

Self-supported Films of Amburana Cearensis Bipolymer as an Alternative for Biodegradable Packaging

Carla Eiras (✉ carla.eiras.ufpi@gmail.com)

Universidade Federal do Piauí: Universidade Federal do Piauí <https://orcid.org/0000-0001-8861-774X>

Railson Machado Pinto

UFPI: Universidade Federal do Piauí

Juliana Nadielle Barbosa Cunha

UFPI: Universidade Federal do Piauí

José Regilmar Teixeira da Silva

IFPI: Instituto Federal de Educacao Ciencia e Tecnologia do Piaui

Ricardo de Araújo

UFPI: Universidade Federal do Piauí

Hernane da Silva Barud

University of Araraquara: Universidade de Araraquara

Lívio César Cunha Nunes

UFPI: Universidade Federal do Piauí

Research Article

Keywords: Amburana cearensis gum, casting films, biodegradability, food packaging

Posted Date: April 11th, 2022

DOI: <https://doi.org/10.21203/rs.3.rs-1505862/v1>

License:  This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

Self-supported films, prepared from *Amburana cearensis* gum (GAmb), appear as an alternative for the development of biodegradable packaging as a way to minimize the impacts of non-biodegradable residue discarded in the environment. The films were produced using the casting method and the results obtained from the FTIR analysis indicated that the GAmb is mostly constituted by α-L-Arabinofuranose and β-Galactopyranose units. The films, (GAmb/Gly) produced with the addition of glycerol (Gly) at concentrations of 10–30%, presented a variation of 8.4–12.7% in moisture content and from 33–49% for solubility water, respectively. The films also showed amorphous characteristics and a transmittance below 50%, as well as a maximum elastic modulus of 8.51 Mpa. The results also showed that the complete biodegradability of the films occurred after 14 days, corroborating the hypothesis of using GAmb/Gly films as an alternative for biodegradable packaging.

1. Introduction

Natural polymers or biopolymers, as well as polysaccharides, have been used in the development of self-supported films, as they are materials made from renewable sources, have a low production cost and may be biodegradable under different conditions [12].

Polysaccharide films have been an alternative to replace those based on synthetic materials, to reduce the accumulation of non-biodegradable residues discarded in the environment [9]. In 2018, approximately 359 million tons of plastic were produced on a global scale, which has sparked several concerns involving the non-biodegradability of these materials in nature, as well as the negative impact on the terrestrial and aquatic ecosystems [24]. Thus, polysaccharides, such as cellulose [23], chitosan [31] and starch [2], have to come to be studied and applied to the development of films for biodegradable food packaging.

The packaging has different functions, such as protecting the food from the external environment, reducing the interaction of the product with factors that lead to its degradation such as contamination by microorganisms, contact with water vapor, oxygen, or with different compounds that may alter the taste of the food, to extend the shelf life of the product [15].

In other cases, packaging can play the role of a semipermeable barrier [26], reducing product contact with water vapor and oxygen. This function is mainly observed in applications that use biopolymer films on minimally processed products, in the case of ready-made foods such as fruits and vegetables [14], as well as fresh salmon fillets [6]. However, the preparation of self-supported polysaccharide-based films is often limited by the emergence of cracks after the process of drying the films, making them brittle and a little flexible [16]. Thus, a strategy that has been employed to improve the mechanical properties of a film, such as the reduction of its rigidity, has been to add plasticizers [8].

Plasticizers are additives that act by reducing rigidity between the polymer chain molecules, resulting in an increase in the flexibility of the material and consequently of the film [27]. Among the plasticizers

commonly used, we can mention glycerol (Gly), sorbitol, and polyethylene glycol [18], with the latter being the most used in the preparation of films obtained from the evaporation of a solvent present from the film-forming solution, a technique also known as casting, which is done to films with an excellent visual aspect and attractive mechanical properties [4].

The use of new biopolymers, aiming at the formation of self-supported films and the development of biodegradable packaging, has attracted the attention of different research groups around the world [29]. In this sense, the species *Amburana cearensis* (*A. cearensis*) stands out for presenting in its composition substances with antioxidant, antibacterial, antifungal, and anti-inflammatory properties, mainly due to the presence of phenolic and flavonoid compounds in different parts of the species, such as in the methanolic extract of the exudate, stem bark, and seeds [20].

Despite all the described properties, until now, no studies have been found regarding the use of the polysaccharide present in the exudate of the *A. cearensis* species for the development of films and especially casting films. This finding indicates the innovative character of this study, which makes use of biopolymer extracted from the exudate of the *Amburana cearensis* species in the formation of self-supporting films developed by the casting method and the results point to its possible use in the development of biodegradable food packaging.

2. Materials And Methods

2.1. Materials

The *Amburana cearensis* gum (GAmb), isolated from the exudate collected from the trunk of the species *A. cearensis* (SisGen of number A5A1D05), was collected between July and September 2018, in Cocal da Estação - PI, coordinates 33°28'03"S and 28°33'41" W. Furthermore, Glycerol (99.0%, Impex), Sodium Hydroxide (NaOH, Dynamic), Sodium Chloride (NaCl, Synth) and Ethylic Alcohol (98.9%, Dynamic) were commercially obtained.

2.2. Exudate extraction and GAmb isolation process

Initially, cuts were made in the trunk of *A. cearensis*; after the exudation process, the exudate was collected and exposed to the sun for two weeks until it had fully solidified. Subsequently, the dried exudate was stored to be used in the gum isolation process [22].

Then, the solid exudate was macerated and passed through a 75 µm particle size sieve to remove major impurities and reduce particle size. Afterward, 5 g of exudate was added to 100 ml of distilled water and left to stir (at 1000 rpm) for 1h. At the end of this period, the solution with pH 4.2 was neutralized (pH 7.0) by adding 0.05 M Sodium Hydroxide. Subsequently, 1 g of Sodium Chloride was added to facilitate the precipitation of the polymer in the subsequent step. The resulting solution was stirred at 1000 rpm for 1 h. After that time, 300 mL of Ethylic Alcohol was added to it and, after approximately 1 minute of stirring, this was stopped, so that the precipitation process occurred within 20 minutes. After the precipitation

time, the supernatant was removed from the precipitate, leaving only the polymer isolated and the final yield was calculated to be 86%. Finally, the material was dried at 100°C for 3 h, then macerated, passed through a 75 µm sieve, and stored for subsequent films preparation.

2.3. Preparation of self-supported films

The self-supported GAmb films were prepared through the solvent evaporation technique, also called the casting method. The GAmb/Gly films had their glycerol concentration varied by 10%, 15%, 20%, 25%, and 30%, thus being called GAmb/Gly(10), GAmb/Gly(15), and so forth.

For the formation of the GAmb film containing 10% Gly, initially, 0.06 g of glycerol in 30 ml of distilled water was added and the resulting mixture was left under stirring at 900 rpm for 5 minutes. Then, slow addition of 0.6 g of GAmb was made to avoid the formation of agglomerates of the biopolymer during the mixture, which was kept under stirring (900 rpm) for 30 minutes. After that time, the solution was heated to 80°C and, upon reaching this temperature, stirring was continued for another 30 minutes. At the end of 30 minutes, heating was stopped, and stirring continued until the solution cooled to around 50°C. Then the film-forming solution was homogeneously dispersed in a plastic Petri dish (size 90 x 15 mm) and taken to the oven, where it remained for 20 h at 50°C for total solvent evaporation. Subsequently, the plate was removed from the oven and kept at room temperature ($\pm 22^{\circ}\text{C}$ in an air-conditioned room) until its complete cooling, when the film was removed from the plate, which was stored for subsequent characterizations. The other films prepared at concentrations of 15–30% of glycerol followed the same methodology and for comparison purposes, GAmb films were also prepared without the addition of glycerol, that is, 0% Gly.

2.4. Fourier transform infrared spectroscopy (FTIR)

The characterization of the films by FTIR was performed with the aid of a Spectrum 100 (PerkinElmer) spectrometer, using the attenuated total reflectance (ATR) mode, in the range of $4000\text{-}600\text{cm}^{-1}$, with an accumulation of 16 scans, resolution of 4 cm^{-1} and 0.5 cm^{-1} range.

2.5. X-ray diffraction (XRD) analysis

The X-ray diffractograms of the films were obtained using Shimadzu equipment, model XRD-6000, with CuK α radiation ($\lambda = 1.5418\text{\AA}$), tube voltage of 40kV and current of 30mA, with a scanning speed of $2^{\circ}/\text{min}$ and 2θ angle ranging from 5° to 75° .

2.6. Biodegradation study

The biodegradability test of the films was carried out at the Laboratory for Research and Development of New Materials and Sensor Systems (MATSenS) of the Federal University of Piauí – UFPI, and the soil was collected at the Technology Center - CT of UFPI in April 2021, at coordinates $5^{\circ}3'23''\text{S}$ and $42^{\circ}47'59''\text{W}$. Initially, the collected soil was passed through a sieve with a diameter of 55 cm and an internal mesh of 2.8 mm x 4.5 mm to remove larger stones and make the soil more homogeneous, then the soil was stored for the biodegradation tests.

2.6.1. Biodegradation by mass loss

At first, the GAmb films with glycerol were cut in dimensions of 14 mm x 14 mm and the initial mass (W_1) of each sample was determined. Then, they were wrapped in polyester fabric to facilitate the removal of the films after the test. The polyester/sample systems were added, at a depth of 7 cm, in containers containing 200 g of previously collected soil. Subsequently, these containers with soil and the samples were sprinkled with 120 mL of distilled water and kept at room temperature ($\pm 22^\circ\text{C}$ in an acclimatized room). Day after day, the films were removed from the containers, dried in an oven at 105°C until they reached a constant mass and then their final mass (W_2) was determined, totaling 14 days of analysis. Finally, all experiments were done in triplicate. Percent biodegradation (%) was calculated as a function of mass loss using Eq. (1):

$$\text{Biodegradation (\%)} = (W_1 - W_2)/W_1 * 100 \text{ (Eq. 1)}$$

2.6.2. Biodegradation by released CO₂

Samples of the 14mm x 14mm size films were placed at a depth of 7 cm in containers containing 200 g of the previously collected soil. Subsequently, the soil was sprayed with 120 mL of distilled water, and a transparent polypropylene bottle containing 20 mL of 0.1 M Sodium Hydroxide was attached to this system to capture the CO₂ released by the microbial activity of the film in the ground. The containers were hermetically closed and kept at room temperature ($\pm 22^\circ\text{C}$ in an air-conditioned room). The same procedure was performed for a soil sample without the presence of any film, which is called control system or test blank. Day after day, the amount of CO₂ produced by microbial activity in the soil was evaluated, totaling 14 days of analysis.

The quantification of CO₂ was obtained by titration of a 0.1 M NaOH solution with a 0.5 M HCl solution, using barium chloride (BaCl₂) for precipitation of carbonate ions, in addition to phenolphthalein as an indicator solution. Carbon dioxide levels could be calculated and plotted as a function of incubation time [1]. The quantification of CO₂ produced in the containers was generated from the spent volume of 0.5 M HCl in the titration of 0.1 M NaOH; therefore, the amount of CO₂ generated in each container was calculated in mg using Eq. (2):

$$CO_2 = (V_B - V_A) \times 50 \times f_{HCl} \times 0.044 \text{ (Eq. 2)}$$

Where CO₂ = carbon dioxide generated; V_B = volume of 0.5 M HCl spent in the blank titration.; V_A = volume of 0.5 M HCl spent on sample titration; 50 = factor to transform equivalent in μmol of CO₂; f_{HCl} = 0.5 M HCl factor e 0,044 = factor to transform μmol into mg of CO₂.

2.7. Mechanical test

The mechanical tensile properties of the films were obtained in a TA.XT plus texturometer (Stable Micro Systems, United Kingdom), according to the procedures described by the ASTM D882-99 standard. All

tests were performed in triplicate.

2.8. Optical property

The UV-Vis spectra of the films were obtained on a Varian Cary 500 UV-Vis spectrometer in the wavelength range of 200-800nm.

2.9. Thickness

The average thickness of each film was determined using a DIGIMES analog micrometer with a scale from 0 to 1 mm and precision of 0.01 mm, from measurements at fifteen different points in each sample.

2.10. Moisture content

The measurement of moisture content (M_C) was performed for the films with glycerol in samples with dimensions of 20 mm x 20 mm; initially, the initial mass of each film (M_i) was determined, then the films were dried in an oven for 24h at 105°C. Subsequently, the final mass of the films (M_f) was determined and, therefore, the measurements were carried out in triplicate and the average of the values were used in Eq. (3) to determine the moisture content.

$$M_C (\%) = (M_i - M_f)/M_i * 100 \text{ (Eq. 3)}$$

2.11. Water solubility

Initially, the initial mass (M_o) of the films was determined in the dimensions of 20 mm x 20 mm; then, the films were immersed in 30 mL of distilled water and stirred on a stirring table, Orbital SL - 180/D, for a period of 24 h at 180 rpm. After this period, the samples were dried in an oven at 105°C for 24h, and finally, the final mass (M_d) of each sample was determined, as well as the water solubility (S_W) of the films by means of Eq. (4), and again, all measurements were performed in triplicate.

$$S_W (\%) = (M_o - M_d)/M_o * 100 \text{ (Eq. 4)}$$

3. Results And Discussion

3.1. Infrared Spectroscopy

The FTIR analyses of the cast films formed by both GAmB alone and GAmB added glycerol, Fig. 1, allowed the identification of the functional groups present in the biopolymer, as well as to evaluate the effect of increasing the concentration of glycerol in the film.

In Fig. 1, the characteristic vibrational band of hydroxyl groups -O-H was observed at approximately 3400 cm^{-1} , while the band corresponding to the vibrational stretch of -C-H, characteristic of methyl and methylene groups, was observed at 2927 cm^{-1} . Furthermore, the vibrational bands at 1616 cm^{-1} and 1421 cm^{-1} can be attributed to the vibrational stretching of symmetric and asymmetric -C = O groups,

respectively. Therefore, the 1038 cm^{-1} band can be attributed to the vibrational stretch of -C-O-C- of uronic acid [21]. Moreover, the FTIR results of GAmb films indicate that the biopolymer is mainly constituted by α -L-Arabinofuranose and β -Galactopyranose units, Fig. S1 (supplementary material), suggesting that its basic structure is mainly composed of arabinogalactan heteropolysaccharides.

Still in Fig. 1, it is possible to verify that the increase in the concentration of glycerol in the GAmb films promotes an increase in the intensity of the FTIR bands, which indicates that this behavior may have resulted from hydrogen bonds between the -OH groups of the plasticizer and the biopolymer.

3.2. Study of moisture content and water solubility

Figure 2 shows the moisture content and water solubility studies of the GAmb films prepared with glycerol; this study was not performed for the GAmb film without the presence of glycerol due to the fragility of the films. The moisture contents of the films ranged from 8.4%, for the GAmb/Gly(10) film, to 12.7%, for the GAmb/Gly(30) film. Therefore, these values indicated the existence of few water molecules adhered to the molecular chains of the GAmb biopolymer with glycerol, which could guarantee greater durability of the packaged product due to the lower amount of water present in the GAmb films.

The moisture content found for GAmb films makes them promising materials for applications in minimally processed food packaging, such as fruits, fish fillets, and others, as they have lower moisture contents than those reported in the literature for different films based on polysaccharides, as in chitosan, pectin and lemongrass essential oil films, which had a moisture content ranging from 28.78–31.35% [11]. Therefore, films with lower moisture content tend to have lower interactions between the water molecules in the films and the packaged product, resulting in greater efficiency in food preservation.

Different explanations can justify the lower moisture content of GAmb films, one of which can be attributed to the chemical structure of the polysaccharide, where the dense crosslinking between the chains decreased the accessibility of -OH groups by the water molecules [25].

The water solubility values of GAmb/Gly films ranged from 33–49% (Fig. 2); in addition, considering the hydrophilic nature of GAmb, the films were not fully dissolved in water, but partially lost their integrity with time. Water solubility results indicated that GAmb/Gly films have moderate water resistance.

3.3. Film diffractograms

Figure 3 shows the XRD patterns of GAmb and GAmb/Gly films, with the broad peak close to 20° , indicating that the gum has an amorphous characteristic. This amorphous characteristic is also noticed in other gums, such as chitosan and Arabic gum [28]. The films containing glycerol at concentrations of 10–30% showed results similar to those obtained for the GAmb film without glycerol (GAmb); however, an increase in intensity was observed at the 20° peak for the films with plasticizer, confirming the presence of glycerol in the biopolymer. Accordingly, the plasticizer facilitated the development of GAmb-based films without changing the amorphous character of the heteropolysaccharide, even after the addition of higher percentages of glycerol.

3.4. Biodegradability

The biodegradation of GAmb films with glycerol is shown in Fig. 4; thus, GAmb films showed increasing biodegradation over the fourteen days test and higher percentages of glycerol did not influence the biodegradation of GAmb, justified by the similar behavior of the biodegradation curves as a function of mass loss.

Initially, on the first three days, the decomposition process of the films occurred in an accelerated manner for all GAmb films with glycerol; for example, a mass loss of $\approx 24\%$ was observed for the GAmb/Gly(20) film on the first day, while on the second day this value was $\approx 48\%$, and subsequently, on the third day, it was $\approx 59\%$.

After the third day, biodegradation continued to increase, but slowly, as the results showed that the mass loss intervals decreased. On the sixth day, the film had already been $\approx 81\%$ biodegraded; on the tenth day, it was $\approx 92\%$, and by the end of the fourteenth day the film was practically all biodegraded, showing a mass loss of $\approx 98\%$. After 14 days, it was not possible to measure the mass of GAmb/Gly films.

The CO_2 (mg) values produced in the mineralization process of GAmb films with 10–30% glycerol are also shown in Fig. 4. Initially, it is observed that the curves of GAmb/Gly films have similar behavior, even in higher amounts of plasticizer, demonstrating that glycerol did not influence the mineralization process of GAmb films, as was observed in biodegradation by loss (a) of mass.

The release of carbon dioxide occurred gradually and increasingly during the 14 days of testing, for example, the film with 20% Gly had, on the first day, a release of 0.0440 mg of CO_2 ; on the fifth day; 0.286 mg of CO_2 ; on the ninth day, 0.999 mg of CO_2 ; and, finally, on the fourteenth day, 1.51 mg of CO_2 . In addition, all films had similar behavior to the film with 20% glycerol. These results indicate that the biodegradation process of GAmb films by the release of carbon dioxide (b) was effective and corroborated the biodegradation test by loss of mass. Therefore, the low degree of crystallinity of GAmb may have positively influenced the rapid biodegradation process of the films, as well as its ability to retain water molecules. Tables (S1 and S2), with the values of the mass loss and CO_2 release tests, are found in the supplementary material.

Figure 5 also shows the images of GAmb films with biodegraded glycerol every two days, totaling 14 days. It is observed that the loss of mass occurred gradually, as with the film with 20% Gly: on the second day, a mass loss of $\approx 47\%$ was recorded; on the sixth day, $\approx 81\%$; on the tenth day, $\approx 92\%$; and, on the fourteenth, $\approx 98\%$. Therefore, the visual biodegradation analysis of the films, shown in Fig. 5, corroborates those observed in Fig. 4. These results showed that the development of GAmb-based films for biodegradable packaging is promising, mainly due to the rapid biodegradability of GAmb films. These results are interesting, according to the literature, in comparison with polylactic acid films, a biopolymer widely used in biodegradable packaging, as its complete biodegradation can occur in months [7].

3.5. Mechanical properties

Films based on biopolymers must resist the stress encountered during their application to protect and maintain the integrity of the food, and they must also be flexible, adapting themselves to possible deformations without breaking [19]. Thus, Fig. 6 shows the stress-strain curves of GAmb plus glycerol films in different percentages, and Table 1 shows the values of the modulus of elasticity, tensile strength, and elongation to rupture obtained in the mechanical test of the films.

Figure 6 shows a change in the mechanical behavior of GAmb films, from brittle to ductile, as the percentage of glycerol is increased. From a mechanical point of view, there was a decrease in tensile strength with the increasing percentage of Gly among GAmb films with 10% Gly (6.41 MPa), 15% Gly (5.43 MPa), 20% Gly (4.70 MPa), 25% Gly (4.16 MPa) and 30% Gly (2.30 MPa). This is due to the glycerol plasticizer, which, when added to the biopolymer, promotes an increase in the free volume between the biopolymer chains, leading to greater chain mobility and film flexibility. Therefore, this behavior, caused by the addition of plasticizer, is important to make the GAmb film applicable in packaging, as it increases its deformation capacity.

The film with 10% glycerol is very rigid, that is, not very flexible, with an elastic modulus of 8.51 Mpa and elongation to break of 1.26%, which is not interesting for packaging applications due to its rigidity. However, the other films had acceptable deformations for packaging. In that case, the film with 15% Gly had a modulus of 3.44 Mpa and elongation of 2.73%; the one with 20% Gly had a modulus of 1.72 Mpa and elongation 12.20%; the one with 25% Gly had a 0.89 Mpa modulus of elasticity and 16.76% elongation, and the one with 30% Gly had a 0.33 Mpa modulus of elasticity and 21.79% elongation. All values are presented in Table 1 and, in graphic form, in Fig. 6. Therefore, among the films, those that presented the best mechanical values for packaging purposes are among the films with 15% and 30% Gly.

According to the data shown in Table 1, the samples containing the plasticizer glycerol showed an increase in the elongation to rupture, indicating that the presence of Gly acted by increasing the deformation capacity of the films with 15%, 20%, 25% and 30% Gly.

Table 1

Values obtained in the mechanical test of GAmb films with 10%, 15%, 20%, 25%, and 30% glycerol.

Samples	Modulus of Elasticity (MPa)	Tensile Strength (MPa)	Elongation to break (%)
GAmb/Gly(10)	8.51 ± 0.0150	6.41 ± 0.0277	1.26 ± 0.0057
GAmb/Gly(15)	3.44 ± 0.0329	5.43 ± 0.0190	2.73 ± 0.0133
GAmb/Gly(20)	1.72 ± 0.3883	4.70 ± 0.0164	12.20 ± 0.0866
GAmb/Gly(25)	0.89 ± 0.0128	4.16 ± 0.0132	16.76 ± 0.0132
GAmb/Gly(30)	0.33 ± 0.0046	2.30 ± 0.0161	21.79 ± 0.0733

5.6. Transmittance determination and visual aspect

The light transmittance spectra of GAmb films without glycerol (GAm) and containing Gly at different concentrations are shown in Fig. 7. The values found were displayed in Table 2, at wavelengths ranging from 300nm to 800nm.

The light transmittances of GAmb films were below 50% (Fig. 7) and, as the percentage of glycerol was increased from 10–30% of Gly, the transmittance values gradually decreased: at 400 nm, it decreased by 22.17–12.50%; at 600 nm, it decreased from 33.25–19.75%; and, at 800 nm, it decreased from 35.72–22.02%, as shown in Table 2. The results showed that GAmb films became less transparent with the increasing amount of Gly. The reduction in the transmittance values of the films was possibly due to the presence of the plasticizer, which may have acted as an obstacle to the passage or the scattering of light in the film matrix [3].

Also, as stated above, the results of GAmb films with glycerol were better than for other biopolymer films, such as cassia gum [5], gum arabic [13] and chitosan/shellac [30] which had transmittance greater than 80%. Meanwhile, GAmb films' transmittance was below 50%, acting as a more efficient barrier against the passage of UV (ultraviolet) and visible light. Although light transmission decreases with increasing Gly concentration, GAmb films remained transparent. Thus, the results indicated that GAmb films are interesting for applications in transparent packaging and that glycerol can reduce the effect of UV and visible light on packaged products.

Table 2
Transmittance values of GAmb films.

	Transmittance (%)					
	300nm	400nm	500nm	600nm	700nm	800nm
GAm	7.33	28.26	37.35	41.46	43.88	45.46
GAm/Gly(10)	4.89	22.17	30.01	33.25	34.78	35.72
GAm/Gly(15)	4.36	20.09	27.69	30.82	32.63	33.78
GAm/Gly(20)	3.30	17.97	25.40	28.50	30.34	31.32
GAm/Gly(25)	2.36	13.91	20.26	23.36	25.03	26.11
GAm/Gly(30)	2.83	12.50	17.51	19.75	21.09	22.02

Figure 8 shows the images of the *Amburana cearensis* gum films and, first, ripples and cracks are observed in the GAmb film, indicating its fragility. Furthermore, this fragility can be attributed to the strong intermolecular bonds of the compounds that make up the polysaccharide, providing less mobility to the molecular chains and resulting in a rigid and brittle film [17].

As explained above, the use of glycerol for the development of GAmb-based films was important, since this plasticizer, when it remains in the intermolecular spaces of the polymer chains, can promote a

reduction in intermolecular forces, increasing the mobility of molecules and providing films flexibility [10]. Thus, the insertion of glycerol provided the formation of flexible and still transparent films, and the best proportions of glycerol for the formation of GAmb-based films are between 10% and 30%.

4. Conclusions

The properties evaluated in this study showed the feasibility of forming self-supporting films by the casting method, from *Amburana cearensis* gum and glycerol as a plasticizer, whose proportions varied from 10–30%. The FTIR spectra of GAmb films indicated that the biopolymer is mainly constituted by α-L-Arabinofuranose and β-Galactopyranose. The results of FTIR, XRD, moisture content, water-solubility, as well as the others, corroborated the study of biodegradation of GAmb films. In this sense, GAmb films showed increasing biodegradation, and higher percentages of glycerol did not influence this process. Therefore, the results obtained showed that the development of GAmb-based films for future applications in biodegradable packaging is promising, mainly due to the rapid biodegradability of GAmb films.

Declarations

Credit authorship contribution statement

Railson Machado Pinto: Resources, Validation, Investigation, Writing – original draft, Conceptualization. **Carla Eiras:** Resources, Investigation, Writing – review & editing, Conceptualization. **Hernane da Silva Barud:** Resources, Conceptualization, Writing – original draft. **Ricardo de Araújo:** Conceptualization, Methodology, Writing – original draft, Data curation, Investigation. **Lívio César Cunha Nunes:** Writing – review & editing, Investigation Conceptualization.

Conflict of interest

The authors declare that there is no conflict of interest.

Acknowledgements

The authors would like to thank the Coordination for the Improvement of Higher Education Personnel (CAPES), National Council for Scientific and Technological Development (CNPq) for the financial support received through the process 431275/2018-1 (Call MCTIC/CNPq No. 28/2018 - Universal/Range B) and the Research Productivity Grant process 313370/2020-6 (Call CNPq No. 09/2020). The authors also thank the Laboratory of Polymer and Conjugated Materials - Federal University of Piauí (LAPCON-UFPI) for providing working and research conditions.

References

1. Balba MT, Al-Awadhi N, Al-Daher R (1998) Bioremediation of oil-contaminated soil: microbiological methods for feasibility, assessment and field, evaluation. J Microbiol Methods 32(2):3155-164

2. Ballesteros-Mártinez L, Pérez-Cervera C, Andrade-Pizarro R (2020) Effect of glycerol and sorbitol concentrations on mechanical, optical, and barrier properties of sweet potato starch film. *NFS Journal* 20:1-9
3. Silva Barud H, José Lima Ribeiro S, Carone CLP, Ligabue R, Einloft S, Queiroz PVS, PB Borges A, Jahno VD (2013) Optically transparent membrane based on bacterial cellulose/polycaprolactone. *Polímeros* 23:135-138
4. Luciana Vanden Braber N, Di Giorgio L, Aylen Aminahuel C, Iván Díaz Vergara L, Oscar Martín Costa A, Mauri A (2021) Antifungal whey protein films activated with low quantities of water soluble chitosan. *Food Hydrocolloids* 110:106156
5. Cao L, Liu W, Wang L (2018) Developing a green and edible film from Cassia gum: The effects of glycerol and sorbitol. *J Clean Prod* 175:276-282
6. Luyen Cao T, Bin Song K (2020) Development of bioactive bombacaceae gum films containing cinnamon leaf essential oil and their application in packaging of fresh salmon fillets. *Food Sci Technol* 131:109647
7. Castro-Aguirre E, Auras R, Selke S, Rubino M, Marsh T (2018) Enhancing the biodegradation rate of poly(lactic acid) films and PLA bio-nanocomposites in simulated composting through bioaugmentation. *Polym Degrad Stab* 154:46-54
8. Chen J, Wu A, Yang M, Ge Y, Pristijono P, Li J, Xu B, Mi H (2021) Characterization of sodium alginate-based films incorporated with thymol for fresh-cut apple packaging. *Food Control* 126:108063
9. Delacuvellerie A, Benali S, Cyriaque V, Moins S, Raquez JM, Gobert S, Wattiez R (2021) Microbial biofilm composition and polymer degradation of compostable and non-compostable plastics immersed in the marine environment. *J Hazard Mater* 419:126526
10. Farhan A, Mohd Hani N (2020) Active edible films based on semi-refined κ -carrageenan: antioxidant and color properties and application in chicken breast packaging. *Food Packaging and Shelf Life* 24:100476
11. Jovanović J, Ćirković J, Radojković A, Mutavdžić D, Tanasijević G, Joksimović K, Bakić G, Branković G, Branković Z (2021) Chitosan and pectin-based films and coatings with active components for application in antimicrobial food packaging. *Prog Org Coat* 158:106349
12. Kumar Kalita N, Sarmah A, Mohan Bhasney S, Kalamdhad A, Katiyar V (2021) Demonstrating an ideal compostable plastic using biodegradability kinetics of poly(lactic acid) (PLA) based green biocomposite films under aerobic composting conditions. *Environmental Challenges* 3:100030
13. Kang S, Xiao Y, Guo X, Huang A, Xu H (2021) Development of gum arabic-based nanocomposite films reinforced with cellulose nanocrystals for strawberry preservation. *Food Chemistry* 350:129199
14. Khorram F, Ramezanian A, Mohammad Hashem Hosseini S (2017) Shellac, gelatin and Persian gum as alternative coating for orange fruit. *Scientia Horticulturae* 225:22-28
15. Lian H, Shi J, Zhang X, Peng Y (2020) Effect of the added polysaccharide on the release of thyme essential oil and structure properties of chitosan based film. *Food Packaging and Shelf Life* 23:100467

16. Liu C, Yu B, Tao H, Liu P, Zhao H, Tan C, Cui B (2021) Effects of soy protein isolate on mechanical and hydrophobic properties of oxidized corn starch film. *Food Sci Technol* 147:111529
17. Chieregato Maniglia B, Tessaro L, Paula Ramos A, Rita Tapia-Blácido D (2019) Which plasticizer is suitable for films based on babassu starch isolated by different methods?. *Food Hydrocolloids* 89:143-152
18. Mendes JF, Martins JT, Manrich A, Neto ARS, Pinheiro ACM, Mattoso LHC, Martins MA (2019) Development and physical-chemical properties of pectin film reinforced with spent coffee grounds by continuous casting. *Carbohydrate Polymers* 210:92-99
19. Mohsin A, Qamar Zaman W, Guo M, Ahmed W, Mahmood Khan I, Niazi S, Rehman A, Hang H, Zhuang Y (2020) Xanthan-Curdlan nexus for synthesizing edible food packaging films. *Int J Biol Macromol* 162:43-49
20. Pereira OG, Maria GST, Amorim CC, Lopes BDSA, Suzana AMM, Maria SST (2017) Isolation and structure elucidation of flavonoids from Amburana cearensis resin and identification of human DNA topoisomerase II-a inhibitors. *Phytochemistry Letters* 22:61-70
21. Paula, RCM, Rodrigues JF (1995) Composition and rheological properties of cashew trees gum, the exudate polysaccharide from *Anacardium occidentale* L. *Carbohydrate Polymers* 26:177-181
22. Paula RCM, Budd PM, Rodrigues JF (1997) Characterization of *anadenanthera macrocarpa* exudate polysaccharide. *Polymer international* 44:55-60
23. Qi Y, Lin S, Lan J, Zhan Y, Guo J, Shang J (2021) Fabrication of super-high transparent cellulose films with multifunctional performances via postmodification strategy. *Carbohydrate Polymers* 260:117760
24. Rai P, Mehrotra S, Priya S, Gnansounou E, Sharma, SK (2021) Recent advances in the sustainable design and applications of biodegradable polymers. *Bioresource Technology* 325:124739
25. Singh RS, Kaur N, Rana V, Singla RK, Kang N, Kaur G, Kaur H, John FK (2020) Carbamoylethyl locust bean gum: synthesis, characterization and evaluation of its film forming potential. *Int J Biol Macromol*, 149:348-358
26. Tahir HE, Xiaobo Z, Mahunu GK, Arslan M, Abdalhai M, Zhihua L (2019) Recent developments in gum edible coating applications for fruits and vegetables preservation: a review. *Carbohydrate Polymers* 224:115141
27. Teixeira SC, Silva RRA, Oliveira TV, Stringheta PC, Pinto MRMR, Soares NFF (2021) Glycerol and triethyl citrate plasticizer effects on molecular, thermal, mechanical, and barrier properties of cellulose acetate films. *Food Bioscience* 42:101202
28. Xu T, Gao C, Feng X, Yang Y, Shen X, Tang X (2019) Structure, physical and antioxidant properties of chitosan-gum arabic edible films incorporated with cinnamon essential oil. *Int J Biol Macromol* 134:230-236
29. Yousuf B, Wu S, Gao Y (2021) Characteristics of karaya gum based films: Amelioration by inclusion of *Schisandra chinensis* oil and its oleogel in the film formulation. *Food Chemistry* 345:128859

30. Yuan Y, Zhang X, Pan Z, Xue Q, Wu Y, Li Y, Li B, Li L (2021). Improving the properties of chitosan films by incorporating shellac nanoparticles. *Food Hydrocolloids* 110:106164
31. Zhou H, Tong H, Lu J, Cheng Y, Qian F, Tao Y, Wang H (2021) Preparation of bio-based cellulose acetate/chitosan composite film with oxygen and water resistant properties. *Carbohydrate Polymers* 270:118381

Figures

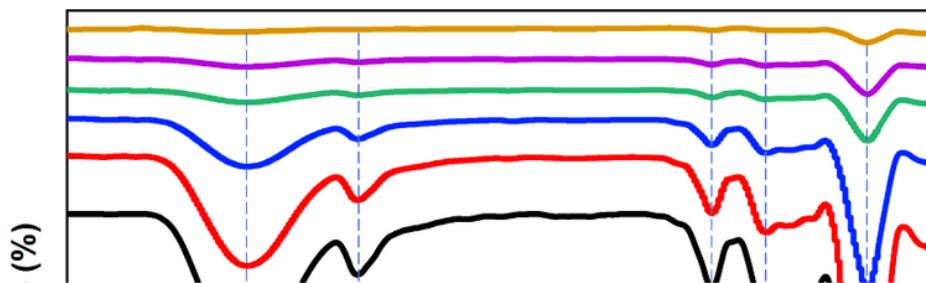


Figure 1

FTIR spectra of the GAmb film without glycerol (GAm) and films containing Gly varying proportions from 10% to 30%.

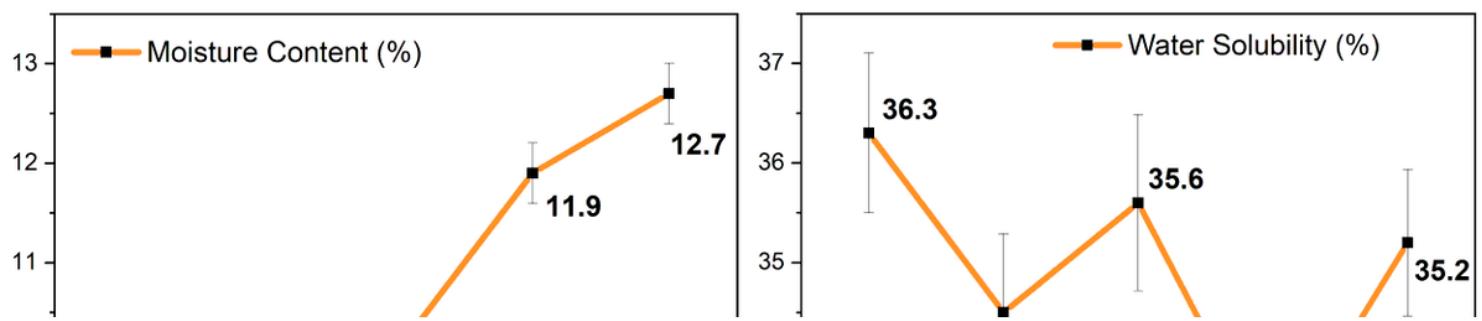


Figure 2

Moisture content and water solubility of films with glycerol.

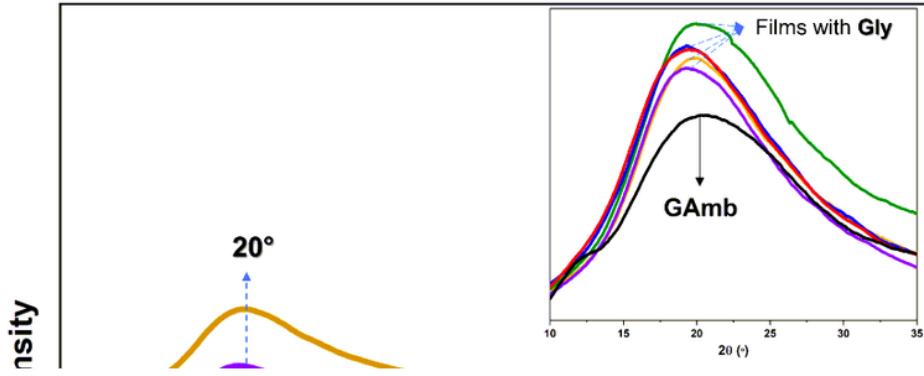


Figure 3

Diffractometry of GAMb films.

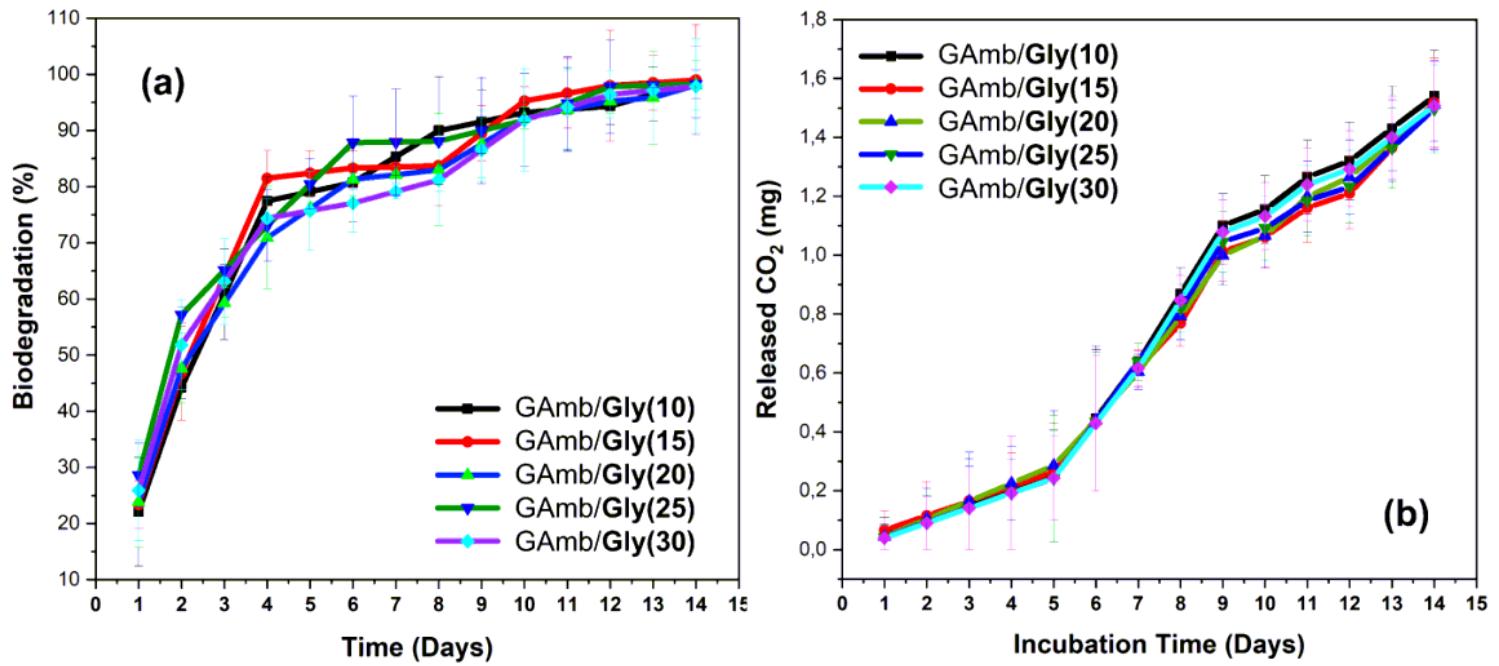


Figure 4

Biodegradation of films by loss of mass (a) and by released CO₂ (b).

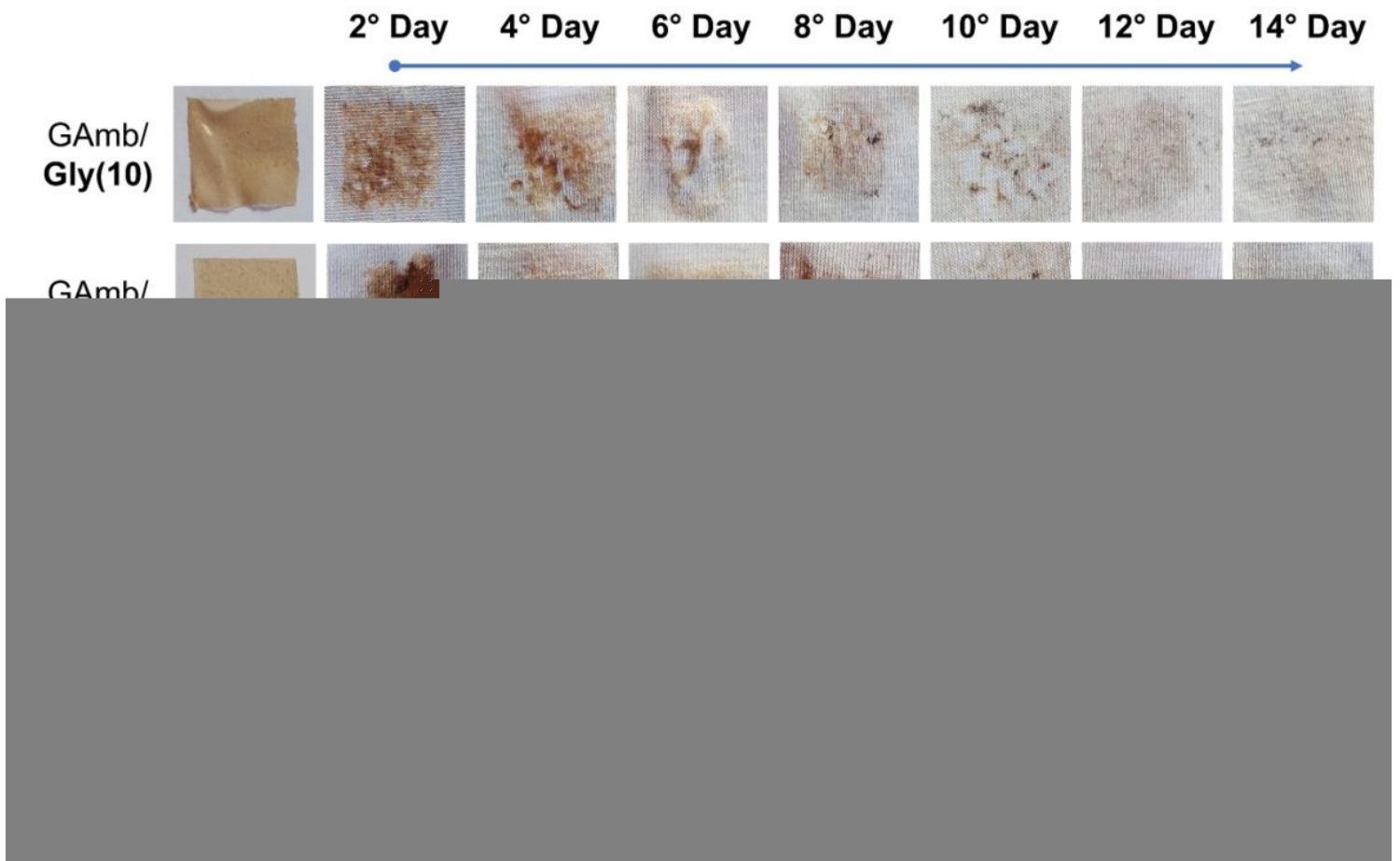


Figure 5

Biodegraded film images every 2 days.

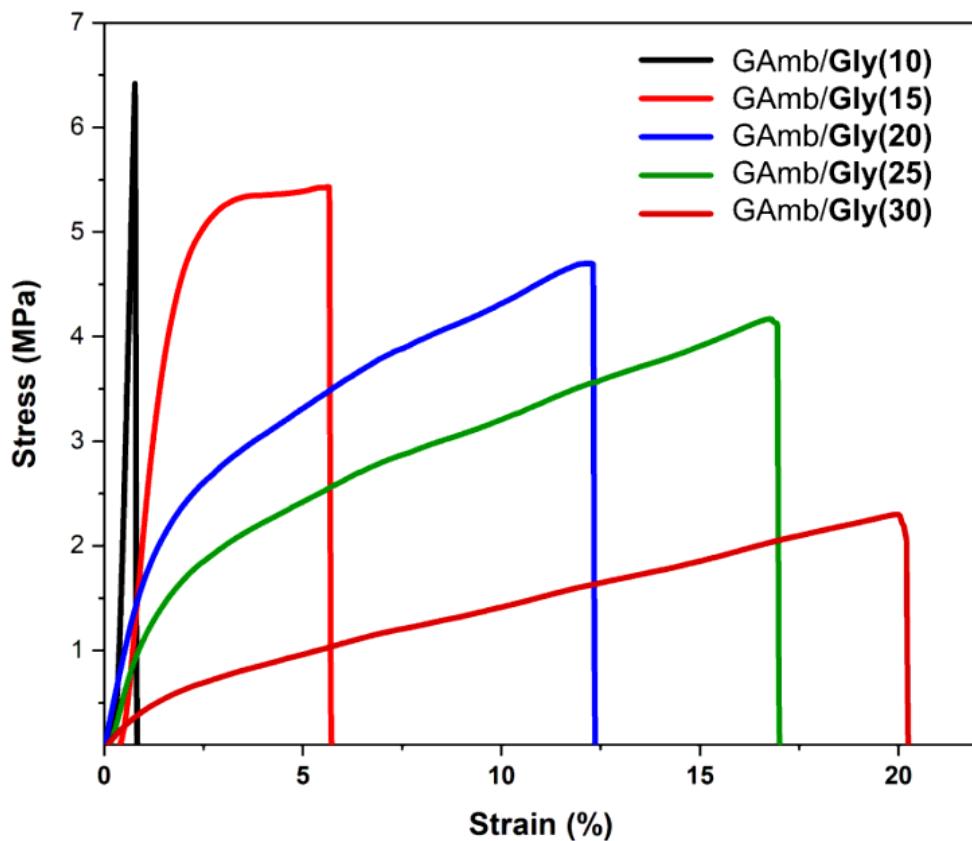


Figure 6

Stress-Strain curves of GAmB films with plasticizer.

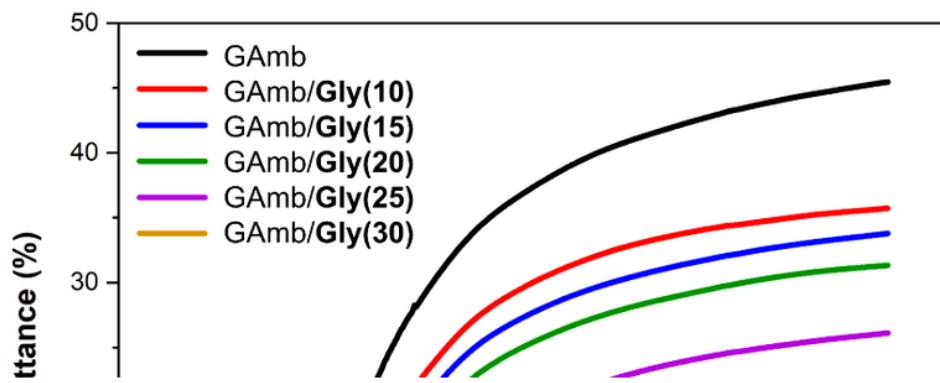


Figure 7

Film light transmittance.



Figure 8

Images from the GAmb and GAmb/Gly films.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [SupplementaryMaterial.docx](#)