



Memories of the Agricultural and Livestock Area of the VI CCIUTM, Ecuador

Characterization of Edible Films Based on *Cordia lutea* Lam

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Abstract | Consuming healthy and good quality foods has promoted the development of new conservation technologies, such as edible coatings. The aim of the present study was the characterization of *Cordia lutea* gum films. The films were prepared by heating gum-water solutions at 80 ± 1 °C for 5 minutes. The chemical analyzes of acidity, pH and ° Brix were made in the gum of *C. lutea*. The variables determined in the films were opacity, thickness, tensile strength, water vapor permeability, elasticity, film solubility and microbiological analysis. Results showed that the optimum concentration of gum for elaboration of films was 40% (v/v). Films have a good tensile strength showing values between 10.81 and 16.90 MPa. The elasticity showed values between 0.11 and 0.21 MPa. The water vapor permeability ranged between $0.87 - 4.32 \times 10^{-10} \text{ g m}^{-1} \text{ s}^{-1} \text{ Pa}^{-1}$, a solubility between 45.95 and 55.11% was obtained. The thickness of the film varied between 0.18 mm to 0.28 mm. The opacity of the film showed values between 6.98 mm^{-1} and 5.49 mm^{-1} . The microbiological analysis showed a diameter of inhibition of 2.65 cm against *Streptococcus mutans* and 2.12 cm against *Aspergillus spp.*, showing no antimicrobial effect in *Penicillium spp.* and *Rhizopus spp.*

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Introduction

The development of new industrial processes and innovation in the food industry demands the development of packaging with improved characteristics: biodegradable, friendly to the environment and not be harmful to the consumers. These demands lead

to search for new materials, and this may be achieved by the study of new botanical sources.

The edible coatings applied to fruits to maintain their post-harvest attributes have been studied by different researchers (Dong *et al.*, 2004; Rojas-Grau *et al.*, 2008). These characteristics can act favorably on some

characteristics such as weight loss and respiratory rate decrease, besides serving as a vehicle to incorporate other food additives, which improve the quality of the food they cover (Pen and Jiang, 2003). The coatings preserve the quality of fruits and vegetables modifying the internal atmosphere of the fruit and in this way delay maturation and senescence (Rojas-Grau *et al.*, 2009). They constitute a semipermeable barrier to gases and water vapor that also retards food spoilage, improve the mechanical properties of the food, help maintain the structural integrity of the food product, retain volatile compounds and can act as a carrier for food additives (Tanada and Grosso, 2005).

An edible film (PC) is defined as a preformed matrix, obtained by molding, whose thickness is always greater than RC (edible coating) (Del-Valle *et al.*, 2005). Applied to fruits, act as modified atmosphere since allow control breathing and senescence reducing deterioration of the fruit (Cisneros and Krochta, 2005).

Biopolymers are usually used for the preparation of films and coatings due to the low cost and biodegradability. The existing biomaterials have limitations in terms of availability and functional properties (Vieira *et al.*, 2011). Therefore, new biological resources are being continuously explored (Azam *et al.*, 2013).

The main components of edible coatings are polysaccharides, proteins, lipids, and resins (Bermudez and Roza, 2003; Ribeiro *et al.*, 2007). The formulations may also include plasticizers and emulsifiers of different chemical nature to improve the properties of the coatings.

C. lutea is a deciduous shrub of the *Boraginaceae* family that produce a translucent, elliptical berry fruit with a sticky whitish pulp (González *et al.*, 2005; Granda and Guamán, 2006).

Gum *Cordia*, an anionic polysaccharide, has been recognized to produce flexible, transparent films with excellent oxygen barrier (Haq *et al.*, 2014b) and emulsifying properties (Benhura and Chidewe, 2004). Gum *Cordia* also contains antioxidant compounds that may help for the protection of oxygen sensitive products (Haq *et al.*, 2013a).

The gum from *C. lutea* has good adhesion properties, therefore is an ideal candidate for films and coatings. There are previous studies of the elaboration of edible

films using *Cordia myxa* fruit gum (Haq *et al.*, 2014b), applications of gum *Cordia* as a coating material on nuts to retard oxidative rancidity (Haq *et al.*, 2014a; Haq and Hasnain, 2013b; Haq and Hasnain, 2014b). However, there are no studies of the elaboration of films from *C. lutea*.

Research has been reported on edible films based on Mezquite, Arabica and Policaju gums (Valle *et al.*, 2008; Carneiro-Da-Cunha *et al.*, 2009; Bósquez *et al.*, 2010; Maqbool *et al.*, 2010).

There is very few research in biological materials of the *Cordia* family. There are no studies such as the control of the development of microorganisms in vitro or in vivo, carried out with respect to *C. lutea*, Adeosun *et al.* (2013) showed that essential oil from *Cordia sebestena* stem bark had promising antioxidant potential suggesting that *C. sebestena* could be exploited in medicine and food industries.

The presence of some fungi or yeasts in the process of food collection can affect the quality of the product, the conservation time, and the occasional damage to human and animal health, especially those mycotoxigenic agents, capable of producing mycotoxins (Bleve *et al.*, 2003); These metabolites can enter the food chain of humans and animals, through direct or indirect contamination. In the direct, the toxic fungus grows on the food material, while the indirect contamination, the food contaminated by a mycotoxin (Bennett and Klich, 2003). Mycotoxins are secondary metabolites produced by different genera and species of fungi, among which the main ones are *Aspergillus spp.*, *Fusarium spp.* and *Penicillium spp.*, these are colonized and polluting substrates that are used in human and animal feeding, it is estimated that 25% of the world cereal production is contaminated (Cast, 2003).

According to the OMS, between 60% and 90% of the population are affected by dental caries, this disease is more frequent in Latin American countries (Petersen *et al.*, 2005). *Streptococcus mutans* is the microorganism most related to the onset of caries development, observing a positive association between the degree of infection by *S. mutans* and dental caries (Ojeda, 2013).

Based on previous information the objective of this study was to characterize the physico-chemical and antimicrobial properties in vitro against *Penicillium*

spp., *Aspergillus spp.*, *Rhizopus spp.*, and *Streptococcus mutans ATCC35668* of edible films based on *C. lutea*.

Materials and Methods

The fruits of C. lutea were collected from wild C. lutea plants from Manta, Ecuador.

The development of this research was carried out in the Food Sciences Research Laboratory of the Faculty of Agricultural Sciences of the Eloy Alfaro Lay University of Manabí (ULEAM), which is located between the following coordinates 0 ° 57'10' south latitude 80°44'43' western longitude. Manta-Manabí-Ecuador.

C. lutea processing

Ripe *C. lutea* fruits were selected, discarding those who showed signs of skin damage. Disinfection was carried out by fruit immersion in 1% NaCl solution for 2 minutes followed by rinsing with distilled water. Afterwards, fruits were subjected to a manual pressing and filtering. The obtained liquid extract was filtered for a second time by using a fabric to remove solid particles.

Soluble solids content was determined in the obtained liquid extract with hand refractometer (Atago, Japan) and reported as ° Brix (AOAC, 1990). Titratable acidity was determined by titration with 0.1 N NaOH (AOAC, 1984) and the results were reported as percentage of citric acid. pH determination was done with a potentiometer (AOAC, 1980).

Film elaboration

Film preparation was performed as follows. gum from *C. lutea* was diluted with water in different ratios, 100/0, 80/20, 60/40, 40/60 and 20%/80% (gum/water, v/v). The obtained solution was subjected to a heat treatment from 25 ±1 °C up to 80 ±1 °C, with stirring at 80 ±1 °C for 5 minutes. The solution was homogenised at 11,000 rpm for 4 minutes in an Ultra-Turrax PT-2100 (POLY TRON, Switzerland). 20 ml of the solution were poured onto plastic Petri dishes of 9.5 cm diameter. The plates were dried in a chamber for 24 h at 60 ±1 °C and 80% relative humidity. Afterwards, the samples were kept at 80% relative humidity (RH) for 48 h before the formed films were manually detached.

Film properties

Color: The color of the films was measured in different

sections using a colorimeter (Konica Minolta, Japan) and determining L*, a* and b* parameters. Measurements were performed in triplicate.

Tensile properties of the films: Tensile properties were performed according to Santacruz *et al.* (2015) by using a tensile test with a texturometer (Shimadzu, Japan). Sample films of 5 x 2 cm were loaded in the equipment. The crosshead speed was set at 10 mm/s. The ultimate tensile strength (tensile strength) and elasticity modulus were determined by using a Trapezium X software.

Film thickness: Film thickness was obtained by direct measuring of the film. A micrometer (Mitutoyo, Japan) was used.

Water vapor permeability: Water vapor permeability (WVP) was performed according to ASTM (1996) and (Debeaufort *et al.*, 1993). Film samples were used to seal a hole on the top of a plastic cell. The plastic cell, containing distilled water, was loaded into a desiccator. The desiccator was placed into a chamber at 25 ±1 °C for 24 h. At least three weights of the cell were taken during the 24 h of storage. WVP was calculated from the following equation: (1).

$$WVP = \Delta m \cdot l / (A \cdot \Delta t \cdot \Delta p) \dots\dots\dots (1)$$

Where, $\Delta m/\Delta t$ – weight of moisture loss per unit of time ($g\ s^{-1}$), A – film area exposed to moisture transfer (m^2), l – film thickness (m), Δp – water vapor pressure difference between the two sides of the film (Pa).

Linear regression was used to estimate the slope of the $g\ s^{-1}$ plot. Δp was calculated according to the Eq. (2), where $P_{vap\ sat}$ was the saturated vapor pressure of pure water and equals to 3160 Pa at 25 ±1 °C. ARH was the relative humidity gradient between the cell and the surroundings.

$$\Delta p = (\Delta RH/100) \cdot P_{vap\ sat} \dots\dots\dots (2)$$

Opacity measurements were performed according to Gómez-Estaca *et al.* (2009). A film piece was loaded in a spectrophotometer (VIS spectrophotometer, Jenway, UK) and the absorbance was determined at 600 nm. The opacity was determined according to equation. (3).

$$Opacity = Abs_{600}/x \dots\dots\dots (3)$$

Where Abs_{600} is the absorbance at 600 nm and x is the thickness of the film in mm. Low values of opacity corresponds to high transparency.

Solubility measurement

The film water solubility was determined according to the method of Colla *et al.* (2006) with slight modifications. Film pieces of 3 x 1 cm were dried to a constant weight at 100 ± 1 °C. Each sample was placed into a beaker containing 50 mL of distilled water and was shaken at 100 r.p.m. in an orbital shaker (mrc, Germany) at room temperature for 24 h. After collecting the undissolved film, its dry weight was determined after drying in an oven at 100 ± 1 °C for 24 h.

Microbiological analysis

Evaluation of anti-fungal activity of *C. lutea* gum was performed in *Penicillium spp.*, *Aspergillus spp.*, *Rhizopus spp.*, and *Streptococcus mutans*. The organisms (fungus) were previously isolated from fruit samples bought in a local market (Manta, Ecuador). Strains of *Streptococcus mutans* ATCC35668 (laboratory Microbiologic, U.S.A.) were used.

To prepare the inoculum, the three fungi species were seeded in Petri dishes with 20 mL of culture medium agar DRBC (Difco™) and incubated at 25 ± 1 °C for 5 days.

To prepare the inoculum, lyophilized strains of *S. mutans* were activated in BHI broth (Brain Heart Infusion Broth C5141 Criterion, USA) and incubated in an oven at 37 ± 1 °C for 48 h in microaerophilic for reproduction. The strains were seeded in Petri dishes with 20 mL of BBL agar medium (Blood Agar Base, BD, USA) at 37 ± 1 °C for 48 h. Finally, a 0.5 Mc Farland bacterial suspension was prepared for each strain.

To measure if the strains were reproduced over time, absorbance readings were performed at 625 nm (Jenway 6320D, Germany) at 24 and 48 h of incubation. The absorbance is directly proportional to the concentration of the microorganisms. To correlate the absorbance measure with the concentration of microorganisms, a 0.5 Mac Farland pattern was used, representing a known concentration of microorganisms, which is 1.5×10^8 CFU/mL. The readings included a blank containing virgin BHI broth, this reading should be subtracted from the readings taken to remove the absorbance from the BHI broth.

Antimicrobial activity of *C. lutea* gum was determined by the diffusion method in agar according to the National Committee for Clinical Laboratory Standards (NCCLS). 20 µL of *C. lutea* gum were added to filter paper discs (Fisher Scientific Q2) of 5 mm diameter. Afterwards, the discs were placed in the center of a Petri dish containing the medium inoculated with the microorganisms to be tested. The inoculated plates were incubated at 25 ± 1 °C for 12 days. Halo fungal and bacterial growth inhibition in (cm) was measured on days 1, 2, and 3. In all cases three measurements were performed.

Experimental design and statistical analyzes

A completely randomized design with a unifactorial arrangement was used. The concentration of *Cordia lutea* Lam gum is established as an independent variable. obtained by manual compression at 5 levels (20, 40, 60, 80 and 100%) while the variables determined in the films were opacity, thickness, tensile strength, water vapor permeability, elasticity, film solubility and microbiological analysis.

ANOVA and the significance of the difference between means will be reduced by Tukey's test ($P < 0.05$) using the InfoStat statistical software (Infostat version 2019). All measurements were performed in triplicate.

Results and Discussion

C. lutea gum had 16.00 ° Brix; 0.029% acidity, expressed as citric acid; and a pH of 6.5.

Figure 1 (1-A) shows the profile of L^* from *C. lutea* films along 15 days of storage. Edible coatings with a higher concentration of gum, 100/0 and 80/20, showed a lower L^* ($p < 0.05$). Films with ratios of 100/0 and 80/20 gum/water, had L^* that varied between 39.22 and 48.33 compared to other ratios, which had L^* that varied between 54.11 and 65.12 along 15 days of storage.

Results indicate that high concentrations of *C. lutea* gum for film elaboration led to low L^* values. Figure 1 (1-B) shows the a^* profile of *C. lutea* films over 15 days of storage. The edible coatings with a higher concentration of gum, 100/0 and 80/20, showed a higher a^* ($p < 0.05$). Films with ratios of 100/0 and 80/20 gum/water had an a^* that varied between 1.58 and 1.39 compared to other treatments which had a a^* that

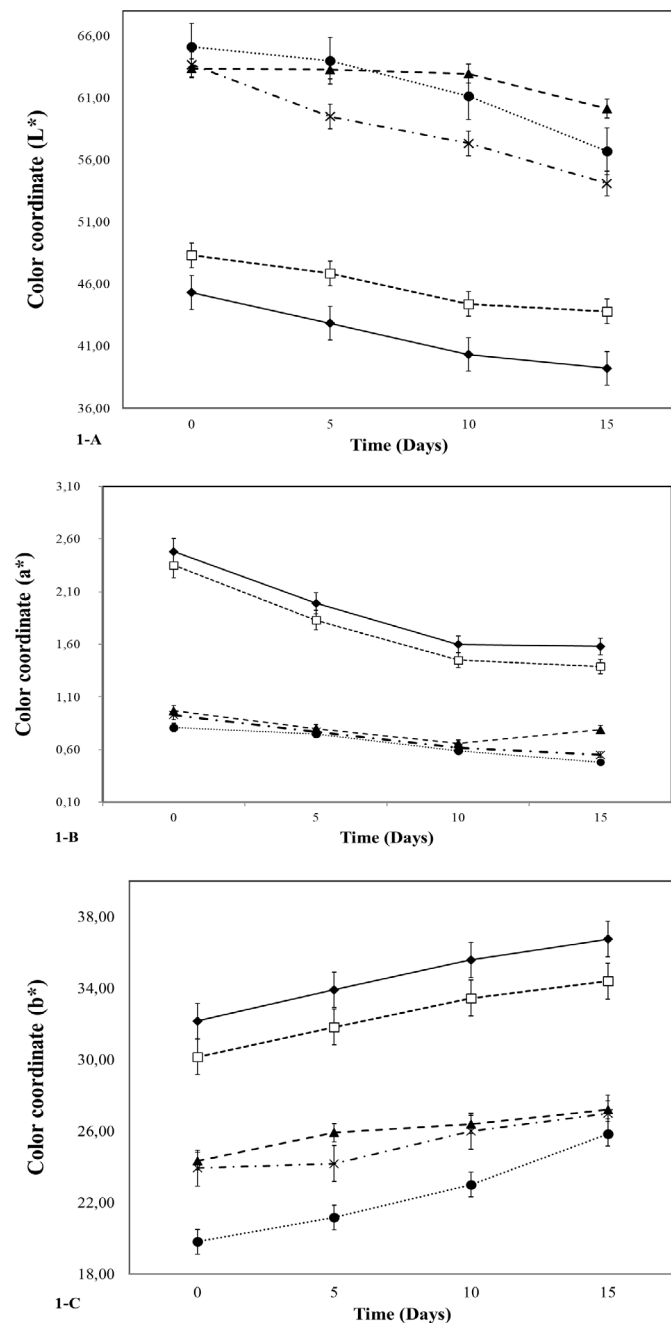


Figure 1: Change of L^* (1-A), a^* (1-B) and b^* (1-C) on *C. lutea* films along storage time. Effect *C. lutea* concentration, *C. lutea*% – water%: $\blacklozenge$ – 100%-0%, $\square$ – 80%-20%, $\blacktriangle$ – 60%-40%, $-x-$ – 60%-40%, $\bullet$ – 20%-80%.

varied between 0.48 and 0.55 over 15 days of storage. The results indicate that high concentrations of gum of *C. lutea* on the elaboration of the film led to higher values of a^* . Figure 1 (1-C) shows the b^* profile of *C. lutea* films over 15 days of storage. The edible coatings with a higher concentration of gum, 100/0 and 80/20, showed a higher b^* ($p < 0.05$). Films with ratios of 100/0 and 80/20 gum/water had a b^* that varied between 36.75 and 34.39 compared to other treatments which had b^* that varied between 25.85 and 27 over 15 days of storage. The results indicate that the use of

high concentrations of gum of *C. lutea* on the elaboration of the film led to higher values of b^* .

Results of tensile strength showed differences among films prepared with different ratios of gum from *C. lutea* ($p < 0.05$). Tensile strengths were the highest for 100 % gum (16.90MPa) and the lowest (10.81Mpa) for films prepared with 20/80 (gum / water) Table 1. The values of tensile strength are like those prepared by (Haq *et al.*, 2013a), who reported values above 10 Mpa in edible films based on *Cordia myxa*. *C. lutea* films had thickness of 0.28 and 0.17 mm for the highest (100%) and the lowest (20% -80%) *C. lutea* gum / water ratio, respectively. In the research carried out by Santacruz *et al.* (2015), film thicknesses based on potato and cassava starch films was 0.15 and 0.13 mm, respectively. The thickness of a film or coating is defined by the properties of the emulsion such as viscosity or density and the influence of the drying process. When the fluid dries, the formed film will be defined by the same properties such as density, viscosity, and surface tension, as well as surface withdrawal speed from the coating solution and percentage of solids (Cisneros and Krochta, 2003). Other authors attribute the thickness of the film as the result of polymer swelling by water absorption (Park, 1993). In solution casting method, the amount of solids poured into the mold greatly affects the thickness of the resulting films. In previous studies of emulsified films, two different methods in terms of casted amount of film forming emulsion (FFE) have been reported (Haq *et al.*, 2016). In one method constant weight or volume of FFE is casted (Bauemler *et al.*, 2014; Tongnuanchan *et al.*, 2015), whereas in other method; the volume of FFE is adjusted so that the constant weight of solids is casted in all treatments (Perez and Krochta, 2001; Fabra *et al.*, 2009; Janjarasskul *et al.*, 2014; Kowalczyk and Baraniak, 2014).

Table 1 shows a significant difference ($p < 0.05$) between the treatments, the results of (WVP), which decrease as the concentration of the gum of *C. lutea* increases, reporting values of $0.87 \times 10^{-10} \text{ g m}^{-1} \text{ s}^{-1} \text{ Pa}^{-1}$ in films based on 100% gum concentration and $4.32 \times 10^{-10} \text{ g m}^{-1} \text{ s}^{-1} \text{ Pa}^{-1}$ in films with concentration of 20% -80% gum / water. Compared with other films and coatings, films obtained in our study showed low permeability to water vapor. Permeability values were between 1.2×10^{-9} and $2.7 \times 10^{-9} \text{ g m} / \text{sm}^2 \text{ Pa}$ for starch films (Kim *et al.*, 2002), $2.7 \times 10^{-9} \text{ g m} / \text{sm}^2 \text{ Pa}$ for

Table 1: Media of film opacity, thickness, tensile strength, WVP, elasticity and solubility of *C. lutea*-water based films.

Concentration gum – water (%)	Film opacity (mm ⁻¹)	Film thickness (mm)	Tensile strength (MPa)	WVP (g s ⁻¹ m ⁻¹ Pa ⁻¹)	Elasticity modulus (MPa)	Solubility (%)
100	6.78 ^a	0.28 ^a	16.90 ^a	0.87 ^c	0.15 ^c	45.95 ^c
80 - 20	5.92 ^b	0.25 ^b	15.81 ^b	1.01 ^d	0.18 ^b	46.33 ^c
60 - 40	5.76 ^c	0.21 ^c	14.93 ^c	1.24 ^c	0.21 ^a	46.89 ^c
40 - 60	5.68 ^d	0.19 ^d	13.37 ^d	2.27 ^b	0.12 ^d	53.17 ^b
20 - 80	5.49 ^e	0.17 ^e	10.81 ^e	4.32 ^a	0.11 ^e	55.11 ^a

^{a, b, c, d, e} Different capital letter superscripts in the columns indicate a statistically significant difference ($p < 0.05$).

^A WVP values can be obtained by multiplication of the displayed values with 1×10^{-10} .

^B Solubility was expressed as g of dissolved film per 100 g of original film.

^C $n = 15$

hydroxypropyl methylcellulose (HMPC), lipid and antimicrobial films (Valencia, 2011). Previous study showed that starches with low amylose content had a high WVP $11.22 \pm 0.69 \times 10^{-11} \text{ gm}^{-1} \text{ s}^{-1} \text{ Pa}^{-1}$ (Phan et al., 2005). Most edible films are hydrophilic in nature and found a dependent positive relationship between water vapor permeability and thickness of the films (Gennadios et al., 1994; Park and Chinnan, 1995). McHug (1993) consider that as film thickness increases the resistance to mass transfer through it, accordingly, the partial pressure of water vapor equilibrium in the inner surface increases the film is increased. The permeability to water vapor is the most widely studied property in edible films, due to the important role of water in the reactions of food spoilage (Cerqueira et al., 2009). The high permeability to water vapor is a major limitation in the use of films based on natural polymers as food packaging materials. One of the main functions of food packaging is to avoid or minimize moisture transfer between the food and the surrounding atmosphere. Water vapor permeability (WVP) should therefore be as low as possible to optimize the food package environment and potentially increase the shelf-life of the food product (Hosseini et al., 2013). Moreover, this may be important to reduce alteration of sensory quality, microbiological, physical, and chemical characteristics of food covered with this material (Gontard and Guilbert, 1994).

The results in Table 1 showed that the 100% gum formulation showed a significant difference ($p < 0.05$) in the opacity values compared to the other two formulations, presenting values of 6.78 mm^{-1} and 5.49 mm^{-1} for the lowest gum concentration of 20% -80%, which may be attributed to the rate at which the gum is present in the mixture because as the rubber concentration in the formulations increase the opacity

values increase. Solubility results showed a significant difference ($p < 0.05$) between treatments, with solubilities between 55.11% for the lowest concentration 20-80% gum/ water and 45.95% for the highest concentration, 100% gum.

In another study realized by Haq et al. (2013a) in edible films based on *C. mixa*, values of 26.71% of film solubility without presence of plasticizer were reported, and 43.81% in the presence of plasticizer. Films made from banana bark presented a solubility percentage of between 7.21% and 25.57%, (Anchundia et al., 2016), Mali (2005), reported a solubility between 19.34% and 30.76% at $25 \pm 1^\circ \text{C}$ for films made with *Dioscorea alata* starch, glycerol, and water. In other studies, the percentage of solubility in films made with banana starch and water was 20.2% (Zamudio, 2005), (Santacruz et al., 2015) reported a solubility of 40.42% in potato starch films and 33.20% in cassava starch films, 100% solubility was reported in edible films based on whey proteins (lactalbumin and lactoglobulin), (Pérez-Gago et al., 1999). A higher solubility is directly related to a high value of water vapor permeability, and this is favorable for some plants that need to maintain high relative humidity (Viña et al., 2007).

According to the results of inhibition of *Penicillium spp.*, *Aspergillus spp.*, *Rhizopus spp.*, and *S. mutans* (Tables 2 and 3), the treatments of *C. lutea* reported an antimicrobial activity against *Aspergillus spp.*, and *S. mutans*. The greater concentration of *C. lutea* liquid extract the larger the halo of inhibition, being the concentration of 100% of gum the most effective with halo values of 2.1 cm for 24 h and 2.5 cm for the 72 h in *S. mutans* and 1.5 cm for 24 h and 2.12 cm for 72 h in *Aspergillus*. It is worth mentioning that an

increase of the microbial inhibition up to 48 h was observed, from this time no greater increase in the inhibition halo was reported. No antimicrobial activity was found against *Penicillium spp.*, and *Rhizopus spp.*

Table 2: Microbiological analysis, halo of inhibition, of *C. lutea* against *Streptococcus mutans*.

Films concentra- tion (gum- water) (%)	24 hours Halo inhibi- tion (cm)	48 hours Halo inhibi- tion (cm)	72 hours Halo inhibi- tion (cm)
100	2.10 ^a	2.26 ^a	2.50 ^a
80 – 20	1.59 ^b	1.61 ^b	1.95 ^b
60 – 40	1.43 ^c	1.46 ^c	1.55 ^c
40 – 60	1.30 ^d	1.38 ^d	1.44 ^d
20 – 80	1.15 ^e	1.26 ^e	1.32 ^e

^{a,b,c,d,e} Different capital letter superscripts in the columns indicate a statistically significant difference ($p < 0.05$). The values correspond to the measure of 3 replicates.

^A Halo of inhibition. Measurements were made on the diameter of the circumference of the halo. Measurements were performed in cm.

^B Measurements performed every 24 hours for 3 days.

^C $n = 15$

Table 3: Microbiological analysis, halo of inhibition, of *C. lutea* against *Aspergillus spp.*

Films concentra- tion (gum – water) (%)	24 hours Halo inhibi- tion (cm)	48 hours Halo inhibi- tion (cm)	72 hours Halo inhibi- tion (cm)
100	1.50 ^a	2.10 ^a	2.12 ^a
80 – 20	1.39 ^b	2.05 ^a	2.06 ^a
60 – 40	1.38 ^c	1.99 ^a	2.00 ^a
40 – 60	1.22 ^c	1.76 ^b	1.76 ^b
20 – 80	1.10 ^c	1.24 ^c	1.24 ^c

^{a,b,c,d,e} Different capital letter superscripts in the columns indicate a statistically significant difference ($p < 0.05$). The values correspond to the measure of 3 replicates.

^A Halo of inhibition. Measurements were made on the diameter of the circumference of the halo. Measurements were performed in cm.

^B Measurements performed every 24 hours for 3 days.

^C $n = 15$

Conclusions and Recommendations

Cordia lutea gum is a good material for the preparation of edible coatings, the films have good tensile strength and elongation, exhibit an acceptable thickness, and have excellent plasticizing characteristics. The results of this study provide further information about *C. lutea*. Also, it provides a basis for further

studies of packaging or edible coatings based on *C. lutea*, or as an input for the plastics and the food industry.

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Novelty Statement

This study proposes the development of edible films based on new unexplored botanical sources, which present exceptional mechanical and antimicrobial properties, which contributes to the advancement of science in the development of new matrices for food preservation.

Author's Contribution

Marlon Castro García: Experiment planning, research execution, data analysis, wrote the draft of the manuscript.

Vanessa Espinoza Posligua: Experiment planning, research execution, data analysis

Francisco Cañarte García: Helped in the review of relevant literature, helped in editing the manuscript

Doris Rizzo Alcívar: Data analysis, helped in editing the manuscript

Christian Rivadeneira Barcia: Helped provide valid suggestions for comparing results with other studies

Alex Dueñas Rivadeneira: He helped conclude the study with his valuable comments and specific suggestions

Conflict of interest

The authors have declared no conflict of interest.

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