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Production and Characterization of Active Pectin Films with Olive or Guava Leaf Extract Used as Soluble Sachets for Chicken Stock Powder

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Abstract: The goal of this study was to improve the functionality of two pectin (PEC) edible films by incorporating olive leaf extract (OLE) or guava leaf extract (GLE). Different concentrations of OLE or GLE (0.1 and 0.2% *w*/*v*) were used, and 30% glycerol was added as a plasticizer. The obtained films were evaluated for their mechanical properties, antioxidant activity, thickness, color, opacity, permeability to gases and water vapor, moisture content, and moisture uptake. Soluble sachets were then prepared and filled with chicken stock powder. The results indicated that incorporating OLE or GLE into the PEC films significantly increased their opacity, greenness, and antioxidant activity, which increased from 8.5% in the control to 83.9% when 0.2% GLE was added. Additionally, the films had lower water vapor permeability than the control film. The moisture uptake of the films was also significantly increased when GLE was added. Furthermore, the developed sachets were tested in real-life scenarios, mirroring their intended usage in households. After being introduced to boiling water, the sachets rapidly dissolved within seconds. These results suggest that OLE or GLE, as natural additives, can be used to improve the functionality and activity of edible films.

Keywords: functional edible packaging; food preservation; pectin films; food wrapping; olive byproducts; plant leaf; circular economy

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1. Introduction

Today, bioplastics, edible films, and coatings are becoming the most effective ways to reduce food packaging's adverse impact on the environment [1,2]. More than 368 million tons of plastics was used in 2019, and a significant amount of this quantity ended up in landfills and the oceans, polluting our air, water, and soil [3,4]. Several researchers have worked to find the best combination between low-price film-based materials and their activation with different plant extracts or additives that potentially have antioxidant, antimicrobial, and anti-biofilm activities [5], to enhance the food's shelf-life or other functionality for food applications [6–9]. As a result of short shelf-life and inadequate packaging, food waste remains a significant global challenge, emphasizing the need for innovative and sustainable packaging solutions [10–16]. Edible films and coatings are prepared mainly from hydrocolloidal materials (e.g., carbohydrates and proteins, or a combination of both sources). Carbohydrate-material-based films show good mechanical properties, although

they are poor in terms of permeability. Meanwhile, edible films prepared mainly from protein show good barrier properties against gases, although they have poor mechanical properties [15,17–25].

In recent years, the development of edible and coating solutions based on pectin has increased due to several reasons. First, they are classified as food-grade materials and are non-toxic [26]. They can also be obtained from renewable available resources such as citrus peel, apple pomace, and sugar beet [27]. They also have good film formation ability, even without plasticizers [28]. Additionally, they can be used in different food products as stabilizers or thickeners, and they have good water solubility, biocompatibility, and compostability [27].

Commercial pectin is derived from a variety of plant sources, including apple pomace (14%), and citrus peel (85%) [6,29]. Fruit processing industries generate significant quantities of fruit waste that, if not utilized, ends up in landfills, contributing to environmental degradation due to microbial decay and greenhouse gas emissions [30]. However, pectin, which is a complex polysaccharide, represents the highest percentage of plant mass composition (about 35% in dicotyledonous plant cells and approximately 5% in woody tissues [31], whereas in grass plants it is about 2%–10%) [32]. Recently, Chandel et al. [27] reported on pectin obtained from 26 sources, along with the extraction methods that were used to produce commercial pectin for different applications, e.g., food, pharmaceuticals [33], cosmetics, and food packaging [15,17,19,28,34].

Pectin film alone does not possess strong functionality in terms of antimicrobial or antioxidant activity, which may potentially discourage manufacturers from using it for food wrappings or coatings. Lately, many researchers have worked to improve the functionality of pectin film due to its availability and low price, by adding essential oils, functionalized nanoparticles [35], and plant extracts. Adding plant extracts or essential oils such as mint [36], lemon [37], oregano [38], orange [37], clove bud [39], cinnamon [40], or lime peel extract [41] to the edible films proved that pectin-based films can be used as food packaging to extend the shelf-life of food products.

Extracts of plant leaves represent a promising approach that can be incorporated, as they have antioxidant and antimicrobial activity. Therefore, olive (*Olea europaea* L.) leaf extracts (OLEs) have been used for centuries in folk medicine as therapeutic infusions, and they are among the main byproducts generated from the olive oil industry [42]. One of the major phenolic compounds found in olive leaves is oleuropein, a glucoside ester of elenolic acid and hydroxytyrosol. Oleuropein has been reported to have significant health benefits, including antioxidant, cholesterol-lowering, cardioprotective, anti-inflammatory, hypoglycemic, and antimicrobial properties [42]. The wide profile of polyphenols in olive leaves gives OLE great potential as a natural antioxidant. OLE has been incorporated as an antioxidant in several food matrices, such as edible oils, frying oils, table olives, meat, and meat products [43–46]. Moreover, Elsayed et al. [47] utilized an OLE coating incorporated with a zinc/selenium oxide nanocomposite to enhance the postharvest quality of green bean pods; they concluded that by using 3% OLE with zinc, the green bean pods' shelf-life increased to 28 days in cold storage, and all attributes improved compared to the other treatments or controls. In addition, guava (*Psidium guajava* L.) leaf extract (GLE) contains several bioactive compounds, especially phenolic compounds that contribute to antioxidant and anti-inflammatory properties [48,49]. However, quercetin is the most potent antioxidant found in GLE [48,50]. Guava leaves are traditionally used to treat gastrointestinal ailments (e.g., diarrhea, stomach pain, gastroenteritis, indigestion, and dysentery) and dermatological problems (e.g., skin infection, skin aging, and ulcers).

Pectin sachets were prepared from lime peel pectin integrated with coconut water and lime peel extract, and they were used to retard soybean oil's oxidation; the obtained results indicated that the pectin sachets retarded the soybean oil's oxidation for 30 days of storage [41].

Due to the lack of previous works, as well as the potential functionality of OLE and GLE that contribute to the shelf-life and preservation of food, both materials were used in

this study as film functionality materials. The main objective of this project was therefore to utilize OLE and GLE at different concentrations in pectin-based films, and to evaluate their contributions to the obtained films, which were used to prepare soluble sachets that were used in this study as filling sachets for chicken stock powder.

2. Materials and Methods

2.1. Materials

Olive leaves were collected from olive trees in Ramallah/West Bank, Palestine, in October 2021. The leaves were collected, washed with tap water, and then dried for 30 days at room temperature (25–30 °C). The leaves were then ground until a fine powder (0.1 to 0.6 mm) was obtained.

The guava leaf samples used in this study were obtained from guava trees in Qalqilya/West Bank, Palestine. The leaf samples were washed with tap water and dried for 30 days in a dry place at room temperature (25–30 °C). The samples were milled and sieved after drying. Particles ranging from 0.1 to 0.6 mm in size were chosen for the extractions. Prior to the extraction, the samples were placed in plastic bags and stored in a dark, dry area. Food-grade vegetable glycerol (GLY) was purchased from Heartlandvapes LLC., Owasso, OK, USA.

2.2. Preparation of Olive and Guava Leaves Extracts

OLE and GLE were extracted following the methodology outlined by Annegowda et al. [51], with certain modifications. Then, 10 g of leaf powder from each material was combined with 100 mL of ethanol in a beaker. The mixture was subjected to sonication for a duration of 2 h, while maintaining the solvent surface at room temperature. Subsequently, the residues were dissolved in ethanol and subjected to another round of extraction. The resulting extracts were filtered using vacuum filtration and Whatman filter paper, followed by concentration using a rotary evaporator set at 50 °C. After that, the crude extract was dried in a freeze-dryer. Finally, the obtained extract was sieved through a stainless steel sieve (with a mesh size of 425 µm) provided by Octagon Digital Endecotts Limited (Lombard Road, London, UK) until a fine powder was obtained. The extraction yield of OLE was about 9.0%, while that of GLE was 11.0%.

2.3. Film Preparation with Olive and Guava Leaf Extracts

Citrus PEC stock solution (2.0 g) was added to 100 mL of distilled water and completely solubilized. A film-forming solution (FFS) containing 0.1 and 0.2 w/v of OLE or GLE was added and continuously stirred for 30 min at room temperature. Then, GLY (30% w/v relative to PEC) was added to the FFS as a plasticizer. The concentrations of both OLE and GLE were chosen in accordance with the preliminary investigation, wherein varying concentrations of 0%, 0.05%, 0.1%, 0.2%, and 0.4% (w/v) were employed. The obtained film samples were subsequently analyzed for their mechanical properties and color characteristics. After careful evaluation, it was found that the lower concentrations (0.05% w/v) did not show any significant effect on the film properties. However, the higher concentrations (0.4% w/v) had an unwanted effect on the color of the films, which became more greenish, opaque, and rigid. Therefore, the concentrations of 0.1% and 0.2% (w/v) were deemed suitable and selected for further experimentation. The final volume was adjusted to 50 mL using distilled water, and then the FFSs were poured onto 8 cm diameter polystyrene Petri dishes and dried in a drying chamber at 30 °C for 12 h. The dried films were peeled off from the Petri dishes and then placed inside a desiccator (50%–55% RH) containing a saturated solution of $Mg(NO_3)_2 \cdot 6H_2O$ for 2 h before analysis of the properties of the prepared films.

2.4. Film Characterization

The effects of OLE and GLE at two different concentrations (0.1, 0.2% w/v) on the films' mechanical properties—including tensile strength (TS), elongation at break (EB), and

Young's modulus (YM)—were measured using a universal testing instrument (Brookfield CT3 Texture Analyzer, model CT3 50K, Brookfield, Chandler, AZ, USA), as described by [8]. The dry films were used for testing the mechanical properties. The films were cut into strips (10 mm wide) and then loaded between the grips of the CT3 Texture Analyzer and tested, with an initial grip separation of about 50 mm and a speed of 0.5 mm/s. At least six strips from each film were tested, and the experiment was repeated three times at a different intervals.

The thickness of the obtained films was tested using a micrometer screw gauge (0–25 mm), where at least 6 different points from the whole films were measured.

The ability of the films to scavenge DPPH free radicals was tested as described by Famiglietti et al. [43]. Briefly, 20 mg of each film was solubilized in 500 mL of distilled water, and then 100 mL of each solution was mixed with 900 mL of DPPH (0.05 mg/mL methanolic solution). After the samples were kept in the dark for 30 min at 25 °C, the absorbance at 517 nm was measured using a UV–visible Spectrophotometer (SmartSpec 3000 Bio-Rad, Segrate, Milan, Italy), where methanol was used as a blank and a sample with methanol was added to DPPH solution as a control. The antioxidant activity of the films was calculated based on the following equation:

$$\%\text{DPPH scavenging activity} = (A_{control} - A_{sample}/A_{control}) \times 100 \quad (1)$$

where A is the absorbance value of the control and the sample at 517 nm. Each sample was measured in triplicate.

Tonyali et al. [52] and Famiglietti et al. [43] provided insights into measuring the films' opacity. In accordance with their methods, the films were measured six times for each sample. The opacity of the films was then calculated using the following equation:

$$\text{Opacity } (\text{mm}^{-1}) = A600/x \quad (2)$$

where $A600$ is the absorbance of the sample at 600 nm, and x is the film thickness (mm).

The moisture content of the film was determined as described by Galus and Lenart [53], by measuring the mass loss of one gram after 24 h of oven drying at 105 °C and expressing it as a percentage. The weight gain of each specimen after 24 h at 50% RH was used to determine the ability of the specimen to absorb moisture. A total of 3 specimens (2 cm^{-2}) were cut from the films and weighed ($W1$), and then the films were dried in the oven at 105 °C for 24 h before being weighed again ($W2$). Following conditioning at 25 °C and 50% RH for 24 h, the film samples were weighed once more ($W3$) after being placed in a desiccator over a saturated solution of $Mg(NO_3)_2$ $6H_2O$.

Water content and uptake were calculated according to the following formulae:

$$\text{Water content } (\%) = \frac{W1 - W2}{W1} \times 100 \quad (3)$$

$$\text{Water uptake } (\%) = \frac{W3 - W2}{W3} \times 100 \quad (4)$$

The color values of the developed films were measured with a colorimeter (chroma Meter Konica Minolta CR-400, Japan) using the CIE color scale to evaluate the parameters L* (lightness/brightness, which ranges from 0 to 100), a* (redness/greenness), and b* (yellowness/blueness) (the two chromatic components, which range from −120 to 120) [54].

The films' barrier properties against water vapor (WV), O_2, and CO_2 were analyzed by means of a MultiPerm apparatus (ExtraSolution s.r.l, Pisa, Italy). The measurements were performed in duplicate for each film (50% RH, 25 °C) according to ASTM F1249-13 [55], ASTM D3985-05 [56], and ASTM F2476-05 [57]. Before testing, the film specimens were conditioned for 24 h at 50% RH and placed in aluminum masks to reduce the film test area to 2 cm^2.

2.5. Sachet Application Experiment

The obtained films (control, pectin with 0.2% OLE, and pectin with 0.2% GLE), were folded and heat-sealed on two sides using a kitchen sealer machine, and then the sachets were filled to the top with about 18–20 g of chicken stock powder before being heat-sealed. Finally, boiling water was prepared, and the sachets was added to the boiling water and stirred until they completely dissolved.

2.6. Statistical Analysis

The obtained data were statistically analyzed using JMP software (SAS Institute, Cary, NC, USA, version 5.0). The data were subjected to analysis of variance (ANOVA), and the means were compared using the Tukey–Kramer HSD test. Differences were considered to be significant at $p < 0.05$.

3. Results and Discussion

3.1. Effect of Incorporation of OLE and GLE in Pectin-Based Films on Thickness and Opacity

Pectin-based films modified with olive leaf extract (OLE) or guava leaf extract (GLE) were obtained at different concentrations (0.1% and 0.2% w/v) in the presence of 30% glycerol (GLY) as a plasticizer. Figure 1A shows the visual observation of the obtained films compared to the control film containing only pectin (PEC). The addition of GLE or OLE increased the greenish color of the pectin films, with a higher intensity observed in the films containing GLE. Previous research has shown that GLE significantly increased the film color compared to the control [58]. This suggests that the differences in the chemical structure of natural pigments and phenolic compounds between GLE and the control may be responsible for the differences in film color [59,60].

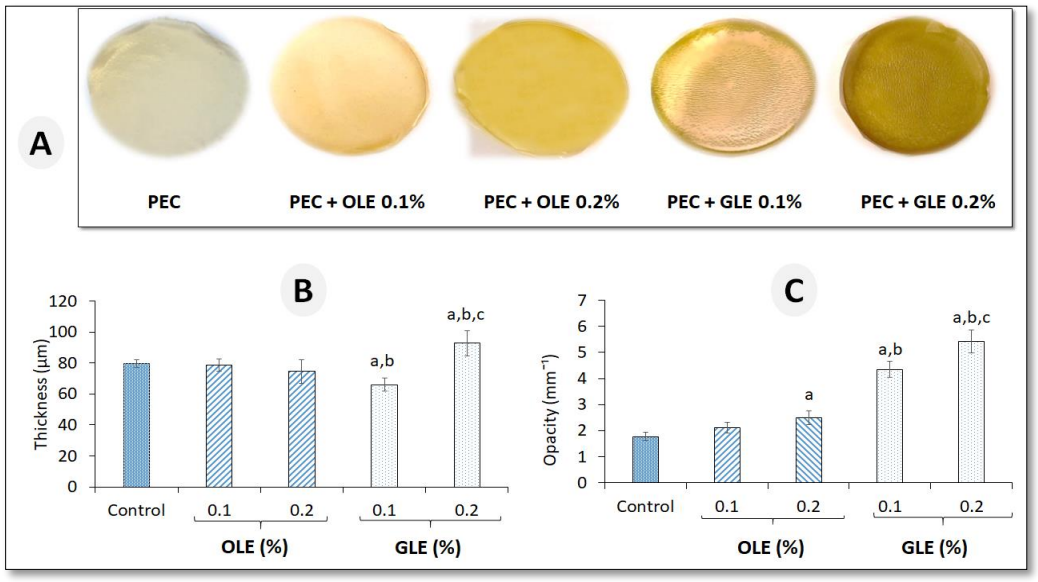

Figure 1. Effects of using OLE and GLE at different concentrations (0.1 w/v and 0.2 w/v) on pectin-based films: observation (**A**), thickness (**B**), and opacity (**C**). The values that are significantly different from the control are indicated by "a" ($p < 0.05$); the values indicated by "b" are significantly different ($p < 0.05$) from films obtained with different materials at the same concentration; the values indicated by "c" are significantly different ($p < 0.05$) from the films obtained with the same material at different concentrations.

Film thickness was also determined, and the results (Figure 1B) indicated that modifying the pectin with OLE did not change the film thickness compared to the control. However, when 0.2% GLE was used, the film thickness significantly increased compared to the control and the films obtained with OLE. This can be explained by the ability of

GLE to increase the intermolecular forces among pectin polymer chains [61]. Moreover, there is no clear explanation for why GLE has different effects on film thickness at different concentrations. In fact, it is thought that the GLE interacts with the pectin molecules differently depending on the concentration. We could hypothesize that when the GLE is present at low concentrations (0.1% w/v), it may be able to penetrate between the pectin molecules and disrupt their interactions. The films would become less thin as a result. At higher concentrations (0.2% w/v), the GLE may not be able to penetrate between the pectin molecules, instead forming a layer on the surface. The films would be thickened as a result.

Additionally, the opacity of the films significantly increased with increasing concentrations of OLE or GLE. Notably, in the films containing 0.2% OLE, the opacity was significantly higher compared to the control film. Similarly, when GLE was used, the results indicated that the film's opacity was twice that of the control film or the films containing OLE (Figure 1C).

3.2. Films' Mechanical Properties

The obtained films were also characterized for their mechanical properties, including tensile strength (TS), elongation at break (EB), and Young's modulus (YM). The results, reported in Figure 2, showed that the addition of either OLE or GLE at different concentrations did not significantly affect the TS value. However, the EB result was significantly lower than that of the control films only in the pectin films prepared with 0.1% GLE. The YM of the films significantly decreased in the films prepared with either OLE or GLE compared to the control film containing only PEC. This indicates that increasing the concentration of OLE or GLE led to a significant decrease in YM.

Luo et al. [62] investigated the incorporation of different concentrations of GLE into a sodium-alginate-based material, and they found that adding GLE to sodium alginate significantly increased the TS and significantly decreased the EB compared to the control film obtained using only sodium alginate. This obtained result is consistent with the results obtained recently by Chou et al. [58], where they incorporated GLE into fish skin gelatin. Moreover, according to some studies, excessive proportions of the extracts may result in uneven dispersion in the mixture [62,63]. Plant oils reduce the intermolecular forces between polymer chains, decreasing the films' strength and increasing their flexibility [61].

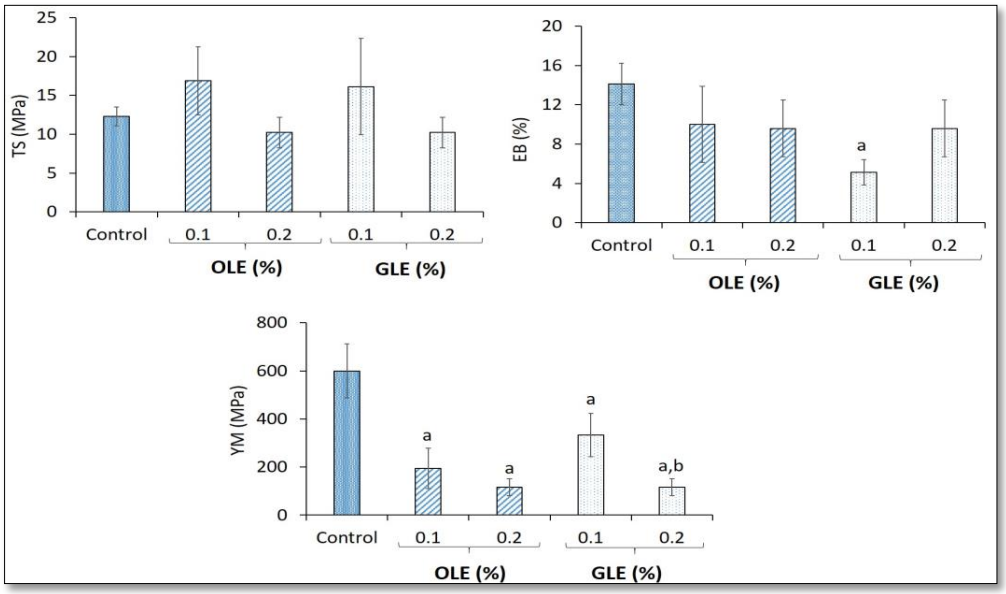

Figure 2. Effect of using OLE and GLE at different concentrations (0.1 w/v and 0.2 w/v) on the mechanical properties (TS, EB, and YM) of pectin-based films. The values that are significantly different from the control are indicated by "a" ($p < 0.05$), while the values indicated by "b" are significantly different ($p < 0.05$) from the films obtained with the same material at a different concentration.

3.3. Antioxidant Activity

The DPPH radical scavenging abilities of the obtained films were evaluated, and the results were compared with the control film that was prepared from only pectin and glycerol. The results are reported in Figure 3. According to many studies, PEC films do not have antioxidant activity naturally; in this context, OLE and GLE have previously been recognized for their antioxidant activity, and they have higher antioxidant activities compared to other materials [42,48,49,62,64]. The pure OLE and GLE were evaluated at two different concentrations (150 and 300 ppm), and the results were 67 ± 1.8% and 76 ± 1.8%, respectively, for OLE, and 61 ± 1.9% and 82 ± 1.2%, respectively, for GLE. The results indicated that when the concentration of pure OLE or GLE increased, the antioxidant activity increased, and GLE at 300 ppm showed the highest activity, reaching 82%, as compared to 76% for OLE. Moreover, the obtained films were evaluated to study the effects of the addition of OLE or GLE to the pectin film-forming solution on the film's antioxidant activity. The obtained results indicated that by increasing the proportion of OLE or GLE from 0.1 to 0.2% *w*/*v*, the DPPH radical scavenging abilities of the films were significantly improved compared to the control film. The addition of 0.2% (*w*/*v*) OLE to the films showed significantly higher activity compared to the control and to the 0.1% *w*/*v* OLE. Moreover, the incorporation of GLE into the films indicated that these films had higher antioxidant activity compared with the OLE at the same concentration. This increased activity may be attributed to the presence of quercetin, which is classified as the most potentially powerful antioxidant compound [48,49]. Similar results were found by Albertos et al. [64] when they evaluated the effects of the addition of different concentrations of OLE to gelatin-based films to enhance the quality of cold smoked salmon, and they reported that increasing the OLE concentrations also increased the antioxidant activity. The addition of OLE and OLE to packaging materials can significantly increase their antioxidant capacity, which can help to protect food from oxidation and deterioration.

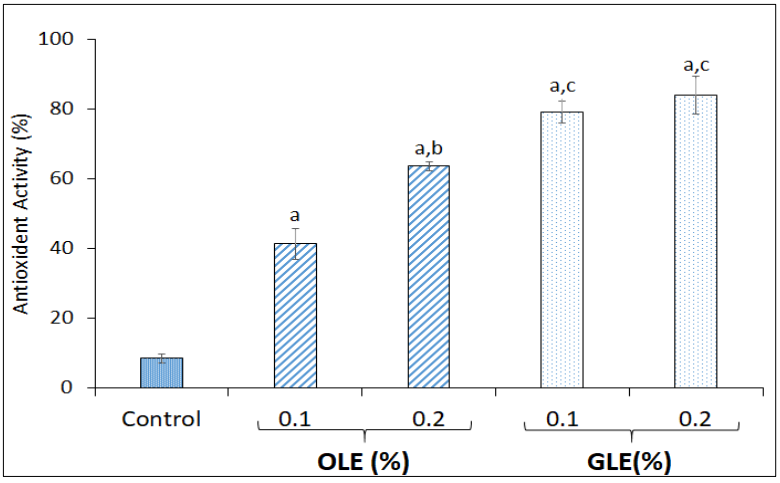

Figure 3. Effects of using OLE and GLE at different concentrations (0.1 *w*/*v* and 0.2 *w*/*v*) on the antioxidant activity of pectin-based films. The values significantly different from the control are indicated by "a" ($p < 0.05$); the values indicated by "b" are significantly different from the others films obtained with the same material (OLE); the values indicated by "c" are significantly different from the films made of OLE or GLE at a concentration of 0.1% or 0.2% ($p < 0.05$).

3.4. Water Content and Water Uptake

The effects of the incorporation of different concentrations of OLE and GLE on the water content and uptake of pectin-based films were measured, and the results are reported in Figure 4. The results show that OLE and GLE do not have a significant influence on the film's moisture content at any concentration. However, the moisture uptake of the pectin films modified with GLE increased significantly compared to the control film prepared

from pectin alone or the pectin-based films containing OLE. The highest moisture uptake was found in the film that contained 0.2% GLE, reaching 20.20 ± 1.80%, while the control film had about 13.90 ± 0.88% moisture uptake. Luo et al. [62] prepared sodium alginate films incorporating GLE and concluded that films containing GLE tended to have lower moisture content than the control films. Similar results were found by adding grape juice to protein-based films, where the moisture content did not change with increasing grape juice concentration [8].

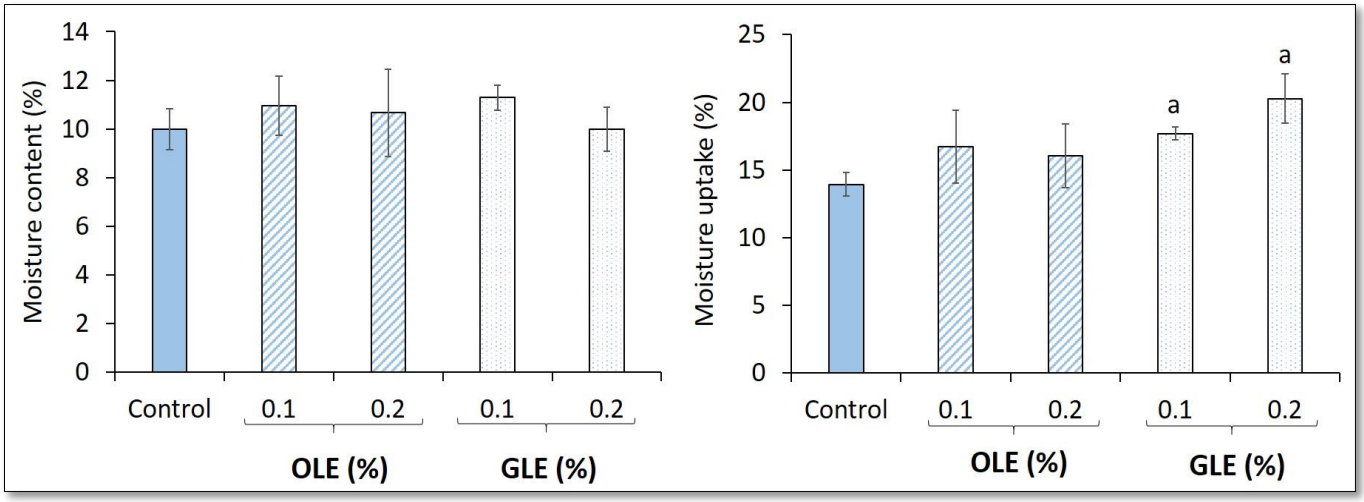

Figure 4. Effects of using OLE and GLE at different concentrations (0.1 w/v and 0.2 w/v) on the water content and water uptake of pectin-based films. The values that are significantly different from the control are indicated by "a" ($p < 0.05$).

3.5. Effects of OLE and GLE on the Color of Pectin-Based Films

The effects of adding different concentrations of OLE and GLE on the color of pectin-based films are shown in Table 1. The L* values of the films containing OLE (0.1 and 0.2% w/v) were significantly increased compared to the control, indicating that the films were lighter. In contrast, the L* values of the films containing GLE decreased significantly compared to the control and the films containing OLE, indicating that these films were darker. The a* value, which indicates greenness, was significantly changed in the films modified with OLE and GLE.

Table 1. Effects of different concentrations of OLE and GLE on pectin-based films' color.

Films	L*	a*	b*
PEC (control)	83.44 ± 0.09	−3.09 ± 0.04	17.41 ± 0.30
PEC + OLE 0.1%	85.02 ± 0.05 ^{A}	−1.50 ± 0.01 ^{A}	11.13 ± 0.17 ^{A}
PEC + OLE 0.2%	86.92 ± 0.14 ^{A,B}	0.72 ± 0.04 ^{A,B}	3.36 ± 0.29 ^{A,B}
PEC + GLE 0.1%	79.83 ± 0.91 ^{A,D}	−2.01 ± 0.03 ^{A,D}	21.76 ± 1.80 ^{A,D}
PEC + GLE 0.2%	74.89 ± 0.38 ^{A,C,D}	−3.08 ± 0.11 ^{C,D}	34.50 ± 0.43 ^{A,C,D}

The values that were significantly different from the controls are indicated by "^{A}" ($p < 0.05$), while the values indicated by "^{B}" were significantly different from the films obtained with OLE ($p < 0.05$), the values indicated by "^{C}" were significantly different from the films obtained with GLE ($p < 0.05$), and the values indicated by "^{D}" were significantly different from the films made of OLE or GLE at a concentration of 0.1% or 0.2% ($p < 0.05$). Further experimental details are given in the text.

The films containing OLE were greener than the control films, and the films containing GLE were even greener. However, the b* value, which indicates yellowness, decreased significantly when the concentration of OLE was increased. This indicates that the films became less yellow. In contrast, the b* value was significantly increased when GLE was incorporated into the pectin films. This indicates that the films became more yellow. In conclusion, the addition of GLE to the films resulted in a darker, more greenish, and more

yellowish color. These findings explain the opacity results reported in Figure 1C. The obtained results are consistent with the results achieved by [62,63].

3.6. Permeability Properties

Table 2 reports the effects of the incorporation of OLE or GLE at different concentrations on the gas (CO_2 and O_2) and water vapor (WV) permeability of the pectin-based films. The permeability of the films that contained either OLE or GLE was higher toward all gases and WV compared to the control film (pectin alone). Gradually, the CO_2 permeability significantly increased when the OLE concentration increased. On the other hand, when increasing the concentration of OLE or GLE, the WV permeability of the films remained almost constant. The obtained results show a lower permeability toward CO_2 compared to Viscofan NDX—the commercial casing material used for processed meat products—and a similar value of O_2 permeability but a higher WV permeability. The WV permeability of films is a function of both the molecular diffusion coefficient and the water solubility of the film material [65]. The obtained results are consistent with those previously obtained by [64], who concluded that the addition of 3.75 and 5.63% OLE to gelatin-based films increased the WV permeability significantly, which they explained as being due to the increasing film thickness and the water solubility factor. However, the obtained results could also be explained by the presence of phenolic compounds that may accumulate in the polymer matrix and form voids, which can lead to higher WV permeability values compared to films that do not contain phenolics [62,66].

Table 2. Gas and water vapor (WV) permeability of 1% PEC films prepared in the presence of different concentrations of OLE or GLE with 30% GLY.

Films	CO_2	O_2	WV
	$cm^3 \cdot mm \cdot m^{-2} \cdot day^{-1} \cdot kPa^{-1}$		$g \cdot mm \cdot m^{-2} \cdot day^{-1} \cdot kPa^{-1}$
PEC *	0.08 ± 0.03	0.01 ± 0.00	0.12 ± 0.01
PEC + OLE 0.1%	0.15 ± 0.02 ^{A}	0.01 ± 0.00	3.87 ± 0.76 ^{A}
PEC + OLE 0.2%	0.35 ± 0.01 ^{A,B}	0.05 ± 0.00 ^{A,B}	4.64 ± 0.02 ^{A}
PEC + GLE 0.1%	0.31 ± 0.05 ^{A}	0.05 ± 0.00 ^{A}	4.64 ± 0.11 ^{A}
PEC + GLE 0.2%	0.37 ± 0.01 ^{A,B}	0.04 ± 0.00 ^{A}	3.45 ± 0.79 ^{A}
Viscofan (NDX) **	3.71 ± 0.16	0.03 ± 0.01	0.08 ± 0.01

* Data from Al-Asmar et al. [19]; ** data from Porta et al. [67]. The values that are significantly different from the control are indicated by "^{A}" ($p < 0.05$); the values indicated by "^{B}" are significantly different ($p < 0.05$) from the films obtained with the same material at different concentrations.

3.7. Film Application as a Soluble Sachet for Chicken Stock Powder

One of the important issues related to this type of research is the application of the obtained films that are prepared based on pectin—a well-known material made from citrus peels. OLE and GLE are both natural compounds that have antioxidant and antimicrobial properties. When these extracts are incorporated into pectin films, they improve the film's antioxidant and promising barrier properties, which will potentially extend its shelf-life. This is an active area of research, and more work is needed to understand it fully.

In this study, the obtained materials were kept for up to one year at room temperature, and the films' properties were evaluated the obtained results were extremely promising. Therefore, pectin films that contain OLE or GLE are promising for use as soluble sachets for chicken stock powder. A soluble sachet is a type of packaging that is made from a material that dissolves in water. This allows the food product to be easily poured out of the sachet, without the need for a separate container. Soluble sachets are a convenient and environmentally friendly alternative to traditional packaging materials such as plastic and foil. Pectin films containing OLE or GLE are sustainable and innovative materials that can be used as soluble bags for chicken stock powder (Figure 5). These films have the potential to improve the quality and shelf-life of chicken stock powder while also reducing environmental impacts. As shown in Figure 5, the pectin sachets were prepared and heat-

sealed using the kitchen sealer machine, and chicken stock powder was transferred from commercial plastic foil to our sachets and then added to boiling water to demonstrate their solubility. The sachets were completely dissolved within a few seconds in boiling water, and the chicken stock was ready to use. As a result, pectin films that contain GLE or OLE are promising and warrant further research.

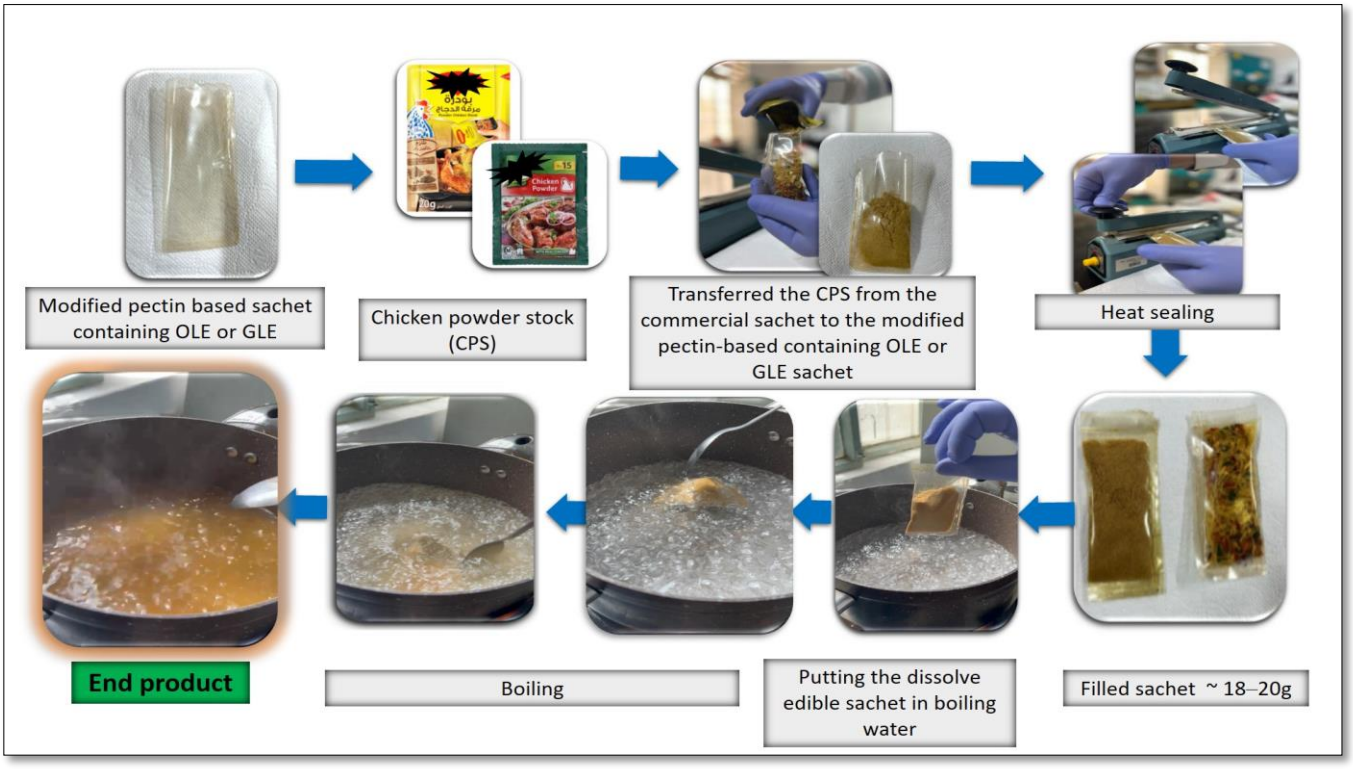

Figure 5. Scheme demonstrating the preparation and use of the pectin sachets containing OLE or GLE filled with chicken stock powder and dissolved in boiling water.

4. Conclusions

In conclusion, natural antioxidants and antimicrobials are becoming increasingly important today due to the worldwide strategy to reduce the use of synthetic additives in our foods. In this work, we successfully functionalized pectin films by incorporating OLE or GLE. The films produced in this study showed lower water vapor permeability than the commercial casing used for processed meat. Additionally, the results indicated a higher antioxidant level compared to the pectin film obtained without OLE or GLE. This helps to reduce the oxidation reactions that can occur during food distribution and storage. This suggests that the obtained films had a significant impact on extending the food's shelf-life. Finally, the films were used to produce soluble sachets filled with chicken stock powder, which was used to prepare soup.

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