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Novel sustainable plastic-free cosmetic packaging and product

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Abstract

Background*: The appearance of plastics has represented a great advancement, as packaging systems, due to their unlimited tuning capacity to achieve the desired properties. In fact, the cosmetics industry generates 120 billion units of plastic packaging each year. However, their use is being restricted due to their difficulty in degrading. In order to prevent this, the aim of this work is to find a solution of the excessive plastic single use packaging systems by developing a water-free cosmetic product and a water-soluble packaging.*

Methods*: an experimental test has been performed, using natural materials such as alginate. Furthermore, the incorporation of active ingredients (ascorbic acid) in three concentrations, 5%, 15% and 20 wt.% were also evaluated. The cosmetic product was freeze-dried to create a water-free structure and the primary packaging was left drying on a Teflon mold.*

Results*: We showed that ascorbic acid can be freeze-dried in high concentrations, as 20 wt.%, and creates a sponge. The addition of alginate creates a more robust sponge. The sponge is stable for months without oxidating. The drying process of the packaging created a flexible film which could acquire any desired film and it could be perfectly sealed with natural polymers. Both structures, the sponge and the film, could be instantly dissolved with water and could be used as a cosmetic.*

Conclusion*: The present work developed a plastic-free cosmetic and packaging, providing an alternative to plastic use. Moreover, this cosmetic can incorporate active ingredients in high concentrations that can be stable for months.*

Keywords: sustainable; packaging; biodegradable; plastic-free; ascorbic acid; vitamin C.

Introduction.

The appearance of polymeric materials has represented a great advancement in the scientific community due to their unlimited tuning capacity to achieve the desired properties. These polymeric materials have generally been used as packaging systems, either as primary or secondary packaging. Several properties have been tackled in order to have depute mechanical properties, texture or colors. Nevertheless, their ability to degrade after its use or even to reuse the packaging for another purpose has never been thought of.

More than 10 million tons of plastic end up in our oceans every year [1]. Among these, the skin care (cosmetics) industry generates 120 billion units of plastic packaging [2]. From these, 95% of these containers are single-use and only 14% is recycled [3]. If we continue at this rate, the World Economic Forum considers that there will be more plastic than fish in the ocean in the year 2050. Therefore, it is essential to reduce the use of plastics in the cosmetics sector and to promote a more sustainable ecosystem.

The aim of this work is to develop a novel cosmetic product that contains no water in order to allow an external primary packing that can be water-soluble. The overall aim is to find a solution of the excessive plastic single use packaging systems and to even allow a subsequent use of the packaging system. In this way, it will be contributing to various United Nations Sustainable Development Goals (SDGs) such as guaranteeing sustainable cities and communities, responsible consumption and production and life below water [4].

Materials and Methods.

Product:

In order to produce the designed materials, alginate-based systems were used. Briefly, alginate was dissolved in water at two concentrations of 1.5 and 3 wt.%. Once the solution was fully dissolved, it was casted in a plastic mold. The solutions were frozen overnight at -20ºC. Frozen solutions were afterwards placed in a freeze-drier for 48 hours, obtaining a sponge-like cosmetic. The initial alginate solution would be mixed with several bioactive molecules to induce positive effects on the skin, such as ascorbic acid (AA). We have evaluated the use of AA in 3 different concentrations: 5 wt%, 15 wt% and 20 wt%.

The oxidation process was evaluated visually by the change of color of the sponges. Sponges are white, however, when oxidation occurs, they change to a more yellow-brownish color. In order to perform this test, sponges were kept at room temperature, in an opaque container so light could not enter.

Packaging:

In order to prepare the blister or first packaging, the same alginate solution was used. For this purpose, the solution was diluted to 1, 2 and 3 wt%. and placed on a Teflon mold. The solution was left overnight inside the turbulent flux to allow obtaining a thin film. The main idea is to obtain a film with the appropriate elastic properties to prevent its rupture and also with a high solubility in water, in order to be able to degrade easily.

Once the film was obtained, the freeze-dried sample previously obtained was placed in contact with the film, allowing wrapping up the sample with the film. The film incorporating the freeze-dried samples was sealed with an alginate solution and left overnight for drying. The newly developed samples and degradable blister was applied on the skin after hydrant the skin.

***Results*.**

Product:

Initially, a sponge-like formulation of 5%, 15% and 20% of AA was prepared in order to prove that it could be freeze-dried without altering its appearance. AA sponges were able to be frozen and freeze-dried correctly. While freezing the AA formulation somehow expands, taking up more volume than in the liquid state. When freeze-drying, the different crystals somehow interlock to obtain a sponge-like structure (Figure 1). However, these sponges are fragile and are difficult to manipulate.

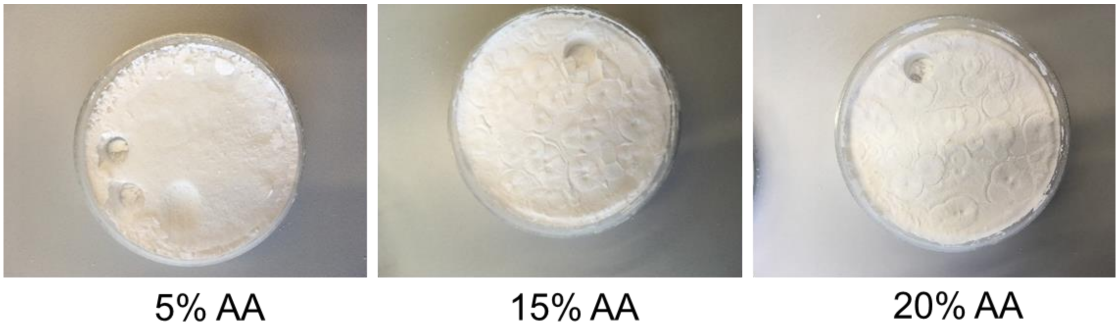

Figure 1. Sponges obtained with different concentrations of ascorbic acid.

Once we had validated that ascorbic acid could be freeze-dried at high concentrations such as 20%, we then introduced alginate in order to create a more robust sponge. Initially, we analyzed 1.5% and 3% wt of alginate and both concentrations created sponges. As expected, the sponge with higher concentration of alginate (3%) had a more robust structure (Figure 2).

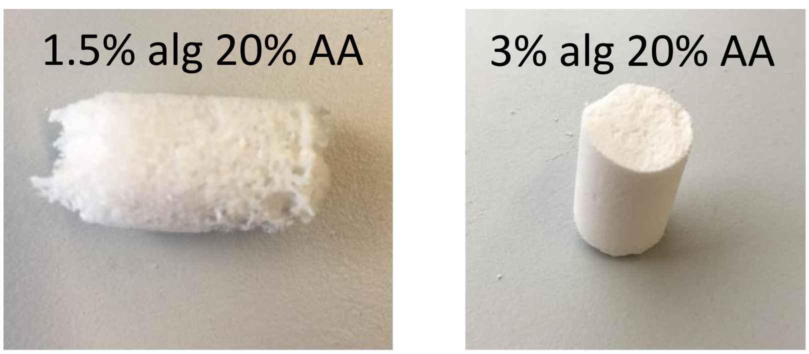

Figure 2. Sponges obtained with different concentrations (1.5% and 3%) of alginate and 20% of ascorbic acid.

Our next step was to visually observe the oxidation of AA for 3 months. Figure 3 shows how the sponges were able to maintain their white color for months, indicating that oxidation was not occurring.

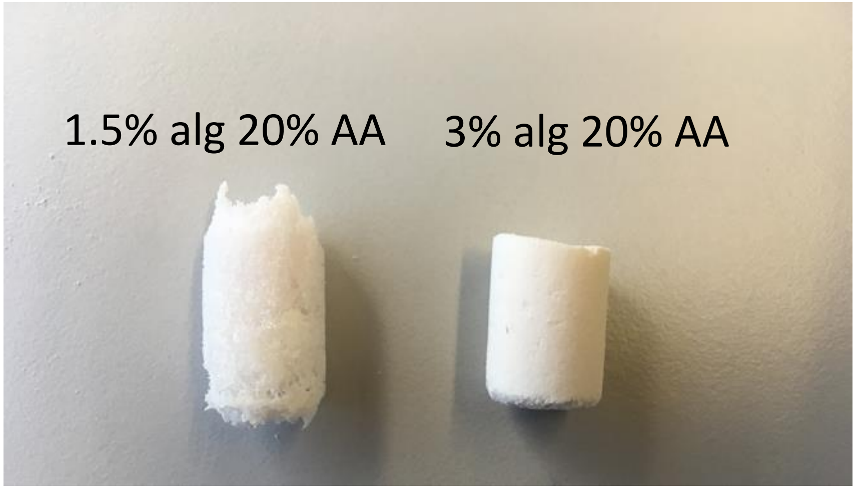

Figure 3. Oxidation evaluation of sponges with 20% ascorbic acid and different concentrations (1.5% and 3%) of alginate.

<u>Packaging:</u>

We then developed a film that could act as a primary packaging for the previous explained sponge. Initially, we tried three different concentrations of alginate (1%, 2% and 3%) in order to determine the ideal one that could give the best properties as elasticity. Apparently, all the concentrations were able to create a thin transparent film (Figure 4).

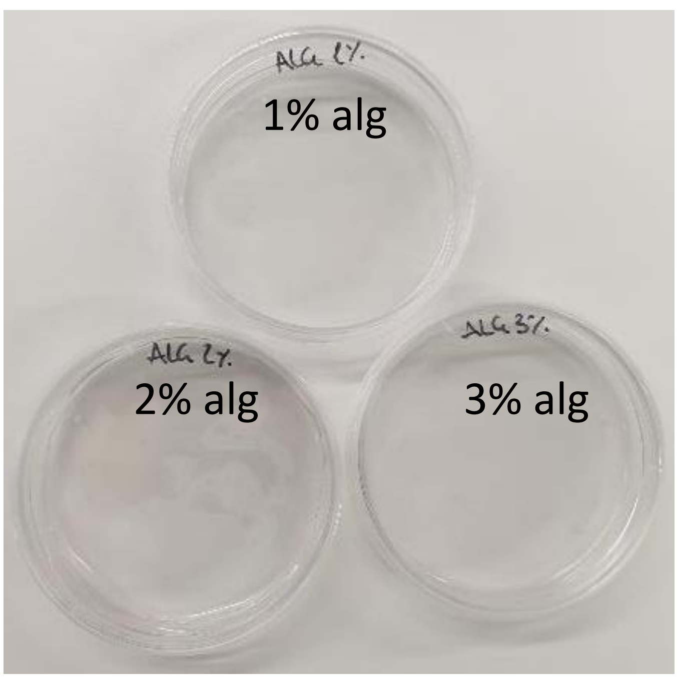

Figure 4. Films as a primary packaging of different concentrations of alginate (1%, 2% and 3 wt%).

We then evaluated different characteristics of the films (Table 1). In general, lower concentrations 1% and 2% behave very similarly in many aspects such as the elasticity, the fabrication process, the isolation from the mold and the distortion. As expected, the viscosity increases as the concentration is higher.

Table 1. Properties of the films of different concentrations of alginate (1%, 2% and 3wt%).

	Alginate 1%	Alginate 2%	Alginate 3%
Viscosity	liquid	medium	dense
Color	transparent	transparent	transparent
Elasticity	good	good	low
Fabrication process	easy	easy	medium
Isolation from the mold	medium	medium	hard
Distortion	high	high	high

Finally, the optimal AA sponge was kept inside the optimal film, sealed with natural polymers (Figure 5). The flexible film was able to conform into the desired shape.

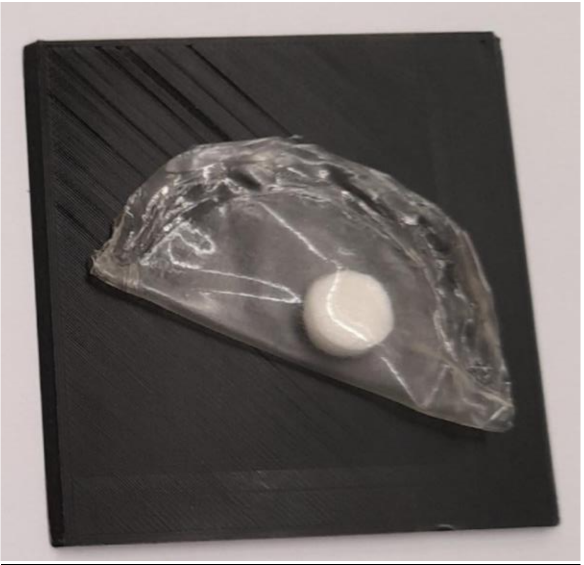

Figure 5. Product (sponge) and primary packaging (film) together.

<u>Sponge on the skin</u>:

In order to use the newly developed material as a cosmetic, the blister was removed allowing the use of the sponge-like material. In order to use the product, the skin was humidified and the product was rubbed against the skin, allowing its instant dissolution. The removed primary packaging was as well applied on the skin, allowing complete dissolution of the primary packaging. Overall, both materials were completely dissolved, not leaving any residue.

Discussion.

Sponge-like cosmetic:

As shown in the figure 6, AA is initially dissolved in water, to later freeze the solution at -20ºC. By lowering the temperature and freezing the sample, we avoid oxidation processes, since the molecules and oxygen lose their vibrational states and therefore are deactivated to produce oxidation reactions. The interesting thing is that during the freezing process AA forms crystals that increase the volume of the sample. Finally, by removing the water through lyophilization, the crosslinking of the crystals allows a sponge structure to be maintained. This process of controlled crystallization has been previously described by other authors [5]. Our results show that high concentrations of AA, such as 20%, could be incorporated and freeze-dried correctly (Figure 1). It was expected that ascorbic acid could freeze-dried as it was previously stated that vitamins and drugs could be successfully freeze-dried if they were previously frozen between -4ºC and -20ºC [6]. However, when it only contains AA, its cohesion is low and its handling is also low. For this reason, we have used alginate in order to enhance the cohesion between the crystals. Alginate is an ideal candidate as it has been already used in cosmetics, biotechnological and medical applications due to its physical and biocompatible properties [7,8]. In consequence, the sponges using higher concentrations of alginate present a more robust appearance and are easier to manipulate than the ones with lower concentrations of alginate (Figure 2).

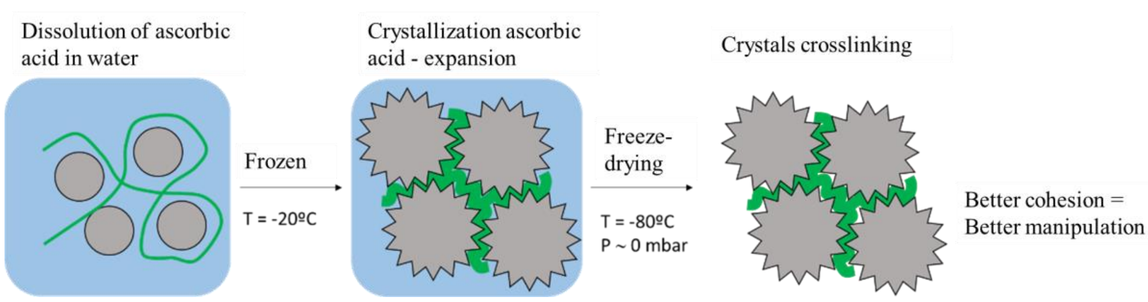

Figure 6. Possible mechanism of formation of ascorbic acid sponges.

Regarding the oxidation process, we demonstrated that AA sponges were stable (without oxidation) for over months. This can be explained by the method of obtention of the sponges, the freeze-drying. Freeze-drying is a process in which the pressure and temperature are reduced in such a way that the water contained in a solid is capable of passing from a solid to a gaseous state without having to go through the liquid state. What this allows is to maintain the structure of the solid without deforming while the water is eliminated [9]. What is obtained is a macroporous structure which is constituted by, in the case of solutions of proteins and similar molecules, fibers of these molecules. Depending on the temperature at which it is frozen, the morphology of the pores and their sizes can vary, ranging from aligned pores to spherical pores with different sizes [10]. The overall idea was to develop a sponge that contains ascorbic acid (AA) or any molecule and that could be released once in contact with an aqueous medium. It should be noted that once the sponge was fully freeze-dried and was stored correctly, the AA did not oxidize visually (Figure 3). This is in consistence with other researchers which described that freeze-drying prevents enzymatic browning and evaluated that this method presents more maintenance of bioactive compounds in comparable with the thermal methods [11,12].

Packaging:

The three concentrations evaluated (alginate 1%, 2% and 3%) can be possible candidates for the elaboration of the film (Figure 4). Due to its viscosity and different properties, 2% alginate could be the best one (Table 1). However, other additives should be incorporated in order to obtain a more resistant film. The combination of the film and the sponge were completely sealed with alginate and/or sodium chloride (Figure 5). This combination and sealing method should be easy to scale-up to an industrial transformation.

The present work aimed at providing alternative solutions to plastic use in the cosmetic field [1,2]. By using polymers from natural origin and by allowing its manipulation under specific manners, were able to produce a water-soluble material that was provided in the absence of water. These allowed the production of waterless product that presented a unique strategy, having the primary packaging as cosmetic itself as well. The reduction of plastic waste is reduced by 100%. Furthermore, the incorporation of active ingredients, such as AA, was shown to be possible in higher concentrations compared to traditional systems in cosmetics. Combined with this higher concentration, the formula presented only very few ingredients in its compositions, avoiding the use of preservative agents in its structure due to the absence of water.

Conclusion.

The current work shows the possibility of reducing the use of single-use plastics that may aim at reducing the overall plastic consumption in the plastic industry which is endangering the survival of several species. This project can have a significant impact on cosmetic field, not only due to the reduction of plastic consumption, but also due to the enhanced efficiency and preservation, the reduction in water consumption during fabrication as well as the reduction in the weight for cosmetic transportation due to the absence of water.

Acknowledgments.

This work has been supported by a grant from the Sociedad Española de Químicos Cosméticos (SEQC).

Conflict of Interest Statement.

NONE

References.

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