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Application of tapioca and corn starches as an alternative for synthetic polymers in cosmetic products

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The demand for innovative eco-friendly ingredients is a current trend in the pharmaceutical and cosmetic fields. Starches can be a good alternative because their gelatinization property could increase the stability of emulsions. The objective of the present study was to develop a gel formulation based on tapioca and corn starch and to evaluate its stability, physical-mechanical and sensory properties according to the experimental design. A general full factorial experimental design with three levels was elaborated for each polysaccharide under study. The best formulation was evaluated in terms of rheological and sensorial properties. Only the formulation with tapioca and corn starch in combination was stable, showing a thixotropic behavior without changes in rheological parameters after 28 days. Sensorial analysis classified the formulation as soft, easy to spread and giving a hydration sensation. The nature of the polymers could be responsible for a synergistic effect on the spreadability parameter. According to the results obtained, the use of starches for the development of topical products can be suggested as a natural alternative to the polymers and silicones commonly used as rheological additives. The developed formulation could be a green alternative with proven physical-mechanical stability and excellent sensorial properties.

Keywords: Starches. Stability. Sensorial analysis. Rheology. Natural products.

INTRODUCTION

The search for new pharmaceutical and cosmetic ingredients is necessary in order to produce formulations with favorable physicochemical and physical-mechanical characteristics and to obtain more stable topical products that are also safe and pleasant to the senses (Gilbert *et al*. 2013). Thus, the selection of suitable raw materials compatible with one another and skin compatible is essential for the development of innovative cosmetics. In addition to the standardization of production methods, stability tests and sensorial evaluation are essential to ensure the best product performance (Calixto, Maia Campos, 2017).

Botanical extracts, vegetable oils and other natural products are promising ingredients to be applied to the development of innovative cosmetic products (Garbossa, Maia Campos, 2016). In addition, starch can be a good alternative as a biodegradable ingredient in cosmetic formulations because its gelatinization property could increase the stability of emulsions and result in more stable formulations with good performance (Ai, Jane, 2015).

Starches are polysaccharides from different sources which are extensively used due to their versatility, natural approach and low price. They consist of a plant polymer composed of amylose and amylopectin and of glucose polymers formed by dehydration. Amylose is more soluble in water than amylopectin and is responsible for the helicoidal structure of the substance (Miles *et al*., 1985; Ai, Jane, 2015). These carbohydrates from natural sources are utilized by the cosmetic sector due to their characteristics of gelatinization, increased stability and sensorial improvement (Brode, 1991). Tapioca starch, for example, is a pre-hydrated starch from cassava roots that can be less granular than corn starch, so that the different proportion of granules can influence gel stability (Atichokudomchai, Saiyavit, 2003). In addition, studying the possible interactions between raw materials provides

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important information for the solution of problems such as stability or sensorial properties.

The parameters evaluated in texture analysis of formulations such as firmness, cohesiveness, consistency, viscosity index and work of shear can be correlated with the integrity of the formulation (Jones, Woolfson, 1997; Wasan, Nikolov, Aimetti, 2004). In addition, studies of fluid behavior such as rheology are another important tool for the determination of physical stability. Using the study of matter flow, it is possible to predict different behaviors of the formulation such as flow index and thixotropy (Gaspar, Maia Campos, 2003; Wagemaker *et al*., 2015)

A cosmetic formulation needs to have physical-mechanical stability in order to maintain its properties throughout its useful life, but acceptance by the users is also very important. For this purpose, a pleasant perception property is required and a sensorial evaluation can help the development of a cosmetic formulation which will be accepted by the users (Gilbert *et al*., 2013; Filipovic *et al*., 2017).

The experimental factorial design is often used to solve or prevent problems of formulation stability (Ferreira *et al*., 2007). Product behavior can be predicted based on the rational organization of the influence of each factor on a response. This allows industries to save time in the research and development of new products (Calixto, Infante, Maia Campos, 2018).

Thus, the use of starches in combination could be suggested as a green alternative to the rheological additives used in cosmetics, resulting in increased emulsion stability, uniform film formation for sunscreens, and/or better pigment dispersion for makeup formulations compared to acrylate polymers. Furthermore, the combination of starches could be a good low-cost sensorial modifier. For this purpose, a factorial experimental design was developed in order to analyze the influence of tapioca and corn starch on work of shear, an instrumental measure which is correlated to sensorial perception (Ferreira *et al*., 2007; Gilbert *et al*., 2013; Filipovic *et al*., 2017; Calixto, Infante, Maia Campos, 2018).

In this context, the objective of the present study was to develop a green and biodegradable gel formulation based on tapioca and corn starch submitted to factorial design experiments and to evaluate the physical stability, physical-mechanical and sensorial properties of the product. The formulations obtained could then be applied as a sustainable alternative for the improvement of cosmetic formulation performance, with low cost and easy applicability.

MATERIAL AND METHODS

Material

The corn and tapioca starches used in the present study were obtained from a local market (Ribeirao Preto, Sao Paulo, Brazil). Vegetal glycerin, butylene glycol, disodium EDTA and phenoxyethanol, methylparaben, ethylparaben, propylparaben, butylparaben and isobutylparaben were provided by Mapric (Sao Paulo, SP, Brazil). The formulation was prepared by starch gelatinization and the process was patented, as required by INPI (*Instituto Nacional da Propriedade Industrial* – Brazil), under registration number BR1020170257452.

Studied formulations

Twenty-seven formulations were prepared by weighing all the ingredients in a beaker except the parabens and butylene glycol. All ingredients were then heated to 70°C and shaken constantly. After 10 minutes, the preservatives and butylene glycol were added to the formulation, followed by 10 more minutes of shaking.

Accelerated stability test

The formulations were submitted to preliminary stability tests. They were prepared and packaged (30 g) in containers with a lid which were stored at room temperature (25ºC) and tested by thermal stress at temperatures of 37ºC and 45ºC. They were then analyzed regarding macroscopic aspects, organoleptic characteristics and pH for periods of 7, 14, 21, 30, 60 and 90 days (Calixto, Maia Campos, 2017).

Experimental design

A general full factorial experimental design with three levels was elaborated for each polysaccharide under study. In order to assess the influence of the presence and concentration of the ingredients in the formulations, two continuous numeric factors were defined: "Polysaccharide concentration" and "Glycerin concentration". The polysaccharide combinations chosen to compose the three designs were: "Tapioca", "Corn starch" and "Tapioca + Corn starch" (Table I). For Tapioca + Corn Starch, we used the same amount of each, meaning that 10 % can be seen as 5% tapioca and 5% corn starch. The sensory predictor variable "work of shear" was chosen because this physical-mechanical property is a predictor of the sensorial characteristic "spreadability". The lower the work of shear, the better the formulation spreadability (Behera *et al.*, 2015; Calixto, Maia Campos, 2017). The analyses were performed 24 hours after the development of the formulations.

Twenty-seven analyses were performed in triplicate (Table II), for a total block of 81 experiments. The statistical design and planning were assessed using Minitab® software 17 (Minitab Inc., State College, PA). This strategy of analysis with the instrumental and sensorial characterization tests is part of a complete protocol for the development of innovative cosmetics.

TABLE I – Design of the experimental parameters

Factors	Levels	-1	0	1
Polysaccharide concentration	3	5%	7,5%	10%
Glycerin concentration	3	3%	6%	9%

Texture profile analysis

The texture analyses were performed using a TA.XT plus Texture Analyzer (Stable Microsystems, United Kingdom). The method consists of inserting an analytical probe into the sample at a defined speed, leading to the pre-defined recovery period between the end of the first compression and the beginning of the second, as well as the shear during the same period. The "work of shear" parameter was calculated with the area of the resulting force (N) vs time (t) graph (Brode, 1991; Atichokudomchai, Saiyavit, 2003; Behera *et al.*, 2015; Calixto, Maia Campos, 2017).

TABLE II – Formulations developed for the experimental design

Formulation	Carbohydrate Polymers	Total Concentrations	Glycerin
1	Tapioca	5%	3%
2	Tapioca	7.50%	6%
3	Tapioca	10%	9%
4	Tapioca	10%	3%
5	Tapioca	5%	6%
6	Tapioca	7.5%	9%
7	Tapioca	7.5%	3%
8	Tapioca	10%	6%
9	Tapioca	5%	9%
10	Corn Starch	5%	3%
11	Corn Starch	7.50%	6%
12	Corn Starch	10%	9%
13	Corn Starch	10%	3%
14	Corn Starch	5%	6%
15	Corn Starch	7.5%	9%
16	Corn Starch	7.5%	3%
17	Corn Starch	10%	6%
18	Corn Starch	5%	9%
19	Tapioca+Corn Starch	5%	3%
20	Tapioca+Corn Starch	7.50%	6%
21	Tapioca+Corn Starch	10%	9%
22	Tapioca+Corn Starch	10%	3%
23	Tapioca+Corn Starch	5%	6%
24	Tapioca+Corn Starch	7.5%	9%
25	Tapioca+Corn Starch	7.5%	3%
26	Tapioca+Corn Starch	10%	6%
27	Tapioca+Corn Starch	5%	9%

Rheological behavior

The samples were considered stable when submitted to the accelerated stability test. Their physical stability was assessed by rheological determinations performed with a model DV-III RV Brookfield rotational rheometer (Stoughton, MA, USA) with a cone-plate configuration, connected to a Brookfield software program, RHEOCALC Version V 1.2.19.

The measurements were made under the following experimental conditions: 25°C, 0.5 g samples and CP52 spindle. To obtain the ascendant curve, progressively higher rotation speeds were applied (1 to 20 rpm) and the procedure was repeated in reverse with gradually decreasing speeds (20 to 1 rpm) for the descendant curve, 7 times for 5 seconds. The rheograms obtained were mathematically analyzed by the Ostwald model (Equation 1) that relates shear stress and shear rate, with flow index values (related to the degree of sample pseudoplasticity) and consistency index being obtained (Calixto, Maia Campos, 2017). The apparent viscosity was obtained from the curve.

$$T = k\gamma n \quad (1)$$

Sensory analysis

After the instrumental characterization, the most stable and appropriate candidate of green alternative to acrylates, was submitted to sensory analysis. Forty untrained volunteers, 22 women and 18 men aged 18 to 52 years, were recruited. All participants received the equivalent of 25 µg of formulation in an area of 12 cm², which is equivalent to 2 µg/cm², in a randomized forearm region. The procedures were in accordance with the Ethics Committee standards of the School of Pharmaceutical Sciences of Ribeirão Preto (CEP/FCFRP 58368416.6.0000.5403). During the analysis, the subjects remained in a room with controlled temperature and relative humidity (25 ± 1°C and 40-60%) with 15 minutes of acclimatization. The participants were requested to apply the product with one finger and to spread it with 10 small circular motions. After application, they answered a CATA (check-all-that-apply) to evaluate the following parameters: oily, soft, sticky, dry to the touch, difficult to spread, absorption. After 5 minutes, they evaluated the following residues on the skin: oily residue, aqueous residue, white residue and hydrated skin sensation (Parente, Gaston, Manzani, 2010).

Microscopic analysis of the formulations

The formulations with the highest concentration of each starch alone and in combination were evaluated by normal light microscopy (OLYMPUS Model CSH, Japan) with 400-fold magnification for visualization of their microstructure.

Statistical Analysis

Data were analyzed statistically using GraphPad Prism v.5.0 software (Graphpad Software. San Diego, CA). One-way analysis of variance with the Tukey posttest was used for data with normal distribution and the Kruskal-Wallis test with Dunn's posttest was used for data with non-normal distribution. The level of significance was set at $p < 0.05$ in all analyses. The Shapiro-Wilk test was used to determine normality.

RESULTS

Stability

No changes in color, odor, homogeneity or phase separation were observed in formulation 26 after three months of study (Table II). This behavior was maintained even under thermal stress. The pH of the formulation ranged from 4.9 to 5.5, compatible with skin pH, with no significant variations after this period.

Formulations with low starch concentrations exhibited phase separation even without thermal stress, probably because the minimum concentration of polymerization was not reached. On the other hand, the formulations with high starch concentration became very hard and began to crumble.

Only formulations 8, 17 and 26 were stable after one week. However, formulations 8 and 17 were no longer stable after one month. This way they were not considered for the rheologic tests.

Experimental design

In formulations containing only corn starch, glycerin concentration did not imply large changes in response (Figure 1). When present at a concentration of 6% in these formulations, glycerin did not influence work of shear in a significant manner. In contrast, all changes in polysaccharide concentration caused significant changes in the results. The work of shear parameter is a predictor of spreadability in sensorial analyses, as demonstrated by studies showing that the two parameters are inversely correlated (Calixto, Maia Campos, 2017).

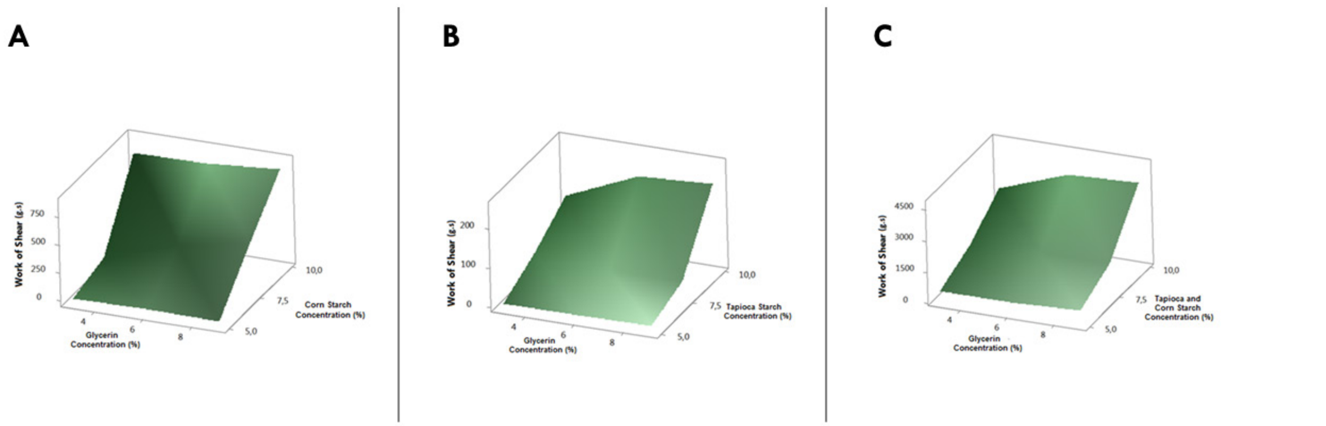

FIGURE 1 – Factorial plot of the main effects of the concentrations of Corn and Glycerin (A), Tapioca and Glycerin (B), Polysaccharide (Tapioca + Corn Starch) and Glycerin (C), respectively, on the "work of shear" response.

By fixing the statistical regression variables (Table II), it was possible to obtain an equation (2) that correlated the two factors at their different levels and their influence on work of shear:

$$\text{Work of shear} = 355.00 - 346.7\,X1 - 75.5\,X2 + 422.2\,X3 - 72.3\,Y1 + 8.2\,Y2 + 64.1\,Y3 + 64.1\,X1 * Y1 - 1.0\,X1 * Y2 - 63.1\,X1 * Y3 - 112.2\,X2 * Y1 + 20.0\,X2 * Y2 + 92.2\,X2 * Y3 + 48.1\,X3 * Y1 - 19.0\,X3 * Y2 - 29.1\,X3 * Y3 \quad 2)$$

The results obtained with tapioca starch were the same as those obtained with corn starch (Figure 1). Higher increases in response were observed with increasing concentrations of the tapioca polysaccharide, mainly at 10%. Glycerin did not show marked changes in response, mainly at a concentration of 6%, which did not have a significant influence ($p < 0.05$). Equation 3 represents this relation.

$$\text{Work of shear (g.sec)} = 75.86 - 69.80\,X_1 - 30.39\,X_2 + 100.19\,X_3 - 16.28\,Y_1 + 6.40\,Y_2 + 9.88\,Y_3 + 15.08\,X_1{*}Y_1 - 6.30\,X_1{*}Y_2 - 8.78\,X_1{*}Y_3 + 25.09\,X_2{*}Y_1 - 10.69\,X_2{*}Y_2 - 14.40\,X_2{*}Y_3 - 40.18\,X_3{*}Y_1 + 16.99\,X_3{*}Y_2 + 23.18\,X_3{*}Y_3 \quad (3)$$

Regarding the interaction between variables, combining low concentrations of tapioca with glycerin yielded low work of shear values and therefore better spreadability. The tapioca concentration of 10% in combination with Glycerin yielded different results, while all other concentrations had no effect.

The combined presence of Corn Starch and Tapioca in the formulation increased the work of shear values, indicating a decline in spreadability. Similarly, corn starch influenced these values more than glycerin (Figure 1), as shown in equation 4.

$$\text{Work of shear} = 1786.7 - 1234.8\,X1 - 388.4\,X2 + 1623.2\,X3 - 347.8\,Y1 + 126.4\,Y2 + 221.3\,Y3 + 306\,X1{*}Y1 - 171\,X1{*}Y2 - 135\,X1{*}Y3 + 202\,X2{*}Y1 - 56\,X2{*}Y2 - 146\,X2{*}Y3 - 508\,X3{*}Y1 + 227\,X3{*}Y2 + 281\,X3{*}Y3 \quad (4)$$

Sensorial Analysis

The forty study participants who tested the stable formulation with the combined starches (Formulation 26) responded to a check-all-that-apply questionnaire and the results are shown in Figure 2. Most subjects found the formulation easy to spread and smooth and less than 50% of the participants attributed characteristics such as stickiness and oily feel to the formulation. After 5 minutes, a clear majority pointed out that the formulation left a feeling of hydration on the skin, with few answers reporting the presence of some type of residue. Thus, Formulation 26, based on combined starches, proved to be an excellent candidate for application to cosmetic development, being well accepted by consumers.

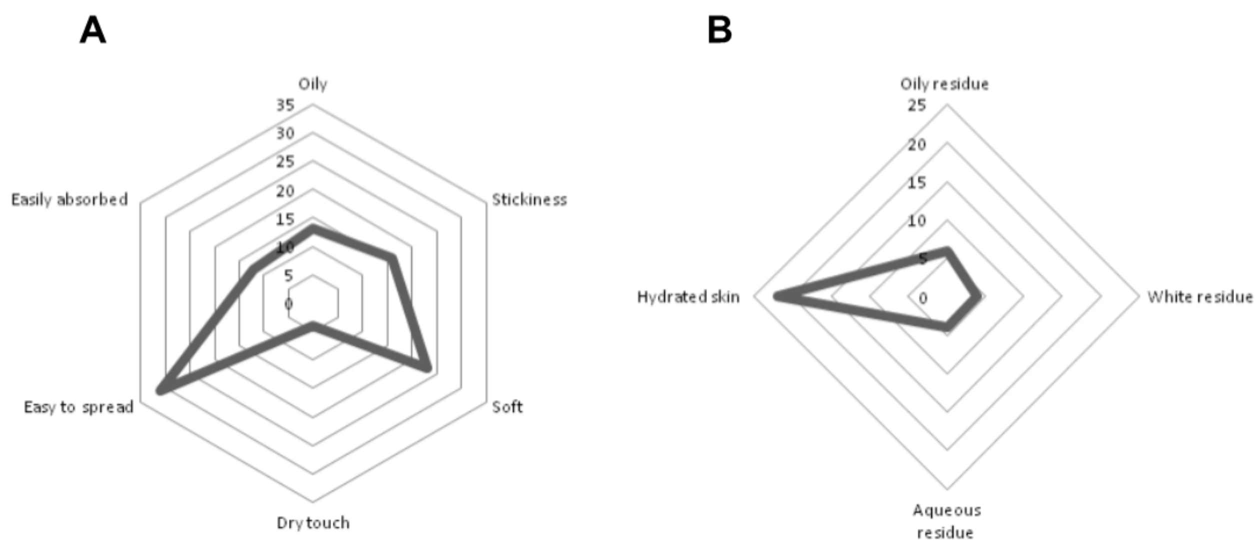

FIGURE 2 - Sensory analysis of formulation 26 immediately (A) and five minutes after application (B) for 40 participants.

Rheological Behavior

Formulation 26 was the only one that remained stable for three months under thermal stress. For this reason, its rheology was determined, and the results are presented in Figure 3. It was possible to note a pseudoplastic behavior of the formulation with the presence of low thixotropy. The formulation did not exhibit high variations in rheological behavior for 90 days, especially at room temperature. Although there was a decrease in apparent minimum viscosity, especially among formulations subjected to thermal stress, the behavior of the rheological curve did not change during the study. Thus, the formulation demonstrated physical stability.

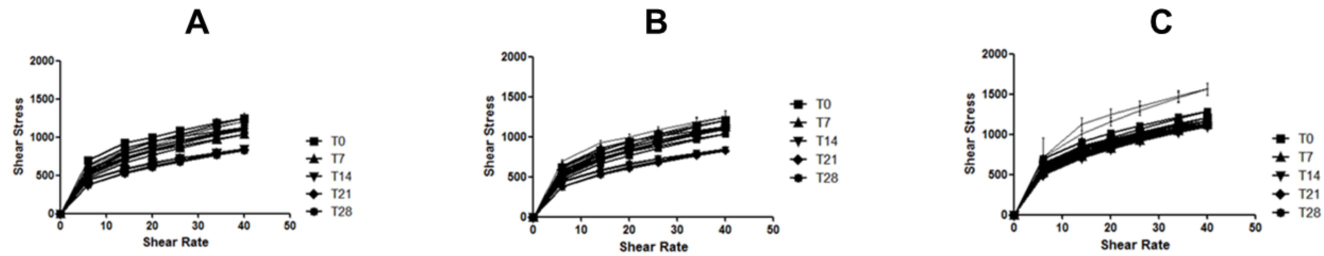

FIGURE 3 – Rheological behavior of formulation 26 at room temperature (A), 37°C (B) and 45°C (C).

Figure 4 shows the variation of the rheologic parameters according to the time of study of the formulation. Formulation 26 submitted to thermal stress of 37°C exhibited a significant difference only between T0 and T14, showing that after a certain time it remained stable.

The apparent minimum viscosity of the non-Newtonian system (Figure 4) did not show significant differences between time points at any of the temperatures used.

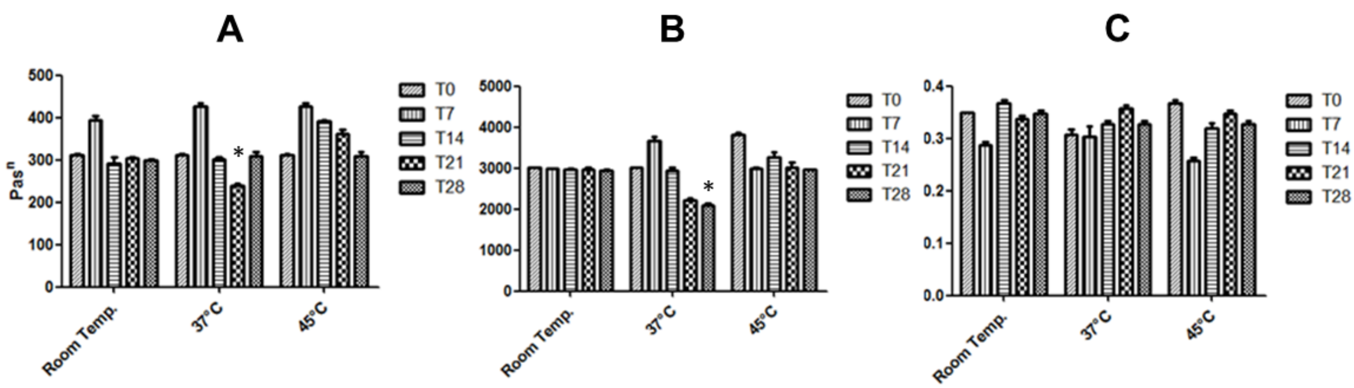

FIGURE 4 – Consistency (A), apparent minimum viscosity (B) and flow index (C) of formulation 26. (*) $p<0.05$ compared to T7.

Synergistic interaction between starches

As shown in Figure 5, formulation 8 containing only tapioca starch (10%) showed a structure with less granules than formulation 17, containing only corn starch (10%). In contrast, the formulation with both starch types, the target of the present study (Formulation 26), showed more granules than the formulation with only tapioca starch but less granules than the formulation with only corn starch. Thus, even though both materials are starches, their different natures helped to improve the quality of the final formulation.

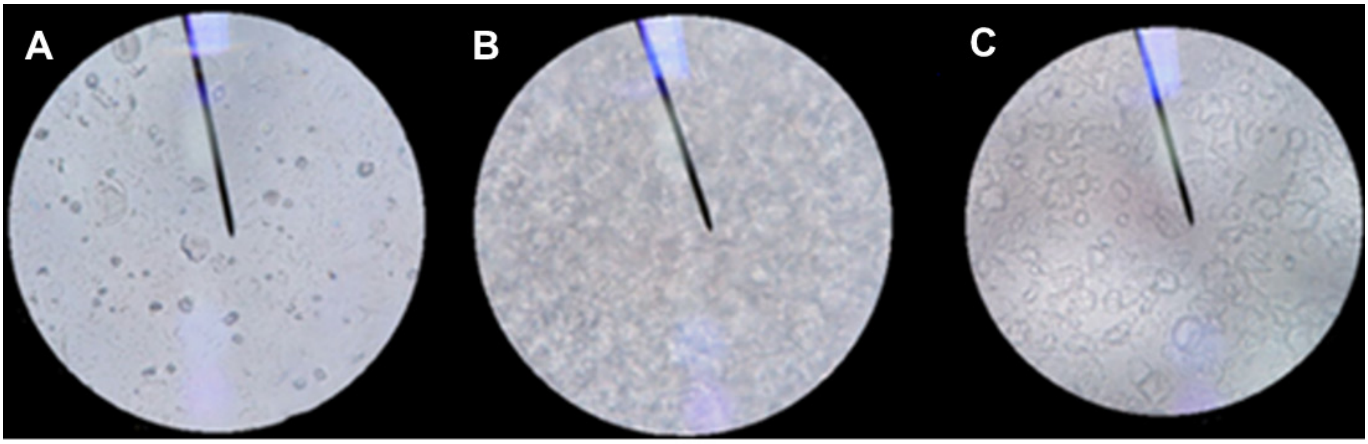

FIGURE 5 - Normal light microscopy of formulations 8 (A, 10% tapioca starch), 17 (B, 10% corn starch) and 26 (C, tapioca and corn starch, 5% each, total 10%). Magnification: 400x

DISCUSSION

The 27 developed formulations were submitted to the work of shear test - i.e., the work necessary for a formulation to be spread over a given surface – 24 h after its development. This test has correlations with the sensory properties, as demonstrated in previous studies by our research group. Higher work of shear values indicates worst spreadability, corresponding to an unwanted sensorial property predicted for cosmetic formulations (Calixto, Maia Campos, 2017; Calixto, Infante, Maia Campos, 2018).

Glycerin can be a polymer plasticizer, helping to improve the cross-link between polymer chains (Bajer *et al*., 2012). For this purpose, we chose to vary the concentration of glycerin, also a humectant agent, in the cosmetic formulations, important for a formulation with starches since glycerin is highly hygroscopic and the loss of water could affect the stability of the formulation.

The maximum polysaccharide concentration combined with 6 and 9% Glycerin concentrations induced the highest work of shear values. Therefore, the best solution would be to combine polysaccharides with any of these two concentrations of glycerin to obtain better work of shear values. The cosmetic formulation was stable only with the combination of the two starches and glycerin. However, it is important to highlight that only formulations 8, 17 and 26, all containing 6% glycerin, remained stable after one week. Thus, it appears that, in the present study, glycerin concentration was not a crucial factor but only a limiting one regarding the stability of the formulations and physical-mechanical refinement.

Sensorial analysis is a very important parameter for the cosmetic area because it can directly indicate how and if consumers will accept the product (Infante, Calixto, Maia Campos, 2016; Calixto, Infante, Maia Campos, 2018). In addition, if we want to apply this gel-based cosmetic formulation to dry-touch sunscreens, for example, it is important that it shows good performance regarding another sensorial characteristic in addition to spreadability (Calixto, Maia Campos, 2017). Sunscreen formulations usually show high levels of white residue after application and if our starch combination also presented this characteristic, it could not be a good candidate for the cosmetic field. However, formulation 26 did not show any sensorial residue and therefore could be a good candidate for use in cosmetic development.

Since starches are polysaccharides, i.e., biodegradable polymers, they may show excellent compatibility with biological tissues. De Paepe and collaborators (2002) used rice starch as an alternative for the improvement of skin barrier function due to its film forming property. Another study used modified starch and green coffee oil as a UV booster in sunscreen formulations, reducing the amount of UV filters (Marto *et al*., 2016).

It is important to point out that our study focused on non-modified starches, which are less expensive than those used in the cited study. Thus, the use of our starch combination in sunscreen formulations could be a good alternative for the development of formulations with a superior performance on the skin. This suggestion would represent a reduction in the final price of the sunscreen and would reduce skin incompatibility since starches are biocompatible and do not penetrate the stratum corneum (de Paepe *et al*., 2002; Marto *et al*., 2015; Marto *et al*., 2016; Marto *et al*., 2018).

In the rheological characterization, a pseudoplastic behavior is desirable in topical products such as cosmetics because the decrease of viscosity with the increase of the shear rate could improve parameters for a better sensory perception (Wagemaker *et al*., 2015). This means that the formulation would be easier to spread and would not act as a dilatant.

The thixotropic behavior of starches has been previously described in the literature; however, our study shows how the association of two starches from different natural sources behaves rheologically in a cosmetic formulation (Evans, Haisman, 1980; Willett, Jasberg, Swanson, 1995; Thebaudin, Lefebvre, Doublier, 1998). A low thixotropy (area between the two rheological curves) probably indicates a film forming capacity of the formulation, something desirable for some cosmetic products (Gaspar, Maia Campos, 2003; De Melo, Maia Campos, 2019).

The consistency index represents a better parameter for the analysis of rheological behavior since it integrates the points of the curve, whereas the minimum apparent viscosity is related only to the highest point of the rheological curve (Wagemaker *et al*., 2015; Laba, 2017). It is possible to observe in figure 4 that the consistency index suffered more variations at a thermal stress of 37ºC over a period of one month. No variations were observed at room temperature in the rheological study, a fact indicating that the microstructure of the cosmetic formulation with starch association did not vary during the study period, highlighting the physical-mechanical stability of the preparation.

Starches can directly influence the rheological behavior and the sensorial perception (Daudt *et al*., 2015). Thus, the results of the present sensorial analyses show that formulation **26** is a promising gel-based cosmetic formulation.

The formulation containing the starches in combination showed better work of shear values, with the sensorial analyses showing a possible correlation between these parameters.

This characteristic may be related to the nature of the polymers used in this study. First, it is necessary to understand the nature of starch since this was the major component of the cosmetic formulation. Starch can build polymer networks under the action of water and heat. First, the starch granule absorbs water and increases in volume. Then, with excess water, the granule bursts and with the heat the process of gelatinization occurs, forming a polymer network that can stabilize the water drops (Figure 6). The presence of glycerin helps make these networks stronger (Fredriksson *et al*., 1998; Sandhu, Narpinder, 2007).

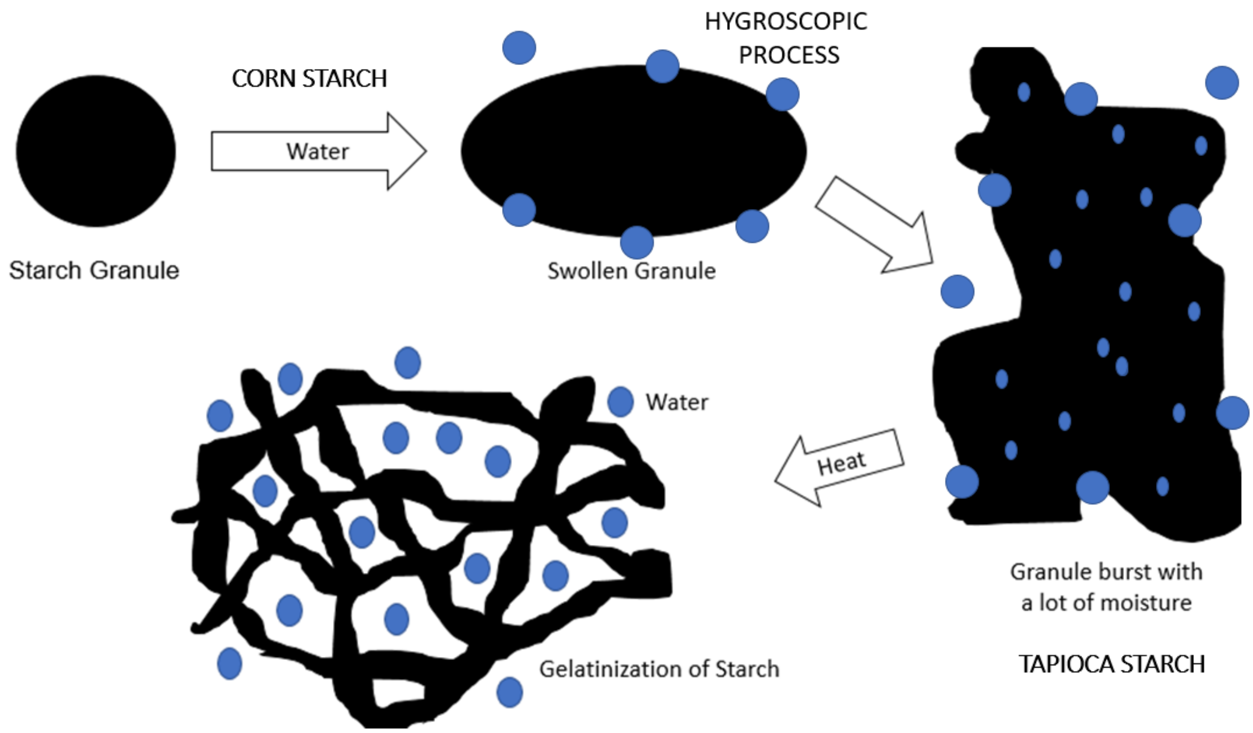

FIGURE 6 – Process of starch gelatinization.

Corn starch differs from tapioca starch in terms of granule size and is not previously swollen, whereas tapioca starch, which is a derivative of manioc, suffers previous hydration (Mishra, Rai, 2006). In this way, the starch granule bursts and the gelatinization process can be optimized. When these starches were combined, a synergist interaction was observed, with the tapioca starch building the polymer network earlier than corn starch. Thus, tapioca builds the polymer network and corn starch, with the hydrated granules, helps improve the viscosity of the formulation.

In addition, several studies have demonstrated that different starch sources could result in variations of starch granule size, for example, and this characteristic can influence the rheological behavior (Singh *et al.*, 2003; Luchese, Spada, Doublier, 2017). The concentration of amylose, a longer and more linear carbohydrate polymer of starches, affects the rheologic behavior by influencing how easily water can penetrate starch granules (Lii, Tsai, Tseng, 1996). This variation in botanic source could help explain how the interaction between these two starches was more stable for the purposes of a cosmetic formulation.

It is important to highlight that more than 95% of formulation 26 was from natural sources. The use of acrylate polymers in cosmetic products has been contested since consumers are concerned about the impacts of these polymers on nature (Duis, Coors, 2016). Thus, the cosmetic formulation developed here can be an alternative to the use of acrylate polymers.

The factorial analysis experiment revealed that the formulation based on tapioca and corn starches showed good results for application to the development of cosmetic products since it can improve the stability and sensorial properties of these products. In addition, the factorial experimental design could help save time for the development of cosmetic formulations. The starches obtained from different sources showed a synergic interaction since the structure of each one improved a different parameter of physical stability, with the consequent improvement of the global stability and sensorial properties of the cosmetic formulation. Thus, the use of starches for the development of topical products can be suggested as a natural alternative to the polymers and silicones commonly used as rheological additives.

Formulation 26, based on combined starches and stable after 90 days of study could be a green alternative for pharmaceutical and cosmetic companies as a topical formulation with proven physical-mechanical and physical-chemical stability in addition to an excellent sensorial acceptance.

ACKNOWLEDGMENTS

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SISGEN ACCESSION NUMBER

The activity of access to Genetic Heritage/CTA, in the terms summarized below, was registered in the SisGen (Register number A93D2A1 for Tapioca Starch utilization), in compliance with the provisions of Brazilian Law 13.123/2015 and its regulations.

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