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Feasibility study of a cosmetic cream added with aqueous extract and oil from date (*Phoenix dactylifera* L.) fruit seed using experimental design

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Synopsis

This article reports on the feasibility study of a cosmetic cream added with aqueous extract and oil from date (*Phoenix dactylifera* L.) fruit seed using experimental design. First, the mixture design was applied to optimize the cosmetic formula. The responses (dependent variables) were the spreadability (YSp) and viscosity (YVis), the factors (independent variables) being the weight proportions of the fatty phase (X1), the aqueous date seed extract (X2), and the beeswax (X3). Second, the cosmetic stability study was conducted by applying a full factorial design. Here, three responses were considered [spreadability (Sp), viscosity (Vis), and peroxide index (PI)], the independent variables being the concentration of the date seed oil (DSO) (x1), storage temperature (x2), and storage time (x3). Results showed that in the case of mixture design, the second-order polynomial equations correctly described experimental data. Globally, results show that there is a relatively wide composition range to ensure a suitable cosmetic cream from the point of view of Sp and Vis. Regarding the cosmetic stability, the storage time was found to be the most influential factor on both Vis and PI, which are considered here as indicators of physical and chemical stability of the emulsion, respectively. Finally, the elaborated and commercial cosmetics were compared in terms of pH, Sp, and centrifugation test (Ct).

INTRODUCTION

Numerous works are devoted to the valorization of date (*Phoenix dactylifera* L.) seeds (DS) under different forms: activated carbon (1), livestock feed (2), preparation of citric acid and proteins (3), and uses in traditional medicine (4), knowing their antimicrobial and antiviral properties (5).

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Concerning the chemical composition of DS, other investigations revealed the presence of phenolic compounds (among others) (6) and fat (7). This last constituent contains various fatty acids, including linoleic acid and polyphenols whose concentration is higher than that of olive oil (8). This composition makes the DS oil and extracts the interesting ingredients in cosmetic formulations, enhancing the oxidative stability (9) and skin protection of the final product (10). On the other hand, it was also underlined that the seed oil, as fatty acid–rich product, presents a high commercial value in cosmetics and others (11).

Despite the absence of official standard concerning the natural cosmetics (12), the development of phytochemical-rich products is characterized as a market tendency in cosmetics (13). In addition, the increased wariness toward modern cosmetics has stimulated renewed interest in herbal cosmetics (14,15). At the same time, various research works are devoted to this topic. Thus, Anchisi *et al.* (16) have studied the stability of new cosmetic formulations with vegetable extracts as functional agents and Papageorgiou *et al.* (17) have developed new cosmetic formulations by replacing chemical preservatives with extracts of *Lonicera caprifoleum* and *Lonicera japonica* in combination with different chemicals. Bowe (18) has reviewed the cosmetic benefits of some natural ingredients, including green tea for which the photoprotection against ultraviolet (UV)-induced DNA damage was underlined. For their part, Gilani *et al.* (19) have evaluated the antimicrobial activity of cream formulated with essential oil of *Trachyspermum ammi*.

Categorized in the intersection between drugs and cosmetics, cosmeceutics are able to enhance, by external application, the beauty and health of skin (20). In fact, the traditional use of plants against skin illness is an enough common practice in domestic medicine of lots of cultures (21). As underlined by these authors, there are no studies on traditional knowledge concerning cosmetic products, although the interest in natural and/or organic cosmetics has increased among the consumers (15).

This article reports on the assay of obtaining and characterization of a cosmetic cream added with date (*P. dactylifera*) seed oil (DSO), by applying (i) mixture design for the optimal formulation and (ii) full factorial design for the stability study of the final product. It has been already underlined that the use of an experimental design can significantly improve the development of cosmetic emulsions (22).

Despite the absence of works about cosmetic formulation with DS derivatives, numerous authors suggest the possibility to incorporate DSO in cosmetics, based on its chemical composition and UV-protection abilities (23–26). Studying skin permeation of diclofenac, Kim *et al.* (27) have previously demonstrated the potent skin-permeation-enhancing effect of palmitic and oleic acids, two molecules also present in DS (23). In addition, the use of olive oil as oleaginous excipient in oral, topical, and parenteral solutions was reported (9), so this oil was used in this study as a component of the fatty phase of the investigated cosmetic cream.

MATERIALS AND METHODS

INGREDIENTS

Besides lecithin that was provided by the manufacturing unit of margarine "SOFARMA" in the Boumerdès area (40 km east of Algiers), other ingredients were either purchased in the city of Boumerdès (sweet almond oil and embossed beeswax of type Ickowicz (Bollone, France) or prepared in the laboratory: DSO, olive oil, DS aqueous extract (by immersing 0.1 g of DS powder in 100 ml distilled water for 7 days at room temperature (~25°C), the suspension was then filtered through Whatman filter paper (No. 42). All materials were stored at +6°C and protected from light until use.

Regarding the biologic activity of DS, we have already shown that this material presents an interesting antioxidant activity whose value can reach, according to the type of extraction solvent, more than 90% when the free radical 2,2-diphenyl-1-picrylhydrazyl (DPPH•) method was used (submitted to *Journal of Agricultural Science and Technology*). So, we believe that the bioactive components of the DS are present either in its oil (nonpolar molecules) or in its aqueous extract (polar molecules), both components being incorporated in the formulated cosmetic cream (see the following sections).

PREPARATION AND CHARACTERIZATION OF THE COSMETIC CREAM

Mixture Design. Ten different cosmetic cream samples were prepared as shown in Figure 1, whereas the proportions of the three employed ingredients were obtained using a three-component, constrained mixture design. Such experimental design was widely carried out on diverse food and nonfood formulations including cosmetics, such as jackfruit sauce formulations (28), soy-peanut-cow milk (29), cosmetic emulsions (22), protein mixture formulation (30), and low-cholesterol, low-fat mayonnaise formulation (31).

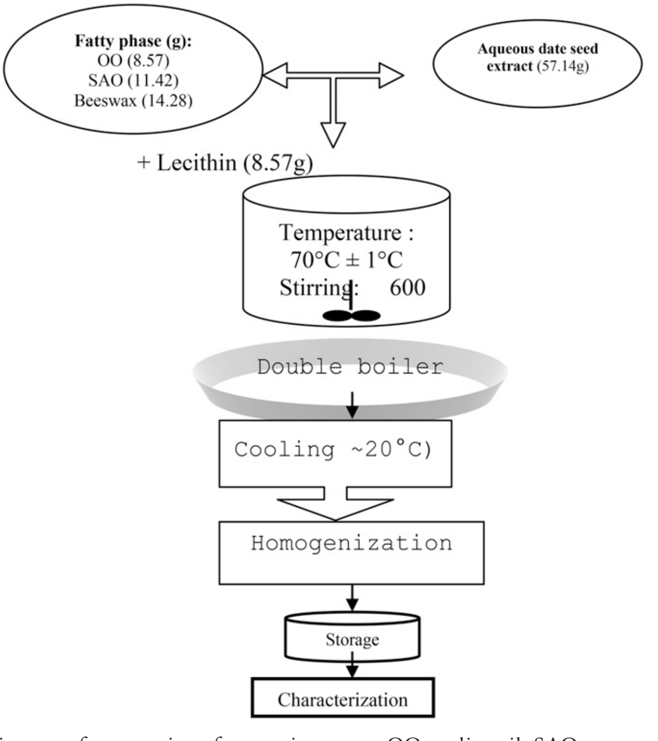

Figure 1. Diagram of preparation of cosmetic creams. OO = olive oil, SAO = sweet almond oil.

To find the optimal mélange, the mixture design (Table I) was applied using MINITAB 15 software. For this, the chosen responses are the spreadability (YSp) and viscosity (YVis), the independent variables being the weight proportions of the fatty phase (X1), the aqueous date extract (X2), and the beeswax (X3). Because of the presence of constraints, the proportions of components should not vary between 0 and 1, as in the case of absence of constraints. But it is possible to obtain with these constraints a new set of components (named pseudocomponents) that take on the values from 0 to 1, this transformation allows making the design construction easier (32).

After hot mixing (agitator of type Heidolph-RZR 0, Schwabach, Germany) of the fatty phase compounds, the emulsifier and aqueous DS extract were added. Once the emulsion was obtained, the heating was stopped and the homogenization was maintained until the final temperature (~20°C) was reached.

Spreadability. The Sp was determined according to the methodology preconized by Czarnecki and Gierucka (33) with minor modifications. The principle applied is that of an extensometer. The dispositive was constituted of two rectangular glass plates, one of them being horizontally fixed on a support. At ambient temperature (~25°C), 1 g of cosmetic sample was placed at the center of the fixed plate using stainless steel microspatula with tapered end, after which the second plate was put down on the sample. A weight of 1 kg was then gently deposed on the second plate, over the sample. After 8 min, the diameter (D) of the imprint induced by the compressed cosmetic sample was measured. The Sp was expressed as follows:

$$\text{Sp (cm}^2\text{)} = \text{surface of the imprint} = \pi\,(D/2)2$$

The measurement was realized in triplicate.

Viscosity. Earlier, it was established that the viscosity of an emulsion is correlated with its stability (34).

To evaluate the physical stability of each cosmetic cream sample (20 g), the Vis was determined using a viscosimeter of type VISCO BASIC Plus/R7 (Barcelona, Spain), with a rate of 10 rpm at temperature of 20°C.

Table I
Mixture Design in Actual and Pseudocomponents (in Parentheses)

Run	Fatty phase (%)	Aqueous phase (%)	Beeswax (%)	Sp (cm^2)	Vis (Pa·s)
1	45 (0)	30 (0)	25 (1)	14.18 ± 0.10	17.23 ± 0.68
2	45 (0)	45 (1)	10 (0)	15.19 ± 0.06	33.81 ± 1.87
3	60 (1)	30 (0)	10 (0)	8.89 ± 0.10	17.23 ± 0.68
4	55 (0.66)	32.5 (0.16)	12.5 (0.16)	11.93 ± 0.17	34.91 ± 2.32
5	47.5 (0.16)	40 (0.66)	12.5 (0.16)	11.93 ± 0.17	28.29 ± 2.44
6	47.5 (0.16)	32.5 (0.16)	20 (0.66)	14.51 ± 0.00	26.34 ± 0.85
7	50 (0.33)	35 (0.33)	15 (0.33)	7.86 ± 0.12	36.13 ± 2.89
8	52.5 (0.5)	37.5 (0.5)	10 (0)	18.58 ± 0.06	38.43 ± 0.54
9	52.5 (0.5)	30 (0)	17.5 (0)	10.55 ± 0.12	22.23 ± 0.07
10	45 (0)	37.5 (0.5)	17.5 (0.5)	10.74 ± 0.17	35.79 ± 0.01

Fatty phase = olive oil + sweet almond oil; aqueous phase = aqueous date seed extract.

STABILITY OF THE SELECTED FORMULA

Experimental Design. The stability study was approached by applying the experience design methodology. In addition to Sp and Vis, the peroxide index (PI, meq of O_2/kg) was also considered as response. The PI is a good indicator of the stability of the fatty phase of the cosmetic cream. It was determined according to French standard (35). Independent variables were the concentration of the DSO (x1), the storage temperature (x2), and the storage time (x3). So, 8 tests were performed, considering the two levels (low "−" and high "+"). The factor levels, together with obtained responses are recapitulated in the experience matrix (Table II).

Rheological Profile. The rheological profile of 0.5 mg of cosmetic sample stored during 24 h was obtained at 20°C during 2 min, using cone-plate rotational viscometer Thermo HAAKE VT-550 (Karlsruhe, Germany). This instrument is equipped with Software Rhéo Win Data Manager. The analysis was performed in Laboratory of Mineral and Composite Materials (University of Boumerdès, Algeria).

pH, Sp, and Centrifugation Test. The pH was measured at 20°C as described by Anchisi *et al.* (16), using pH-meter JENWAY-3510. In addition, Ct was carried out by means of HERMLE-Z 323 apparatus (Wehingen, Germany) (3000 rpm for 30 min) at ambient temperature, the stability being expressed as percentages referred to the graduated measuring tube (10 ml) (16).

RESULTS AND DISCUSSION

OPTIMIZATION OF THE COSMETIC CREAM COMPOSITION

The weight proportions of the three ingredients and the two responses considered are summarized in Table I.

Table II
Experience Matrix

No	x_1	x_2	x_3	PI	Sp	Vis
1	−1	−1	−1	4.49 ± 0.47	0.86 ± 0.07	3.33 ± 3.17
2	−1	−1	+1	6.42 ± 1.34	9.24 ± 1.97	32.56 ± 5.60
3	−1	+1	−1	5.78 ± 1.27	8.68 ± 0.18	26.78 ± 5.60
4	−1	+1	+1	8.43 ± 0.19	12.36 ± 0.94	31.66 ± 2.74
5	+1	−1	−1	6.41 ± 0.19	9.52 ± 1.97	34.09 ± 5.37
6	+1	−1	+1	6.13 ± 2.83	8.83 ± 1.50	36.60 ± 2.04
7	+1	+1	−1	14.53 ± 0.97	9.07 ± 0.26	30.99 ± 1.91
8	+1	+1	+1	10.13 ± 2.61	7.95 ± 0.38	26.26 ± 2.05
Level (−)	0.01%	4 days	20°C			
Level (+)	0.1%	30 days	50°C			

The normality of variables for both Sp and Vis was established by the Henry's straight line (Figures 2A and 3A, respectively), whereas the reproducibility of experiences was verified by Cochrane criterion for which calculated value (0.367 and 0.364 for Sp and Vis, respectively) was below tabulated one (0.801 for the two responses).

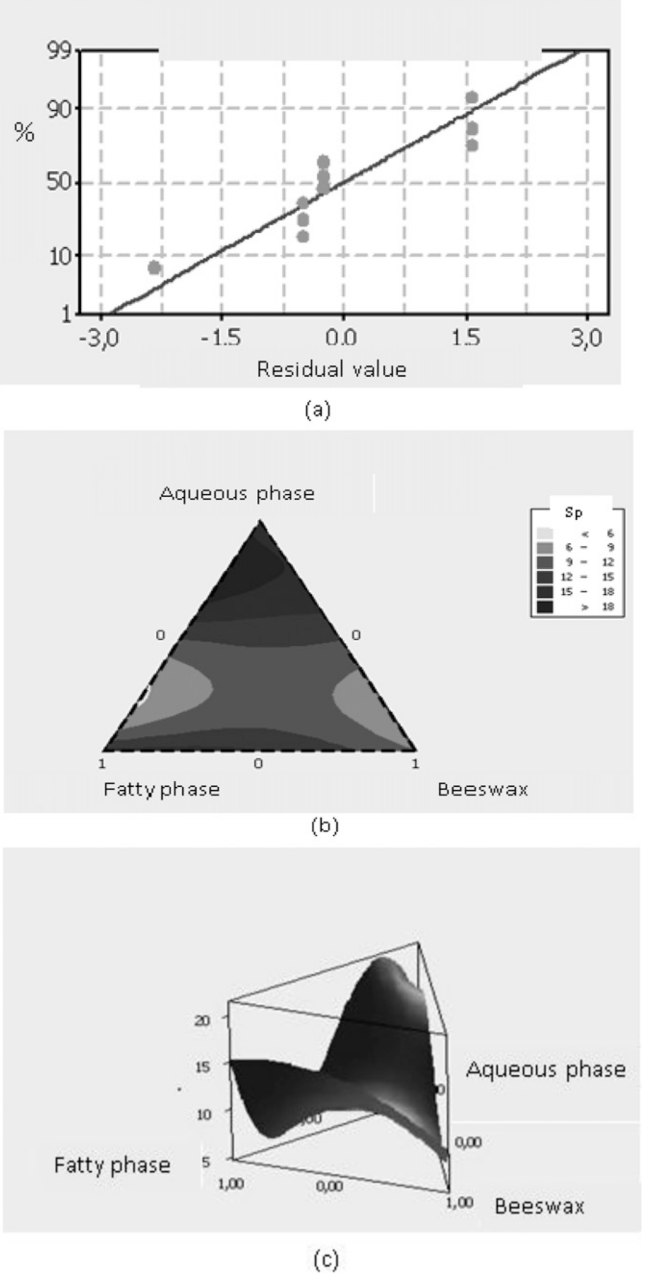

Figure 2. (A) Henry' straight, (B) iso-response surface, and (C) response surface. Case of the spreadability (Sp) (cm^2).

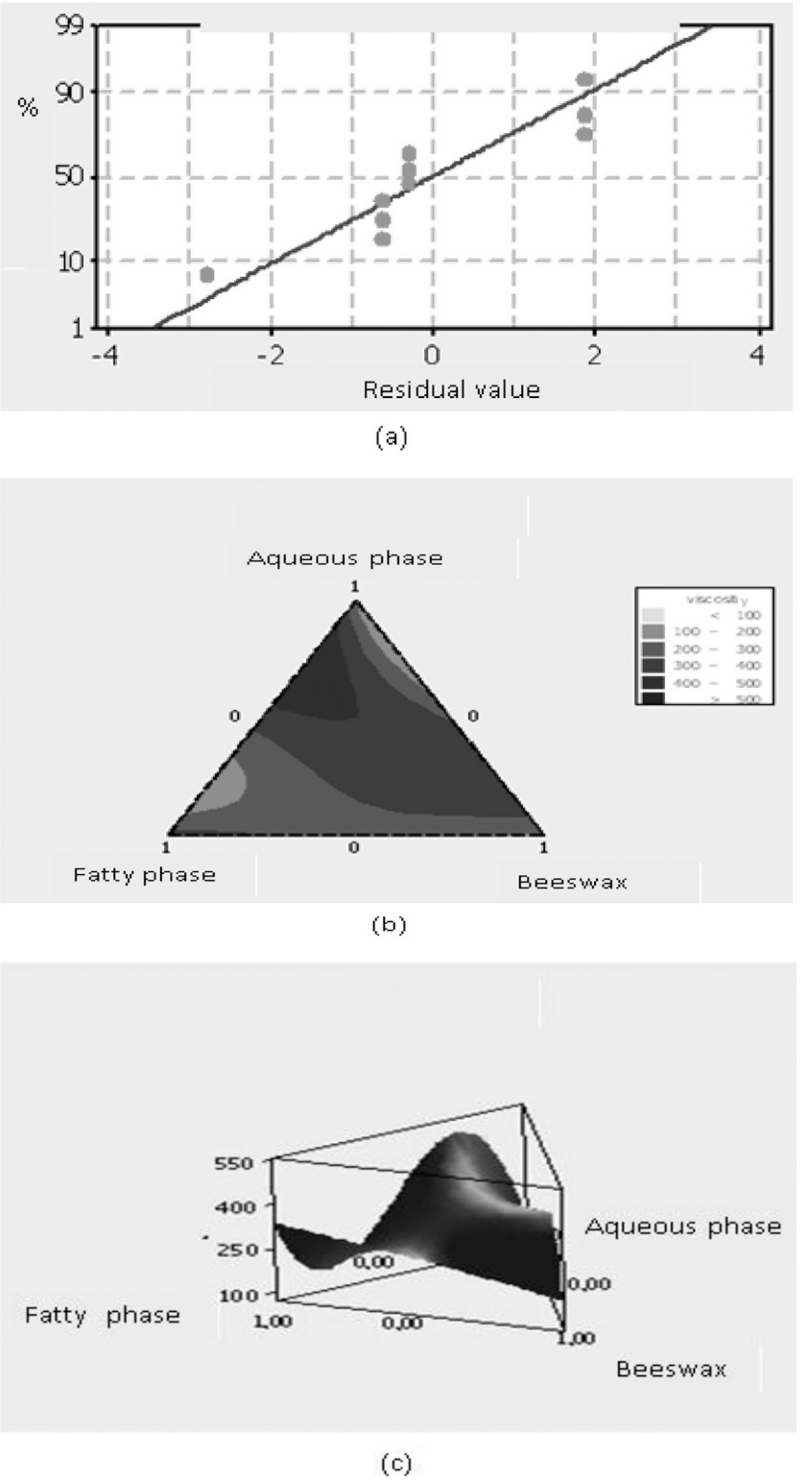

Figure 3. (A) Henry's straight, (B) iso-response surface, and (C) response surface. Case of viscosity (Vis) (Pa·s).

The quadratic equations are in the form:

Spreadability:

YSp = 13.99 X1 + 18.59 X2 + 8.89 X3 − 17.36 X1X2 + 2.01 X1X3 + 3.06 X2X3 − 123.87 X1X2X3

Viscosity:

YVis = 17.23 X1 + 33.81 X2 + 17.23 X3 + 37.53 X1X2 + 43.82 X1X3 + 3.28 X2X3 + 107.18 X1X2X3

The calculated model values in the center of the domain (Sp = 7.87 and Vis = 34.90) are close to those found experimentally (Table I).

The response surface and contour curves related to the Sp are illustrated in Figure 2B and C, respectively.

As that can be seen, the Sp values are positively correlated with proportions of both aqueous and fatty phases, the beeswax proportion being fixed at its mean value.

Compared with the Sp, the Vis shows another behavior (Figure 3B and C). The high values were obtained in the area close to the center of the experimental domain, and at low values of beeswax fractions.

Globally, results show that there is a relatively wide composition range to obtain a suitable cosmetic cream from the point of view of Sp and Vis, knowing that for a moisturizing cream, the values of these two criteria are required to be 15 and 19 cm^2 and 7.16–88.00 Pa·s, respectively (33). Taking into account these data, the formulation corresponding to the test 2 (Table I) seems to be the most appropriate, involving a final product with an acceptable white external aspect and a homogenous viscous texture (Figure 4).

Figure 4. Cosmetic cream sample of the selected formulation.

CHARACTERIZATION OF THE SELECTED COSMETIC

Stability. Table II represents the experience matrix, summarizing experimental conditions and obtained responses according to the full factorial design at two levels.

From these results are then deduced the effects of the factors as represented by the following corresponding models:

PI = 62.32 − 1.45 x1 + 1.93 x2 – 0.01 x3 + 1.102 x1x2 + 1.157 x1x3 − 0.425 x2x3 − 0.605 x1x2x3

Sp = 74.51 – 0.47 x1 + 0.20 x2 + 0.28 x3 − 0.533 x1x2 – 0.733 x1x3 + 0.358 x2x3 − 0.466 x1x2x3

Vis = 31.58 + 0.40 x1 – 2.66 x2 +0.18 x3 − 0.69 x1x2 – 0.74 x1x3 – 0.14 x2x3 – 10.66 x1x2x3

As it can be seen, different factors do not have the same effect on the responses. For Vis and PI, the highest effect (in absolute values) concerns the factor x2 (storage time). It is also clear that the content of DSO (x1) has the same effect on PI and Vis, tending to (i) protect cosmetic cream against oxidation and (ii) reduce the cosmetic viscosity.

Regarding the interactions, some of their effects greatly exceed those of the main factors: DSO/time/temperature (case of the Vis) and DSO/time, time/temperature, and DSO/time/temperature (case of the Sp).

Rheological Profile. Rheological measurements are important not only to assess the physical stability (36), but they are at the same time indicators of the quality of the analyzed system (37). The study of these properties has become a crucial tool in the analysis of cosmetic products, the aim being to produce stable structural profiles (38).

The rheograms related to the enriched (added with DSO and DSAE), standard (without DSO and DSAE), and commercial (Mark Dove; Unilever, Mumbai, India) cosmetic creams are displayed in Figure 5.

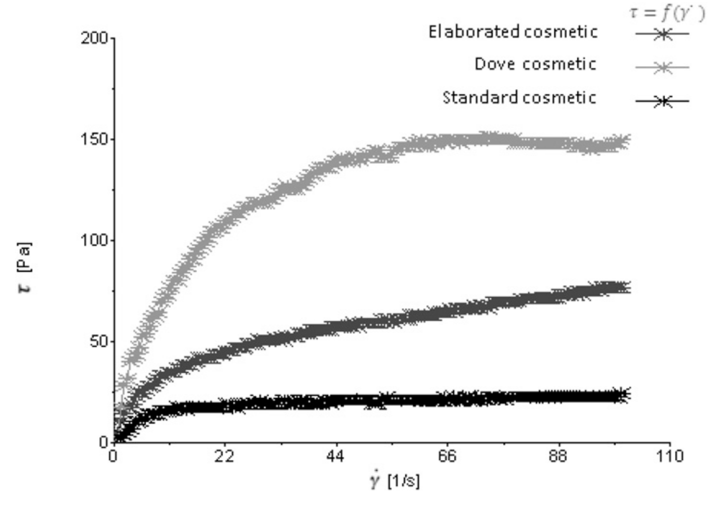

Figure 5. Flow curves related to different cosmetic creams tested.

The rheological behavior of the elaborated cosmetic is similar to those of certain formulations studied by Djuris *et al.* (22), who have used cetearyl glucoside as a natural emulsifier and a mixture of lipophilic coemulsifiers as a stabilizer of the emulsion.

The power model of Ostwald-de Wealk (37) was applied for modeling rheological behavior of the obtained cosmetic cream.

$$\tau = k\gamma^{\eta}$$

where, τ is the sheer strain, k the uniformity index, γ the sheer rate, and η the flow index.

The flow index for the three cosmetics is below 1: standard cosmetic (n = 0.2995), cosmetic added with date seed derivatives (n = 0.4151), and commercial cosmetic (n = 0.4669). The similar values between the last products must be noticed.

From point of view of rheological behavior, the obtained cosmetic is of pseudoplastic type. This finding is concordant with that of Guaratini *et al.* (37) about a cosmetic cream added with vitamins A and E. Moreover, the same authors postulated that such configuration is suitable for cosmetics.

Comparative Values of pH, Sp, and Ct. Table III shows that the pH values of the three compared cosmetics are statistically different ($p \leq 0.05$), but those of the commercial and elaborated cosmetic are similar to the required pH. In opposite, the corresponding Sp and Ct values (Table III) are not statistically different ($p \leq 0.05$) and are in the suitable range.

CONCLUSION

Globally, results show that there is a relatively wide range of ingredient proportions that allows one to obtain a suitable moisturizing cosmetic cream, according to the Sp and Vis.

In opposite to the storage time, the DSO was found to act positively on the both Vis and PI.

From point of view of rheological behavior, the obtained cosmetic cream is of pseudoplastic type.

Since the results confirm the feasibility of the studied cosmetic, it would be interesting to deepen certain analysis (statistics, stability, and dermatological testing).

Considering the potential health of natural ingredients contained in the elaborated cosmetic cream, the latter has promising prospects. In particular, it may generate interest

Table III
pH and Sp Values of the Three Compared Cosmetic Creams

Parameter	DSO/DSAE cosmetic	Standard cosmetic	Commercial cosmetic
pH	6.33 ± 0.72^{b}	3.71 ± 0.02^{c}	7.92 ± 0.01^{a}
Sp (cm^2)	14.78 ± 1.92^{a}	14.99 ± 1.55^{a}	15.97 ± 2.82^{a}
Ct (%)	100	100	100

[a,b,c]Same letters on the same line indicate the absence of significant difference ($p \leq 0.05$) between values.

among warned users and health professionals, i.e., those who are aware that natural cosmetics represent safety alternative to conventional ones and that the latter should contain toxic components rarely listed on the labels, thanks to a loophole in the law.

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