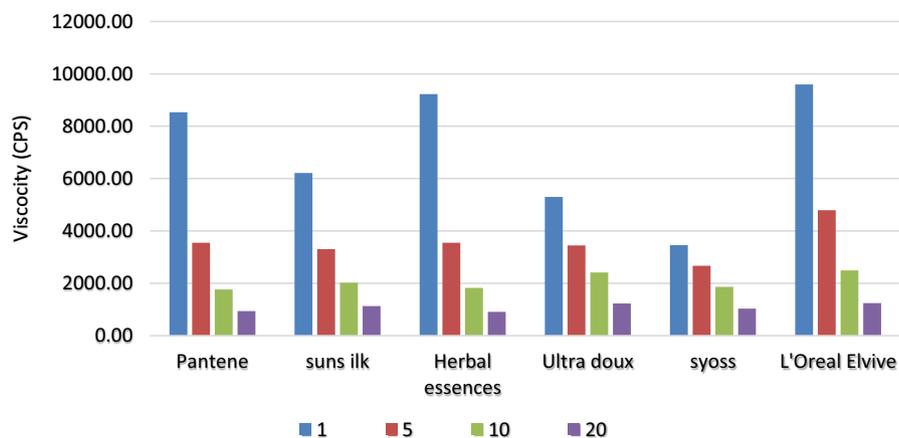


Fig. 1. Viscosity profile of herbal shampoos at zero time at room temperature (25 ± 2 °C).

Table 4

Evaluation of foaming ability and foam stability (mean foam volume (cm³) ± SD, n = 3) for the tested shampoo brands.

	Time for sample		Pantene	Sunsilk	Herbal essences	Ultra Doux		L'Oreal Elvive	
At 25 °C	At zero time	1	107.0 ± 4.4	106.3 ± 7.2	104.7 ± 14.6	109.7 ± 9.0	83.0 ± 0.6	98.3 ± 7.6	
		2	106.7 ± 4.0	106.3 ± 7.2	104.7 ± 14.6	109.7 ± 9.0	83.0 ± 0.6	98.3 ± 7.6	
		3	109.0 ± 0.0	106.3 ± 7.2	104.7 ± 14.6	109.7 ± 9.0	83.0 ± 0.6	98.3 ± 7.6	
		4	106.6 ± 4.0	106.3 ± 7.2	104.7 ± 14.6	109.7 ± 9.0	83.0 ± 0.6	98.3 ± 7.6	
		5	106.7 ± 4.0	106.3 ± 7.2	104.7 ± 14.6	109.7 ± 9.0	83.0 ± 0.6	98.3 ± 7.60	
	After four weeks	1	100.7 ± 5.5	101.7 ± 5.7	98.4 ± 7.3	102.7 ± 7.7	79.4 ± 6.7	93.8 ± 6.7	
		2	110.1 ± 6.5	102.3 ± 5.4	108.5 ± 7.7	111.1 ± 7.4	86.6 ± 5.2	104.4 ± 7.4	
		3	104.5 ± 5.6	99.7 ± 7.0	98.4 ± 6.1	103.9 ± 7.6	87.5 ± 6.7	101.3 ± 6.6	
		4	102.5 ± 3.3	103.4 ± 5.6	100.5 ± 7.5	102.7 ± 6.9	79.7 ± 6.6	92.4 ± 7.1	
		5	99.7 ± 6.7	103.4 ± 5.5	100.1 ± 7.2	104.3 ± 7.5	86.4 ± 6.4	101.3 ± 5.7	
	After eight weeks	1	101.1 ± 6.5	108.6 ± 5.2	106.4 ± 6.6	106.9 ± 6.8	85.4 ± 5.4	103.3 ± 5.7	
		2	102.6 ± 5.7	104.6 ± 6.7	101.4 ± 7.7	107.9 ± 7.9	85.3 ± 5.8	101.96.8	
		3	103.3 ± 5.7	103.6 ± 5.7	101.5 ± 7.1	107.7 ± 7.7	80.3 ± 5.5	96.3 ± 5.6	
		4	105.6 ± 5.4	104.6 ± 5.7	101.7 ± 5.1	107.9 ± 6.9	85.3 ± 5.6	102.3 ± 5.6	
		5	108.7 ± 6.5	104.4 ± 6.7	102.7 ± 5.5	107.6 ± 7.6	86.5 ± 4.4	99.8 ± 6.7	
	At 4 °C	After four weeks	1	106.0 ± 5.4	105.3 ± 6.6	104.7 ± 5.6	108.7 ± 7.0	84.0 ± 4.6	99.3 ± 6.7
			2	107.7 ± 5.6	105.3 ± 5.7	103.7 ± 6.6	108.7 ± 8.0	84.0 ± 5.5	97.3 ± 5.7
			3	112.5 ± 4.6	111.3 ± 5.7	107.8 ± 5.6	109.7 ± 3.3	86.5 ± 4.4	104.2 ± 4.45
			4	106.1 ± 4.1	106.8 ± 7.3	104.4 ± 5.6	109.1 ± 7.0	83.5 ± 4.5	98.7 ± 7.5
			5	105.7 ± 5.0	105.3 ± 6.2	106.7 ± 6.6	108.7 ± 8.0	84.2 ± 5.6	99.3 ± 5.6
After eight weeks		1	108.5 ± 3.4	107.3 ± 5.2	106.7 ± 6.6	110.7 ± 7.9	85.7 ± 5.6	101.3 ± 6.6	
		2	103.7 ± 6.5	103.3 ± 6.6	102.7 ± 5.6	107.7 ± 6.5	81.5 ± 4.4	96.7 ± 5.6	
		3	107.4 ± 5.6	104.3 ± 6.6	102.7 ± 6.7	107.7 ± 6.7	81.6 ± 4.3	96.6 ± 6.6	
		4	102.7 ± 6.2	102.3 ± 5.6	100.7 ± 5.6	105.7 ± 6.6	80.6 ± 5.6	95.3 ± 5.7	
		5	107.2 ± 7.6	107.6 ± 6.7	106.7 ± 6.6	108.7 ± 7.6	84.5 ± 4.5	99.9 ± 5.7	
At 45 °C and 75% humidity		After four weeks	1	105.7 ± 6.7	107.3 ± 6.6	106.7 ± 6.6	108.7 ± 6.7	85.6 ± 5.8	99.9 ± 6.7
			2	108.7 ± 6.7	108.6 ± 6.7	106.7 ± 4.6	111.7 ± 7.7	86.6 ± 6.6	101.3 ± 6.6
			3	111.1 ± 3.3	107.3 ± 6.7	106.7 ± 6.6	111.7 ± 8.7	86.6 ± 0.6	102.3 ± 7.7
			4	108.7 ± 6.3	108.3 ± 5.6	106.7 ± 6.6	111.7 ± 6.3	86.34 ± 4.5	101.3 ± 7.6
			5	109.7 ± 6.3	108.7 ± 6.7	105.1 ± 5.3	110.7 ± 6.7	85.34 ± 4.4	101.5 ± 5.6
	After eight weeks	1	108.2 ± 6.3	108.7 ± 6.7	106.1 ± 5.4	111.4 ± 6.6	84.5 ± 6.5	102.4 ± 6.6	
		2	112.7 ± 5.1	111.7 ± 7.1	109.7 ± 6.1	114.7 ± 7.1	87.7 ± 6.0	104.7 ± 6.1	
		3	111.4 ± 4.8	109.3 ± 6.1	106.7 ± 6.1	110.7 ± 6.1	86.7 ± 6.1	103.6 ± 6.5	
		4	107.7 ± 5.7	107.1 ± 6.3	105.7 ± 7.0	111.2 ± 7.1	80.8 ± 4.4	97.2 ± 6.6	
		5	102.4 ± 6.6	102.2 ± 5.2	102.3 ± 5.6	107.9 ± 6.9	82.9 ± 5.5	97.4 ± 5.6	

Additionally, the influence of storage conditions (4 °C, 25 °C, and 45 °C) on the dirt dispersion profile of the selected shampoos during storage periods of 0, 4, and 8 weeks displayed no significant differences compared to the results obtained at zero time at 25 °C. This further verifies that the selected shampoos are physically stable.

4.5. Wetting ability

The wetting ability of a surfactant depends on its concentration, which is commonly used to test its efficacy. Table 6 presents the

results of the Drave's test, which is the official test that uses velvet discs to test wetting ability. Wetting phenomena are complex and depend upon several processes and factors such as diffusion, surface tension, concentration, and the nature of the surface being wetted. Each wetting agent has to reduce surface tension.

From Table 6, it can be concluded that Syoss contains the maximum concentration of detergents because it had the least wetting time (12.67 ± 5.03 min) in contrast to Sunsilk, which exhibited the maximum wetting time (23.00 ± 8.19 min); hence, it contains minimum concentration of detergents. The other tested shampoos had acceptable ranges of wetting times.

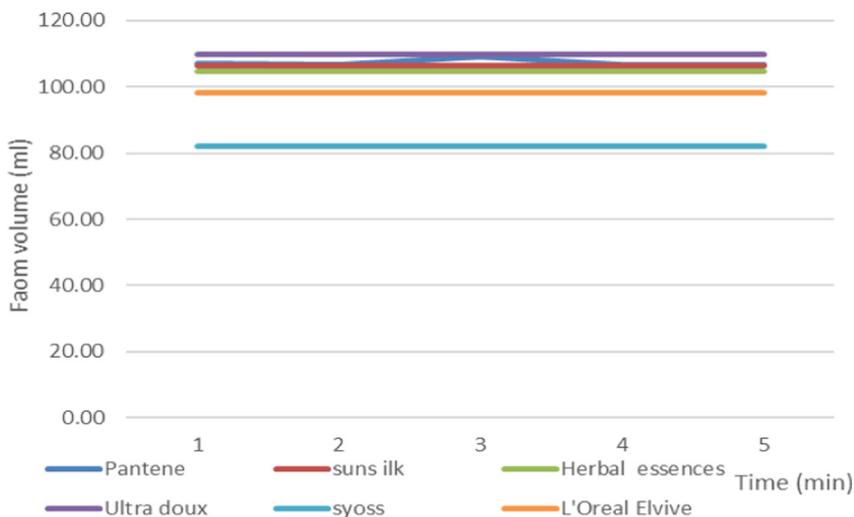


Fig. 2. Foam retention profiles of tested shampoos at zero time at room temperature (25 °C ± 2).

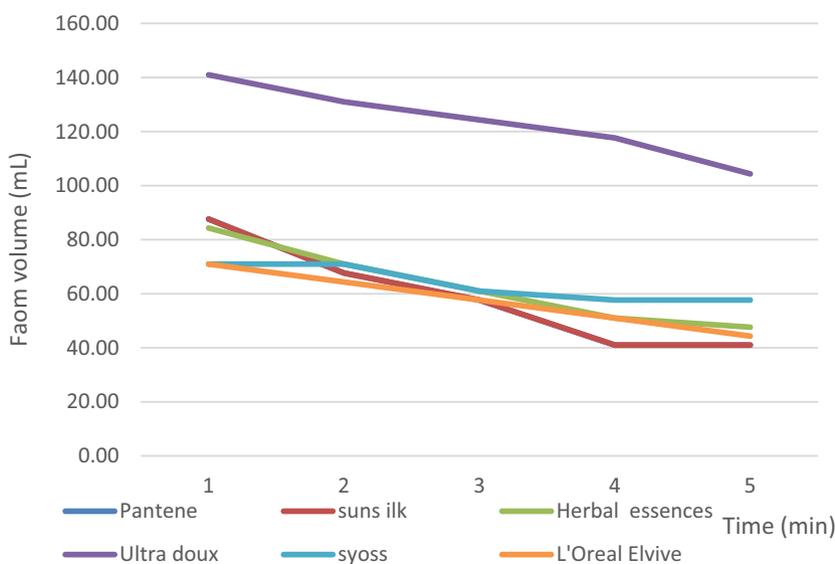


Fig. 3. Foam retention profiles of tested shampoos after one month at 45 °C, 75% relative humidity.

Table 5
Dirt dispersion of the tested shampoo brands.

	Time for sample	Pantene	Sunsilk	Herbal essences	Ultra Doux	Syoss	L'Oreal Elvive
At 25 °C	At zero time	None	None	None	None	None	None
	After four weeks	None	None	None	None	None	None
	After eight weeks	None	None	None	None	None	None
At 4 °C	At zero time	None	None	None	None	None	None
	After four weeks	None	None	None	None	None	None
	After eight weeks	None	None	None	None	None	None
At 45 °C and 75% humidity	At zero time	None	None	None	None	None	None
	After four weeks	None	None	None	None	None	None
	After eight weeks	None	None	None	None	None	None

Furthermore, the impact of the storage conditions (4 °C, 25 °C, and 45 °C) on the wetting ability profile of the selected shampoos during the storage periods of 0, 4, and 8 weeks presented no significant differences compared to the results obtained at zero time at 25 °C. This confirms that the selected shampoos are physically stable.

4.6. Percentage of solid content

Good shampoos usually have 20–30% of solid content, while enables it to be easily applied and rinsed out from the hair. Without enough solids, the shampoo will be too watery and will wash away quickly. The percentages of the solid contents of all tested

Table 6Evaluation of wetting ability (mean second \pm SD, n = 3) for the tested shampoo brands.

	Time for sample	Pantene	Sunsilk	Herbal essences	Ultra Doux	Syoss	L'Oreal Elvive
At 25 °C	At zero time	15.3 \pm 2.1	18.9 \pm 8.2	15.3 \pm 6.1	13.3 \pm 3.8	12.7 \pm 5.0	16.7 \pm 5.7
	After four weeks	15.3 \pm 2.1	17.7 \pm 2.1	15.3 \pm 6.1	13.0 \pm 5.0	12.7 \pm 4.5	12.3 \pm 4.5
	After eight weeks	16.0 \pm 3.3	16.9 \pm 6.5	15.4 \pm 6.3	13.9 \pm 3.6	13.1 \pm 3.4	15.9 \pm 5.1
At 4 °C	At zero time	15.3 \pm 2.1	18.9 \pm 8.2	15.3 \pm 6.1	13.3 \pm 3.7	12.7 \pm 5.0	16.7 \pm 5.7
	After four weeks	16.0 \pm 3.3	16.8 \pm 3.3	15.1 \pm 5.7	12.9 \pm 4.6	12.7 \pm 4.5	15.1 \pm 4.6
	After eight weeks	15.7 \pm 3.1	17.2 \pm 6.4	16.05 \pm 6.1	13.8 \pm 3.8	12.9 \pm 3.9	15.7 \pm 5.0
At 45 °C and 75% humidity	At zero time	15.4 \pm 2.1	18.9 \pm 8.2	15.3 \pm 6.1	13.3 \pm 3.8	12.7 \pm 5.0	16.7 \pm 5.7
	After four weeks	15.3 \pm 2.1	13.7 \pm 2.1	15.3 \pm 6.1	13.0 \pm 5.0	12.7 \pm 4.5	12.3 \pm 4.5
	After eight weeks	15.7 \pm 3.1	17.8 \pm 7.2	16.5 \pm 5.5	14.1 \pm 4.1	13.3 \pm 4.6	15.5 \pm 4.6

Table 7Solid content percentage (mean \pm SD, n = 3) for the tested shampoo brands.

	Time for sample	Pantene	Sunsilk	Herbal essences	Ultra Doux	Syoss	L'Oreal Elvive
At 25 °C	At zero time	23.7 \pm 5.4	16.7 \pm 0.7	17.9 \pm 1.2	24.1 \pm 2.9	19.5 \pm 2.9	26.6 \pm 2.7
	After four weeks	24.1 \pm 4.9	17.0 \pm 3.6	18.1 \pm 3.2	24.7 \pm 5.9	20.0 \pm 4.5	26.9 \pm 4.4
	After eight weeks	23.1 \pm 4.5	16.0 \pm 0.7	17.2 \pm 4.1	23.9 \pm 4.7	19.1 \pm 4.7	25.9 \pm 5.7
At 4 °C	At zero time	23.7 \pm 5.4	16.7 \pm 0.7	17.9 \pm 1.2	24.1 \pm 2.9	19.5 \pm 2.9	26.6 \pm 2.7
	After four weeks	22.9 \pm 5.0	16.9 \pm 4.2	18.0 \pm 3.8	23.9 \pm 4.9	19.9 \pm 5.1	26.3 \pm 4.9
	After eight weeks	23.1 \pm 4.4	16.9 \pm 5.0	17.8 \pm 5.2	24.1 \pm 4.9	19.9 \pm 4.6	26.2 \pm 4.8
At 45 °C and 75% humidity	At zero time	23.7 \pm 5.4	16.7 \pm 0.7	17.9 \pm 1.2	24.1 \pm 2.9	19.5 \pm 2.9	26.6 \pm 2.7
	After four weeks	25.1 \pm 2.2	17.5 \pm 3.1	18.7 \pm 0.3	24.9 \pm 4.7	20.7 \pm 2.4	27.5 \pm 3.7
	After eight weeks	24.4 \pm 4.7	16.9 \pm 5.0	18.1 \pm 3.8	24.5 \pm 4.5	19.9 \pm 4.2	26.9 \pm 4.7

Table 8Evaluation of surface tension (mean dynes/cm \pm SD, n = 3) for the tested shampoo brands.

	Time for sample	Pantene	Sunsilk	Herbal essences	Ultra Doux	Syoss	L'Oreal Elvive
At 25 °C	At zero time	34.7 \pm 2.6	32.2 \pm 0.7	32.5 \pm 2.3	33.1 \pm 2.4	32.5 \pm 1.9	34.1 \pm 2.8
	After four weeks	32.2 \pm 3.3	32.3 \pm 1.1	31.9 \pm 3.2	32.9 \pm 3.4	32.1 \pm 3.6	34.2 \pm 3.5
	After eight weeks	31.3 \pm 4.3	32.1 \pm 1.2	32.7 \pm 3.4	33.1 \pm 3.3	32.6 \pm 3.4	33.9 \pm 4.2
At 4 °C	At zero time	34.7 \pm 2.5	32.2 \pm 0.7	32.5 \pm 2.3	33.1 \pm 2.4	32.5 \pm 1.9	34.1 \pm 2.8
	After four weeks	35.2 \pm 2.0	31.0 \pm 1.1	31.9 \pm 2.3	32.9 \pm 3.1	32.4 \pm 4.1	33.9 \pm 4.5
	After eight weeks	30.1 \pm 3.0	30.2 \pm 2.2	32.7 \pm 4.1	32.9 \pm 3.0	32.7 \pm 4.2	34.1 \pm 4.2
At 45 °C and 75% humidity	At zero time	34.7 \pm 2.6	32.2 \pm 0.7	32.5 \pm 2.3	33.1 \pm 2.4	32.5 \pm 1.9	34.1 \pm 2.8
	After four weeks	28.7 \pm 2.1	28.4 \pm 0.3	29.1 \pm 0.5	29.3 \pm 0.9	30.2 \pm 0.2	31.8 \pm 0.2
	After eight weeks	27.2 \pm 2.2	29.3 \pm 1.1	29.1 \pm 0.5	29.3 \pm 0.9	30.2 \pm 0.2	31.8 \pm 0.2

shampoos are tabulated in Table 8. It was found that all tested shampoos were below the required range (5.16 \pm 1.89 to 6.29 \pm 0.94%), and are expected to wash out easily (Table 7).

Likewise, the effect of the storage conditions (4 °C, 25 °C and 45 °C) on the measurement of the solid content percentage of the selected shampoos during storage periods of 0, 4, and 8 weeks offered no significant differences compared to results obtained at zero time at 25 °C. This confirms that the selected shampoos are physically stable.

4.7. Surface tension

Surface tension can be measured by the amount of surfactant present in shampoos to reduce the surface tension. The lesser the surface tension, the stronger the cleaning ability of the shampoo. A shampoo is considered to be of good quality if it decreases the surface tension of pure water from 72.28 dyn/cm to about 40 dyn/cm (Ireland et al., 2007). All the tested shampoos showed similar reductions in surface tension ranging from 31.68 to 38.72 dyn/cm (Table 8). The reduction in surface tension is an indication of their efficient detergent action. The tested shampoos' surface tensions ranged from 32.20 \pm 0.69 to 34.73 \pm 2.57 dyn/cm (Table 8), which are acceptable results, with the lowest surface tension

indicating that it has the strongest cleaning ability. These results correspond with the wetting data results.

Additionally, the impact of the storage conditions (4 °C, 25 °C, and 45 °C) on the measurement of the surface tension of the selected shampoos during storage periods 0, 4, and 8 weeks presented no significant difference compared to the results obtained at zero time at 25 °C. This confirms that the selected shampoos are physically stable.

5. Conclusion

Shampoo evaluation tests refer to studies and experiments undertaken during production and which, occasionally, ought to be undertaken post-production by regulatory agencies and researchers. In this study, six shampoo brands were evaluated in terms of their pH levels, foam formation, foam stability, viscosity wetting time, surface tension, and dirt dispersion to assess the quality of these shampoos. The results obtained were compared with national standards (reference). The results indicate that all the tested shampoos met the requirements of the standards, which means that they are chemically sound. However, there were slight differences between brands due to their various manufacturing processes, laboratory conditions, and other reasons.

It is difficult to determine which shampoo is the best amongst those tested because no one formulation fared better than the others in all the performed tests. It is also difficult to rank the tests according to their importance, as each is important in its own right. It was observed that many characteristics of these shampoos were in the standard range, although some were out of range for some shampoos. Thus, it is clear that, all tested shampoos can be alternatives for each other since they had comparable results for the different tests.

Further research is required to investigate these brands in terms of their microbiology, rheological evaluations, surface tension measurement, skin sensitization test, eye irritation test, and toxicity.

Conflict of interest

None.

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