Technological Prospection and Development of Smart Film with Phytochemical Actives such *Curcuma longa L.*

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Biodegradable plastics are in evidence regarding packaging, especially for food. Innovative products have their stages better targeted when understanding what has been protected by patents and identifying unexplored trends. This work makes technological prospection and does a film based on PVA added with a dry extract of *Curcuma longa*, evaluating its function as a barrier to light transmission in five concentrations. The results showed that films with different colorings were rigid and slightly malleable. As a barrier to light transmission, the product proved efficient as the concentration of *Curcuma longa L.* increased. The films have been presented as an excellent option for the light barrier; improvements are necessary regarding the solubility of the active in the filmogenic solution.
Keywords: Active Packaging. *Curcuma longa*. Biodegradable Film.

Introduction

Since the most remote time in history, the various species of humans inhabited the earth have lived self-sufficiently and without worrying about storing food [1,2]. When that need arose, nature provided gourds, shells, and leaves. "Later, containers were manufactured with natural materials, such as excavated logs, grasses, and animal organs" [1,2].

With the evolution of society, there was an increasing need to pack food and other goods, whether for storage and conservation or transportation. With the advancement of discoveries with the brilliance of the Industrial Revolution, it began implementing an innovative packaging discovery: plastic [2].

An article of use as diverse as plastic soon followed, applied in almost all branches of society. It led to problems such as the accumulation of plastic waste and its disposal. It is estimated that around 8 billion kilograms of plastic have been produced by 2018 and that the same amount is floating through the oceans yearly. The problems caused by this accumulation are immense, directly affecting marine and human life [3,4].

The demand for increasingly resistant packages (which support even more weight and withstand variables such as temperature and pressure), efficient (which also contribute to the physical and chemical stability of the products they involve) has had a significant increase with the advancement of plastic, a result of population growth and an exponential increase in consumption. Also, over the years and with the recurring problems related to its excessive use, it became necessary to search for alternatives for ecologically correct plastic packaging, understood as bioplastics or biobased plastics, since they are biodegradable, minimizing the problem of disposal [3-5].

Therefore, this work consists of studying current technologies protected by patents on the biodegradable film with antimicrobial and/or antioxidant activity and developing a biodegradable PVA film with *Curcuma longa L.* as an active and evaluation of specular light transmission.

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Active Packaging

For packaging to be considered active, it must present other barriers to protecting and conserving food besides the physical and inert ones to external influences. It must be composed of assets that interact with the person and the environment to provide more safety and durability to food. Thus, it is possible to obtain, for example, plastic films with antimicrobial and/or antioxidant action, plastic sachets with humidity control, and films with temperature-sensitive permeability, among others [6-8].

Several studies are emerging regarding the development of active packaging, the main focus being the production of antimicrobial films, oxygen absorbers, ethylene absorbers, humidity regulators, releasers, and/or absorbers of heat and odors.

The *Curcuma longa L.*

Even in a time of high technology, there is an increasing search for vegetable raw materials (especially essential oils and extracts) or even synthetic ones (polymers with a shorter life cycle and biodegradable, even if they come from petroleum) with low environmental impact. A plant that has long been recognized for its antioxidant and antimicrobial properties and has been incorporated as another option for the production of active packaging is *Curcuma longa L.* [9].Polyvinyl alcohol (PVA) has been an essential polymer for the commercial production of active films because of its excellent characteristics, soluble in water, and biodegradability [10]. *Curcuma longa L.* is a plant belonging to the Zingiberaceae family. They are popularly known as saffron, saffron, Indian saffron, and other nomenclatures, depending on location. It is an herbaceous plant with large and long leaves with rhizomes that can reach 10 cm in length. When cut, they have a reddish-yellow color [9,10].

Curcuma longa L. is a plant native to India and Southeast Asia. It was introduced in Brazil in the 80s. Its use in India dates back to around 4,000 years BC. It was initially used for its nutritional value and later for its various ethnomedicinal properties, including antioxidant, antimicrobial, hypoglycemic, gastroprotective, and anti-inflammatory activity [9-11].

Materials and Methods

Technological Prospection

The database used in this work was collected on September 11, 2021, from the Espacenet platform, the European patent search office, with access to more than 130 million documents. The search was carried out in a space delimited as code C08L, with the following matched terms: packaging, biodegradable, antimicrobial, and antioxidant. From the data collected, it was possible to carry out a quantitative and qualitative analysis, aiming to map generated technologies and possible trends for new technologies involving bioplastics and their uses as packaging.

Materials

Polyvinyl alcohol polymer, also known as PVA (Dinâmica), solvent deionized water (*), and rhizome powder of *Curcuma longa L.* standardized in 95% of curcuminoids obtained commercially with certification were used for the production of the films.

Production of Film

The films were produced using the casting technique of pouring a filmogenic solution into small plates or molds. This technique is best adapted on a laboratory scale for producing plastic films [12].

Five samples were produced with concentrations between the range of 2 and 40 g/L (named A1 to A5) of *Curcuma longa L.*

The filmogenic solutions contain Polyvinyl Alcohol and of solvent deionized water. The polyvinyl alcohol was mixed with the rhizome powder of *Curcuma longa L.* and dissolved in distilled water, under agitation and heating, between 40 and 90 ºC in a Shaker Bath. The filmogenic solution was transferred to Petri dishes, where they dried for 6 days at room temperature.

Specular Light Transmission

The five samples of PVA films with the addition of the active *Curcuma longa L.* were prepared to evaluate specular light transmission and to know their barriers in the range of UV-visible light. Three samples of each film concentration were used. The methodology used was an adaptation of Bucci [13], and the equipment used was a Shimadzu UV-1800 UV-visible spectrophotometer adjusted to a scanning range of 250-750 nm. Readings were recorded at wavelengths 250, 350, 450, 550, 650, and 750 nm, and transmittance results were noted for each.

Results and Discussion

Technological Prospection

Figure 1 explains the number of patents resulting from technological prospecting, comparing their development from 1996 to 2021 and their cumulative result.

After analyzing the data obtained from the Espacenet database, it was possible to identify that works involving antimicrobial, antioxidant, and biodegradable biodegradable packaging, which generated patents, began to appear only in 1996. From 2009 to 2019, there was an increase in the number of deposits.

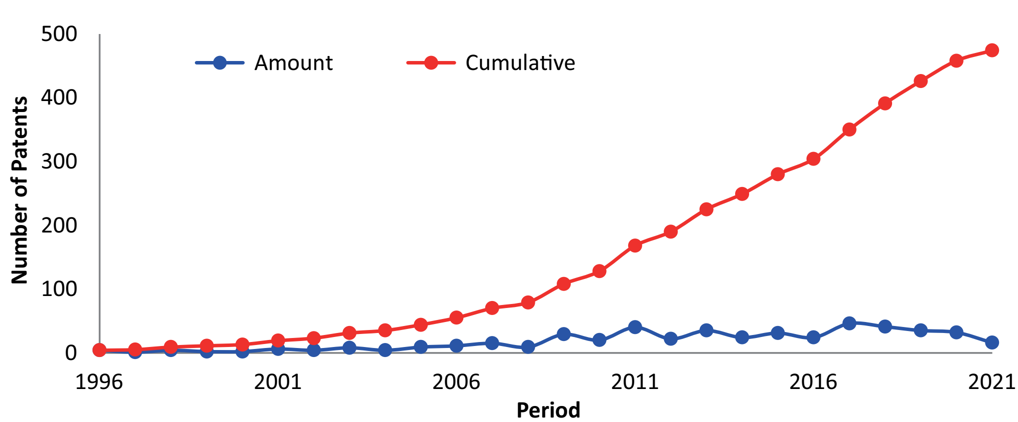
Figure 2 shows the total number of patents filed by country.

The most extensive records of patent deposits are from developed or developing countries that want to expand their technologies, such as the United States and China. Despite being one of the world's largest consumers of plastic and one of the largest generators of plastic waste [14], Brazil held only eight patents out of the 598 available in the database.

The Film of *Curcuma longa L.*

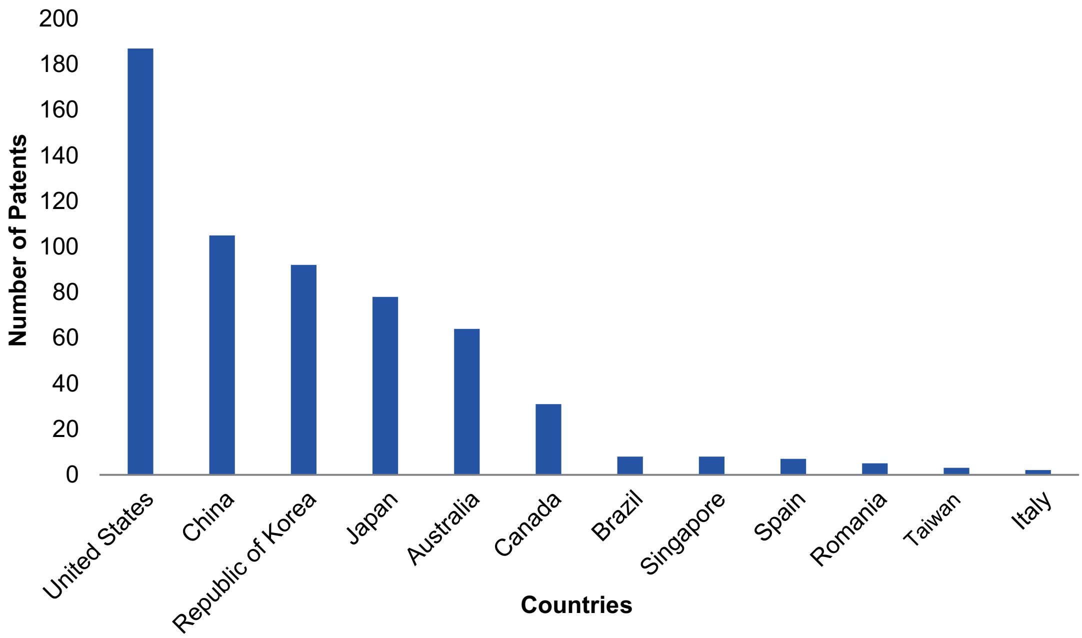
We considered the articcle from Niamsa and Sittiwet [15] to find the best concentration of active [15], was taken into account. The study concludes that the active Minimum Inhibitory Concentration (MIC) would be 4-16 g L^{-1}, while the active Minimum Bactericidal Concentration (MBC) would be 16-32 g L^{-1}. Tests were performed on five samples prepared. The resulting films did not have satisfactory aspects, as the high concentrations of the active did not completely solubilize in the

Figure 1. Ratio number of patents x initial year of application.



Source: Own authorship.

Figure 2. Depositor countries.



Source: Own authorship.

solution, leaving evident small lumps in various parts of the same and even regions where portions of the dry extract of *Curcuma longa*.

Due to the inability of the solvent to solubilize the active, the concentration had to be reduced, hoping to achieve a uniform film with excellent analytical reliability. In this sense, the methodology of [12] was adapted, which understood that when the concentration was reduced by 12,5 times from the MBC, the weight of the filmogenic solution would be adequate. Then, the concentration between the 2 and 40 g/L range (A1 to A5) was defined. Adaptation resulted in more uniform films with good apparent solubility despite still having insoluble microdots (especially at higher concentrations). The images in Figure 3 show the finished films at the five concentrations plus non-solubility points.

The results showed that more studies need to be conducted to find the ideal conditions to prepare the film with this performance using this method. Some studies suggest using surfactants to solubilize *Curcuma longa* and analyze the effective antimicrobial action of this product.

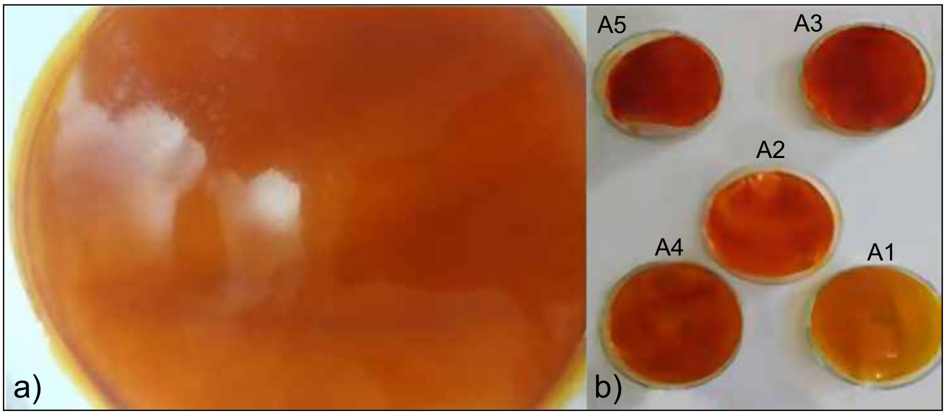
<u>Specular Light Transmission</u>

The results obtained from the light transmission analysis for the five different concentrations of *Curcuma longa L.* change according to the concentration. The readings were taken in triplicate, and an average was taken for each wavelength. From then on, an average of the wavelength averages was made, thus considering only one average per concentration, which was used to plot the graph shown in Figure 4.

Conclusion

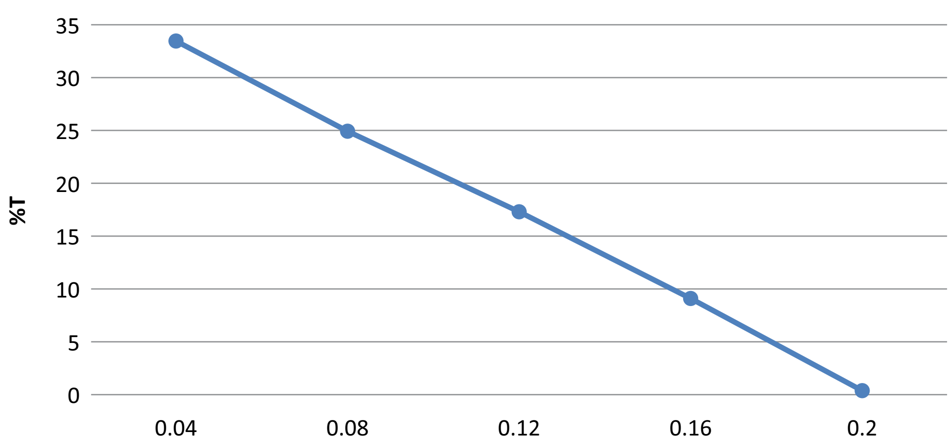
As for prospecting, the data show that from 2009, searches for research related to the development of biofilms with antioxidant, biodegradable, and antimicrobial characteristics took a turn, with their apex of records in 2017. Since then, it has been an active market and ascending. The leading countries in these records are the United States and China. Despite its recognized potential with natural products, Brazil has little expressive numbers in patent deposits,

Figure 3. PVA film (a) uniform appearance.



(a): Obtaining a film based on *Curcuma longa* with a uniform appearance; (b): Obtaining dry films with different concentrations of *Curcuma longa*.

Figure 4. Graphic representation of the 250-750 nm scan of *Curcuma longa L.*



perhaps requiring investment in the area. As for the development of the films, using the casting technique, which is the most used on a laboratory scale, the applied concentrations needed to be improved to reach the total solubilization of the active in deionized water. It suggests decreasing the concentration, changing the solvent, or even opting for prior preparation of a *Curcuma longa L.* solution with a higher affinity solvent. Based on the methodology used and the results obtained through the analysis of specular transmittance, it is possible to understand that the films developed have an excellent light barrier when made at high concentrations, extending their protection in the regions between 350-750nm, covering the ultraviolet and the UV-visible.

Acknowledgments

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