Safety Nanocosmetics: Triblock Copolymer Nanostructured Lipid Carriers and application on Hair Cosmetics

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Abstract. Nanotechnology has been extensively studied for application in the pharmaceutical area. Nanostructured lipid carriers (NLC) are safe lipid nanoparticles that improve the performance of cosmetic products due to their high superficial area. The NLC were produced with the solid lipids, cupuaçu and lanolin, and the liquid lipid, buriti. The production method was by high pressure homogenizer, with three cycles at 600 bar. The produced nanoparticles presented diameters around 200 nanometers and a low polydispersity index. The images obtained by electron cryo-transmission electron microscopy (TEM) showed an NLC solution with nanoparticles with circular projection structures with dimensions between 15 nm to 140 nm, without signs of aggregation between these structures.

The Scanning Electron Microscopy (SEM) analysis showed visible changes in the capillary structure after treatment with the conditioner containing NLC versus the non-treated wicks. The outer cuticle are seal and have a uniform appearance and brightness to the naked eye after application of conditioner containing NLC. The color seems not to vary when comparing the hair treated with the conditioner base (without NLC) and the control. Otherwise, after the treatment with NLC-containing conditioner it was observed an improvement on the average parameter. Then, our results indicated a significant improvement in the brightness caused by the nanoparticle action, as well as a contribution to the retention of moisture in the capillaries, reduction of hair wicks frizz and for greater brightness.

1. Introduction

Human hair is composed mainly of keratin, a protein that is high in sulfur components. This protein forms a network of disulfide bonds that give the hair some mechanical and chemical resistance, and many of the morphological structures of hair vary their chemical and physical characteristics because of the sulfur bridges content. The hair fibers are from 50 to 100 μm of diameter and are protected by a layer called cuticle, which is built by overlapping cells of 45-60 μm long and 0.5 μm thick [1,2]. The cortex is the largest constituent of the hair fiber and it is responsible for its mechanical strength. It is formed by keratin macrofibrils aligned in the direction of the wicks. Distributed in the cortex are melanin granules whose type, size and quantity determine hair color. Inside the cortex lies the medulla, which is frequently broken or even absent in the wicks. Studies have confirmed that the medulla is the part with the highest concentration of lipids in the hair. The outer surface of cuticular...
cells has bound fatty acids such as stearic acid, palmitic acid, oleic acid and 18-methyleicosanoic acid (18-MEA). This surface composition is the reason why the hair is hydrophobic and an electrical insulator [3].

The transport to the inner part of the capillary fiber occurs in three distinct ways: first, the molecules are transported to the fiber/solution interface by combining the diffusion and convection processes, then they are spelling onto the surface and diffused into the fiber. Finally, this stage is affected mainly by the chemical potential factors of the molecule when it is in solution and in the hair. The most common products for hair cleaning are shampoos, usually composed of anionic surfactants. Cationic surfactants are widely used as conditioning agents because they neutralize the negative surface charges of the hair, promoting a reduction of coulombic repulsion between the cuticles [2]. When applied to hair after shampooing, it provides shine, removes knots and decreases friction between the wicks during combing.

Theobroma grandiflorum, better known as cupuacu, is a native fruit from the Amazon Rainforest with a brown hard shell, containing a fleshy white and many lipids [4]. Cupuacu butter has a high water absorption capacity, approximately 240% higher than lanolin, acting as a vegetable substitute. It contains phytosterols (especially beta-sitosterol) that act at the cellular level regulating the water balance and lipid activity of the superficial layer of the skin [5]. The oil of Mauritia flexuosa (buriti) is extracted from the fruit pulp and has a rich composition of unsaturated fatty acids (palmitic and oleic acid) and a high content of carotenoids. Buriti oil increases elasticity and decreases dryness of skin exposed to solar radiation, aids in regeneration of lipids and increases the sun protection factor (SPF), thus being indicated for dyed and damaged hair, as it helps to strengthen them [6,7].

Significant efforts have been employed in the development of technologies for sustained release systems. Micelles, liposomes, polymeric micro- and nanoparticles, and solid lipid nanoparticles (SLN) have been extensively studied for this system, which can generally be used to maintain the effect of the active on the target tissue, solubilize actives, improve physical stability and chemical therapeutic agents, minimize side effects and reduce toxicity [8]. SLN can be easily produced on a large scale, have good storage capacity - exhibit stability for up to 3 years, low toxicity and useful in parenteral, oral, ophthalmic and topical applications [9]. Nanostructured lipid carriers (NLC) have been developed with the aim of improving the encapsulation efficiency and minimizing the expulsion of the active from the particles during storage [10,11].

Previously a theosphere formed by cupuacu butter, Lipoid S45 and Pluronic F68 in the presence of diazolidinyl urea and water by high pressure homogenization was shown as an alternative and promising composition for nanoparticle formulation, but no specific application was discussed [12]. Also, β-carotene-loaded lipid nanoparticles of cupuacu were prepared by a phase inversion temperature technique, and they exhibited an ability to protect encapsulated sensitive bioactive [13].

Some reports on nanostructured lipid carriers using cupuacu/lanolin and buriti were previously registered by our group as patents but not as a paper [14-17].

In this case, we are reporting the use of nanostructured lipid carriers with cupuacu and buriti oil as a cosmetic product for hair protection.

2. Materials and Methods

2.1. Preparation of Nanostructured Lipid Carriers (NLC)

In the preparation of the NLC by homogenization at high pressure, two types of solid lipids were used: cupuacu butter (mp 28.4-29.7°C - INOVAM BRASIL) and lanolin (mp 30-33.7°C - CRODA BRASIL) and liquid lipid: buriti oil (flash point> 93.3°C; bp> 200°C-INOVAM BRAZIL). The solid lipids were heated 10°C above their melting temperature, then the liquid lipid was added. This blend was added to an aqueous solution containing Pluronic F68 stabilizer (Aldrich) at the same temperature of the melted lipids, under 10,000 rpm stirring on Ultra-Turrax forming a pre-emulsion. This pre-emulsion was homogenized at high pressure (600 bar in the first stage and 60 bar in the second
pressure stage) for up to 4 cycles. After homogenization, the emulsion was cooled in an ice bath to the temperature of 15°C, obtaining the nanostructured lipid carriers [15].

2.2. Cytotoxicity
The HaCaT human keratinocyte cell line, kindly provided by Dr. Liudmila Kodach (Academic Medical Center, Amsterdam University), were maintained in Dulbecco’s modified Eagle’s medium (DMEM) supplemented with 100 U/mL penicillin, 100 g/mL streptomycin and 10% fetal bovine serum. Cells were grown in a monolayer at 37°C in a humidified atmosphere containing 5% CO₂. Cells (7 × 10⁴ HaCaT cells/mL) were seeded in 96-well plates and incubated for 24 h, when they formed half confluent monolayers. The cells were washed twice with phosphate buffered saline (PBS), and treated with different particle dispersion concentrations for 1 h. Cell viability was then determined by the neutral red uptake (NRU) as described by Borenfreund and Puerner [18]

2.3. Measurement of Lipid Melting Point
The melt temperature range for the pure lipids and for the mixtures was measured on a Melt Point Dry Melt point automatic apparatus for melting point determination.

2.4. Average size, distribution of particle size and zeta potential
The mean diameter of the nanoparticles was determined by the dynamic light scattering technique (DLS) using the ZetaSizer Malvern apparatus.

2.5. Differential Scanning Calorimetry (DSC)
Calorimetry thermograms were obtained by a DSC-Q10 Differential Scanning Calorimeter (TA instruments) using a standard sealed aluminum sample port under nitrogen at a flow of 50 mL min⁻¹, in the temperature range of 5 to 55°C and heating rate of 5°C min⁻¹. The samples were previously lyophilized.

2.6. Preparation of the Conditioner Base with and without NLC
The base of the conditioner prepared without NLC has a composition of 3.5% keto-stearyl alcohol; 4% cetyl trimethyl ammonium chloride (25%); 1% cocamidopropyl betaine; 0.5% mineral oil; 0.15% methylparaben; 0.05% propylparaben and 100% water (qsp). The procedure was the same as reported earlier [15].

2.7. Cleaning the hair wicks and applying the conditioner with and without nanoparticles
The hair wicks were cleaned with distilled water for 1 min. Then, they were washed with a aqueous solution of Sodium Lauryl Sulphate (27%) in 1:10 ratio and rinsed again with distilled water and dried. Wicks that only passed through this step were named Control. Another proportion of the wicks had the conditioner without NLC applied and were left to act for 2 min, then were rinsed with water at 20°C and dried to controlled environment at 25°C. Another population of wicks was treated with NLC-containing conditioner, resting for 2 minutes and then washed and dried.

2.8. Frizz’s experiment
The treated and untreated 0.5 g weight wicks were placed under a millimeter A3 paper in a hood with a temperature of 27°C and humidity of 55% were photographed by a Fujifilm Finepix T camera with 1.0 mm zoom with flash, in a period of 30 min for 6 h.

2.9. Diffuse reflectance measurements to change the color of the wires
The wicks treated with 2.7% lauryl solution (Control) and those treated with conditioner with and without nanoparticles were analyzed in a GretagMacbeth Color-eye 2180UV diffuse reflectance spectrometer. Each wick was analyzed one at time, making 20 readings of each wick, where the first
10 readings were made in the region closest to the tips of the wick and the last 10 in the region near the root of the hair strand.

**Scanning Electron Microscopy (SEM)**

Hair wicks with and without treatment with NLC were characterized as morphology by Scanning Electron Microscopy (SEM). The test was performed on a Jeol scanning electron microscope (JSM-6360LV), using an acceleration voltage of 20 kV.

**2.10. Cryo-Microscopy Analysis (TEM analysis)**

Cryo-Microscopy Analysis of NLC solution were made by transmission electron microscope JEM-2100 model (JEOL, Japan), LaB6, 200KV; the microscope is equipped with an F-416 camera (TVIPS, Germany) 16 MPixel to digital image acquisition.

The EMMenu software, 4.0.9.51 version (TVIPS, Germany) was used to obtain the image acquisition. The images were not subjected to post-processing procedures and the measurements of particle size were done using Digital MicrographTM software, 1.71.38 version (Gatan Inc., USA). The samples were analyzed after the preparation of NLC solution. The sample was diluted in deionized water to 1% and applied in microscopy grids to analysis.

3. Results and Discussion

**3.1. Determination of the melting temperature (Tm) of the solid lipids**

Initially, the melting point range of each one of the pure lipids was determined at different proportions of cupuaçu butter and lanolin. The data obtained showed that the higher melting temperature obtained for the cupuaçu-lanolin mixture was 70:30 (26.9±3.1°C) and the lowest Tm was 50:50 ratio (24.0–26.4°C). This combination with a higher melting temperature which is more suitable for the production of a NLC since it guarantees the integrity of the nanoparticles during their application. Lanolin was chosen because of its wide application in the area of cosmetics and its low cost. In this way, the continuity of this research was carried out using the ratio 70:30.

**3.2. Preparation of Nanostructured Lipid Carriers (NLC)**

The preparation of NLC was performed by the hot high pressure homogenization method. The NLC were prepared with the solid lipids: cupuaçu butter and lanolin in the ratio of 70:30, respectively. For the optimization of the method, some parameters were evaluated, such as the amount of solid lipids and the number of cycles that the mixture undergoes through the homogenizer (Table 1 and Table 2).

| Stability Time (range of days) | 2.1 g cupuaçu 0.9 g lanolin (3 g SL) | 4.2 g cupuaçu, 1.8 g lanolin (6 g SL) |
|------------------------------|--------------------------------------|--------------------------------------|
|                              | 1<sup>st</sup> cycle | 3<sup>rd</sup> cycle | 1<sup>st</sup> cycle | 3<sup>rd</sup> cycle |
| 7-30 / 62-75 PDI | -42.5 ± 1.9 / | -36.5 ± 3.0 / | -44.9 ± 0.9 / | -47.7 ± 4.9 / |
|                      | -42.2 ± 0.0 | -37.0 ± 0.5 | -42.4 ± 4.7 | -38.5 ± 0.9 |
| Mean size of NLC (nm)   | 180 – 200 | 170 – 175 | 185 – 190 | 178 - 180 |

Table 1. Stability through measurements of the zeta potential, PDI and average diameter through time for the 3 cycles of NLC prepared with different cupuaçu and lanolin mass (solid lipids) at 600 bar.
The pressure that the sample receives inside the homogenizer (200-600 bar) and the percentage of liquid lipid used in the composition of NLC (1 - 40%) was also evaluated [15]. The PDI indicates a population of particles of more homogeneous size. Due to lower PDI, we chose to use 600 bar of pressure and 3 cycles of homogenization as standard conditions. Eventually, a low number of cycles made the cost of production smaller. Particle stability through diameter (nm), zeta potential (mV) and PDI with 2-40% liquid lipid, 6 grams solid lipid (4.2 g cupuaçu and 1.8 g lanolin) prepared at 600 bar pressure after 3 cycles of homogenization were used in the application in hair.

Table 2. Measurements of the zeta potential, PDI and average diameter through time for the 3 cycles of NLC prepared with 6 g of solid lipid (4.2 of cupuaçu butter and 1.8 g of lanolin), 1% liquid lipid (LL) (buriti oil) at different pressures (bar).

| Stability Time (range of days) | 200 bar | 400 bar | 600 bar |
|-------------------------------|---------|---------|---------|
|                               | 1st cycle | 3rd cycle | 1st cycle | 3rd cycle | 1st cycle | 3rd cycle |
| 0 / 7-15                      | -57.2 / | -49.4 / | -54.9 / | -42.8 / | -41.6 / | -33.9 / |
| PDI                           | 0.40 - 0.42 | 0.35 - 0.40 | 0.20 - 0.27 | 0.18 - 0.24 | 0.18 - 0.23 | 0.15 - 0.18 |
| Mean size of NLC (nm)         | 260 - 275 | 235 - 245 | 180 - 200 | 175 - 190 | 185 - 195 | 180 - 185 |

3.3. Cryo-Microscopy Analysis (TEM analysis)

The Cryo-Microscopy Analysis (TEM analysis) of NLC solution are show in Figure 1.

![Figure 1. Images of hair NLC solution by electron cryo-transmission electron microscopy (TEM).](image)

The images obtained by electron cryo-transmission electron microscopy (TEM) shows that NLC solution presents circular projection structures with dimensions between 15 nm to 140 nm, without signs of aggregation between these structures. This analysis showed good distribution of the samples on the grid. This analysis by TEM showed that NLC solution presents low diameter of particles and the dispersity between them in the environment of solution.

3.4. Cytotoxicity

In the case of NLC the IC50 value could not be calculated due to the fact that the test samples did not show any cytotoxicity up to the highest test concentrations in HaCaT cells. This result shows that...
NLC can be used in cosmetic formulations without toxic effects on HaCaT human keratinocyte cell lines.

3.5. Thermal analysis of samples by Differential Scanning Calorimetry (DSC).

The DSC heating charts for the pure lipid cupuaçu, lanolin and the solid lipid formulation without liquid lipid were measured. The thermogram of pure cupuaçu presented three melting events. The peak temperature of these events was observed at 18°C, 32° and 37°C. It’s well known that cupuaçu butter has different polymorphic forms, which are responsible for the observed endothermic peaks on DSC. The polymorphism characterizes the material, showed it physical properties related to the conformational arrangement of the triglyceride chains [19]. Lanolin thermograms shown two melting events around temperatures of 27°C and 44°C. It’s interesting to note that both endothermic peaks are neither well defined nor symmetric. This behavior could be due to lanolin composed of a mix of triglycerides, and it’s known that a narrow peak in DSC means a uniform and crystalline sample.

The melting temperature (Tm) values when analyzed NLC produced at 600 bar and 3 cycles of homogenization, showed that when the concentration of buriti oil is increased the melting temperature tends to diminish significantly from 2% (36.3°C) to 10% (31.9°C) and up to 40% (31.3°C). This behavior may be associated with polymorphic modifications, since the molecular packing can change physical properties such as enthalpies or the melting point, the presence of the liquid lipid creates a more complex structure of glyceride chains [20].

3.6. Measures of frizz.

Wicks washed with 2.7% aqueous lauryl solution (Control), treated with conditioner without NLC and treated with NLC-containing conditioner underwent frizz evaluation, which is a measure of how much a wick expands during the drying process. This expansion occurs by the poor hydration of the hair strands and consequent repulsion between them. A more homogeneous hair without hair strands out of alignment compared to the rest of the strands has an esthetically more beautiful appearance. Figure 2 shows the monitoring of frizz over 5.5 hours, in 30 minutes frames following the described methodology [21].

![Graphs of frizz variation along 3 points of the wick](image)

Figure 2. Graphs of frizz variation along 3 points of the wick: (A) Measured closest to the top of the wick; (B) Measured 15 mm below the top of the wick; (C) Measured 40 mm to the top of the wick; where the control, base conditioner and NLC-containing conditioner are represented by: squares (□), circles (●) and triangles (▲), respectively (each point were measured three times with an average deviation of less of 1.5%).
Comparing the graphs in Figure 2 it’s possible to see the same behavior for the three points. The wicks just washed with the 2.7% lauryl solution, represented in Figure 3(A), presented a great misalignment in relation to each other during the entire study period. This happens even in the washing stage, which is due to the repulsion caused by the strands. After being treated with lauryl solution (which has negative charge), the hair becomes negatively charged causing repulsion between the wires. This misalignment justifies the higher values for the control presented in the graphs of Figure 2. The other samples showed a similar expansion behavior after one hour of experiment. This happens due to the drying process of the wicks. However, the wicks treated with the NLC-containing conditioner maintained this alignment constant during the further hours, when comparing with the control or with the conditioner without NLC. Furthermore, the wicks treated with the conditioners presented a lower thickness than the control, due to the neutralization of the charges in the surface of the wicks, revealing that these conditioner formulations have good potential in the treatment of frizz. Nevertheless, it’s possible to observe that the NLC-containing conditioner (Figure 2(C)) presented the lowest thickness during all the experiment, which indicates an improvement in the efficiency compared to the conditioner without NLC (Figure 2(B)) for the frizz treatment.

The justifications for the graphical quantitative analysis of the frizz in the samples can be well visualized in the photographs presented in Figure 3.

### 3.7. Scanning Electron Microscopy (SEM)

The SEM analysis of all wick samples are shown in Figure 4.

The images of untreated wicks (Figure 4A) showed that the strands presented a deep damage in the structure, observed by the position of the cuticles, quite open and in a brittle state. This can be the result of chemical treatments on the hair, such as hair dye and progressive brush, as well as external aggressions such as brushing, friction in washing and other factors. The hair strands also have spots and small particles, which can be identified as residues of products used for daily treatment of the hair, such as shampoos and conditioners containing silicone, as well as dust, among other particles in the environment that can settle on the hair strands.

Figure 4. Images of hair strands untreated (A), treated with conditioner without NLC (B), with conditioner containing NLC (C), and washed with solution of lauryl 2.7% (D), respectively.
The microscopy images for the hair treated with conditioner without NLC (Figure 4B) showed a deposition of residues on the outside of the fiber and, in addition, it can be observed in this image that the cuticles are open. The images of the hair strands treated with NLC-containing conditioner (Figure 4C) have a regular and clean surface, delimiting that the hair strands have been properly recovered and their cuticles are sealed and well bonded. This condition can be explained by the fact that the nanoparticle-containing conditioner is well absorbed by the hair strands, making the cuticles cohesive and leaving the surface of the thread more regular and homogeneous. These results reveal the important role of the lipid nanoparticles in the restructuring and maintenance of a capillary wicks because more closed cuticles resist better to external aggressions and keep the surface of the hair wicks more compact and homogeneous, increase the reflection of the light and improve the brightness of the wicks.

For wicks treated with conditioner, without NLC, and washed with aqueous solution of lauryl 2.7% (Figure 4D), it is noted that the cosmetic formulation has deposited in the external gaps of the cuticles. These deposits of materials that resemble bubbles may be due to the detergent used for the cleaning of hair wicks, also verifying that the cuticles have certain openings not verified in the case of treatment with a nanoparticle conditioner.

3.8. Measurements of the Hair Wicks Color Parameter.

Color measurements of materials were made by diffuse reflectance spectrometry based on the methodology of Nogueira et al [22]. The instrument measures the reflected wavelengths by storing them at points on a spectral curve, which are processed as numerical data and map the color within a color space allocated in the spectrum visible to the human eye. In the CIELAB color system, the parameter a* is called the coordinate between red and green, and if the values are positive the color approaches red and if they are negative it approaches the green. The parameter b* is the yellow-blue coordinate, with values of b* positives approaching yellow and negatives approaching blue. L* represents the brightness of the object, ranging from L* = 0 (black) to L* = 100 (white). Since DL* is the difference of luminosity and DE* the parameter of total color difference, measures with DE* ≤1 value are considered inherent changes in the wick itself. Figure 5 shows the total color measurements for the control (washed with water and lauryl 2.7%) sample, for the conditioner-treated (base) and nanoparticle-containing conditioner (NLC) treated strands.

![Figure 5. Measurements for hair strands color for the different samples as a function of the total color difference parameter.](image-url)

From the analysis of the presented data, it was possible to infer that the total color change between the control and the conditioner base treated wicks was not so significant. The variation for the control presents an average of 0.55 in the measurements of its sample. For the sample of conditioner without nanoparticles the average of 0.55 was measured. However, for the wicks treated with a nanoparticle-
containing conditioner the mean was 0.74, showing that the total color variation in this wick was much higher than the other two. In addition to the statistical graph shown for each one of the treatments, it is noted that the variation in the measured values was very high for the lauryl treated wicks which indicates that the surface of the hair strands was irregular and rough, reducing the brightness and the reflection of the light reaching the sample. In the case of the treated wicks with non-nanoparticulated conditioner, there is a decrease in the variation of the measurements in relation to the treated lauryl wicks. Whereas the wicks treated with nanoparticle conditioner present a much smaller variation than the other two samples, concluding that the surface of the whole wicks presented greater homogeneity and regularity of the reflected light, increasing the brightness of the hair strands. The fact that the statistical graph for this sample is not contained in the range of variation of the wick treated with base conditioner demonstrates that the improvement caused in the brightness and homogeneity of the reflected light should be due to the contribution caused by the nanoparticles, since it is the difference between the two formulations.

4. Final Conclusion

A formulation composed by the solid lipids: cupuaçu and lanolin and a liquid lipid: buriti oil was developed and characterized. The combination of cupuaçu with lanolin and liquid lipid components presented a good interaction, noted by the melting temperature range (26.9 - 31.4°C) achieved with the proportion of 70% cupuaçu and 30% lanolin. The nanostructured lipid carriers produced had diameters smaller than 200 nm and this observation was appointed using the TEM analysis. The interaction between the structures of the solid lipid allowed the increase of the amount of liquid lipid without damaging the particle size. In addition, no changes were observed in the polydispersity index, indicating that there is one major population of nanoparticles with low polydispersity.

The images obtained by electron cryo-transmission electron microscopy (TEM) showed an NLC solution with nanoparticles with circular projection structures with dimensions between 15 nm to 140 nm, without signs of aggregation between these structures.

The study showed that at a pressure of 600 bar there are no large variations in the values of average diameter, polydispersity index and zeta potential of the nanoparticles after the third homogenization cycle. Thus, this pressure value was used for the entire period of execution of this study. With fewer cycles of homogenization in the process there was a decrease in the cost of production of the nanoparticles, making it more accessible. The final formulation of NLC did not show any cytotoxicity to HaCaT human keratinocyte cell lines.

In the next stage of execution, the treatment of the wicks with the nanoparticulated product and a conditioning base that did not destabilize the nanoparticles was demonstrated. As such, we were able to avoid their aggregation.

In the structural evaluation of the hair wicks by Scanning Electron Microscopy (SEM), changes were visible in the capillary structure for hair strands treated with intense chemical, such as tincture and progressive brushing, leaving the capillaries open and without cohesion. However, in the treatment with conditioner base without nanoparticles it was observed the presence of residues of viscous aspect and punctual ones, due to the presence of the conditioner in the hair wicks. The nanoparticle-treated conditioner samples sealed the cuticles and gave the hair a more uniform appearance and brightness to the naked eye.

The variations in the color pattern of the hair wicks treated with the conditioner without NLC showed no difference in the variation of the luminosity parameter in relation to the lauryl treated wicks, since the variations of the two treated samples were inserted within this range. However, when compared to the samples treated with a NLC-containing conditioner, there was a higher brightness parameter than that assigned to the control and conditioner base samples, quantitatively reiterating the brightness aspect of nanoparticle treated wicks.
The frizz of the samples had a 2.5-fold increase in opening for samples treated with conditioner, while the wicks treated with NLC conditioner presented an opening of 2.0 times. The hair strands treated with lauryl 2.7% did not have a great increase in the area of hair wicks opening, but the hair was dry and rough to the touch and with great disorder of the yarns. This fact given by the repulsion of negative charges of the strands after the treatment with this detergent.

This study as a whole was based on the development of a nanostructured lipid carrier with the intention of treating and restoring the damaged hair wicks by chemical treatments and daily aggressions, obtaining at the end of this study a formulation with low cost production, easy industrial scaling up, absent of heavy residues or difficult to degrade in the environment, such as silicone, otherwise using native and abundant products of the Brazilian Amazon forest and Cerrado flora, such as cupuaçu and buriti in the production of a cosmetic formulation.

5. Acknowledgement

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6. Disclosure Statement

The authors declare no conflicts of interest.

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