Polímeros
ISSN 1678-5169 (Online)

https://doi.org/10.1590/0104-1428.20230068

ORIGINAL ARTICLE

# Consumer perception of biodegradable packaging for food

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**Abstract**

Most of the discarded plastics originate mainly from food and beverage packaging, thus the consumer's perception of biodegradable packaging must be understood. This study aimed to investigate the consumer perception of biodegradable packaging films made of pectin and whey protein isolate. An online questionnaire was conducted to assess the consumer responses. Results showed that the majority of consumers (77.3%) did not observe the biodegradability of the packaging during purchase, although biodegradable packaging can positively affect the purchase decision (71.9%). The acceptance, purchase intention, and preference are influenced by visual aspects, and the consumers preferred lighter and more transparent films, with less saturated colors. Consumers established correlations between color and transparency with film thickness and resistance, these correlations were not observed in the physical analysis of the film. In addition, a variety of applications were highlighted for the films produced, demonstrating the effectiveness of these materials for food and beverage packaging.

**Keywords:** *application, cata, environmental awareness, preference ordering.*

**How to cite:** Oliveira, A. C. S., Ribeiro, M. N., Ugucioni, J. C., Rocha. R. A., & Borges, S. V. (2023). Consumer perception of biodegradable packaging for food. *Polímeros: Ciência e Tecnologia*, *33*(4), e20230045. https://doi.org/10.1590/0104-1428.20230068

## 1. Introduction

The world consumption of plastic is estimated at more than 700 million tons per year and can reach one billion tons in 2021[1,2]. Packaging materials account for most of the amount of non-biodegradable plastics of non-renewable origin, improperly discarded. Thus, there is a depletion of fossil materials with a substantial increase in the use of petroleum-based plastics[1-4]. These aspects have encouraged research on the development of plastic materials from ecologically favorable or "environmentally friendly" polymers[3-5].

Human beings' multiple senses (touch, smell, hearing, sight, and taste) are used to experience and explore the environment and are interpreted by the brain[6]. The association between the stimuli, the attributes, or the sensory modalities is called crossmodal correspondences[7,8]. By incorporating intermodal correspondences to packages, they no longer have only the function of e. g. containing portions and protecting the product[9-11].

Consumers' perception of food, beverages, and packaging has changed over time, mainly due to unlimited access to information. Fact-based, it is noticeable that consumers have been aware of the various environmental issues arising from the consumption behavior of society[12].

The growing environmental concern among consumers regarding food and beverages also includes packaging materials. Most consumers consider packaging as something integrated with food, being considered a residue after consumption. The concern about proper waste disposal has influenced consumers, who have recognized the importance of adequate disposal of food and beverage packaging[13].

One of the ways to assess consumers' perceptions is through a picture associated with online or offline questionnaires. Online questionnaires are advantageous because data collection takes place in short periods, with reduced cost for data collection due to the possibility of using a computer, smartphone, or tablet, in addition to enabling remote data storage and quick visualization[14,15].

In this sense, the study aimed to evaluate, through online questionnaires, the consumer's perception of biodegradable packaging films made from pectin (Pec) and whey protein isolate (WPI) by extrusion/thermo-compression.

## 2. Materials and Methods

This study was approved by the Ethics Committee of the Federal University of Lavras (CAAE: 40665320.4.0000.5148).

### *2.1 Material*

Pectin with 75.7% degree of esterification was supplied by Dinâmica Química Contemporânea (Indaiatuba, São Paulo, Brazil). WPI with 90% protein was purchased from Hilmar Ingredients (Turlock, USA). Stearic acid (95% purity) was purchased from Exodus Científica (São Paulo, São Paulo, Brazil). Glycerol (99.5% purity) and citric acid (99.7% purity) were purchased from Sigma Aldrich (São Paulo, São Paulo, Brazil).

### 2.2 Production of the films

The films were produced by extrusion/thermo-compression as reported previously[4]. The mixture to prepare the extruded material contained 49% polymer, 30% glycerol, and 21% distilled water (w/w). The Pec and WPI concentrations are: $Pec_{100}WPI_0$ (100% m/m Pec), $Pec_{95}WPI_5$ (95% m/m Pec and 5% m/m WPI), $Pec_{90}WPI_{10}$ (90% m/m Pec and 10% m/m WPI), $Pec_{85}WPI_{15}$ (85% m/m Pec and 15% m/m WPI), $Pec_{80}WPI_{20}$ (80% m/m Pec and 20% m/m WPI), these values based on tota polymer mass. The citric acid (1.5%, w/w) and stearic acid (1%, w/w) were used to protect against oxidation and prevent agglomeration of the material. The reagents were homogenized in an industrial blender with a stainless steel beaker, at high speed, 1.5-liter capacity, 800 W power, and 60 Hz rotation (Metalúrgica Skymsen Ltda, Santa Catarina, Brazil). The mixture was extruded in a co-rotating twin-screw extruder (model SJSL 20, NZ Phil Polymer), with L/D = 40, and screw diameter (D) = 20 mm equipped with seven heating zones. The temperature profile from the feeder to the die was 35/50/75/95/100/100/90 ºC, and the screw speed was adjusted to 100 rpm. The extruded material was pelletized (2 mm pellets) using an automatic pelletizer operating at 120 rpm. The films were produced by a hydraulic press (model 370M015, Matoli, Brazil) using 10 g of pellets at 110 ºC for 5 times 5 ton/3 seconds, and 2 times 5 ton/3 minutes. Films about 15 cm in diameter were produced and cooled to room temperature.

### 2.3 Characterization of the films

The films were conditioned at 23 ± 2 ºC and 50 ± 5% RH for 48 hours before characterization[16]. The average film thickness was measured at 10 different points, using a 0.01 mm Mitutoyo digital micrometer (Mitutoyo, Suzano, Brazil).

The mechanical properties were determined through a tensile strength test, using a TATX2i Micro System Texture Analyzer (England) with a 1 kN load cell. The samples were cut into 10 $cm^2$ strips, according to ASTM-D882[16], and the measurements were carried out starting from an initial separation of 50 mm and a test speed of 0.8 mm/s. Tensile strength (TS, MPa), elongation at break (E), and modulus of elasticity (ME, MPa) were determined.

The colorimetric parameters were determined using the CIE Lab system in a CM-5 Konica Minolta spectrophotometer (Konica Minolta, Tokyo, Japan) with D65 illuminant, observation angle of 10°. The parameters luminosity (L*), saturation or chroma (C*), a* (green to red), and b* (blue to yellow) were determined[17].

The total color difference (ΔE) of the films was determined by Equation 1[17]:

$$\Delta E = \sqrt{(L1 - L2)^2 + (a1 - a2)^2 + (b1 - b2)^2} \quad (1)$$

where, L1 is the initial L value, a1 is the initial a* value, b1 is the initial b* value, L2 is the L value measured, a2 is the a* value measured, and b2 is the b* value measured. The values L1, a1, and b1 are fixed values and correspond to the sample $Pec_{100}WPI_0$.

The transparency of the films was measured using the Bel SPECTRO S-2000 spectrophotometer (Monza, Italy) at 600 nm[18]. The films (3 x 1.5 cm pieces) were fixed to allow the beam to pass through the specimens with no obstacles. The transparency (T) was calculated according to Equation 2:

$$T = (Log\%T) / \delta \quad (2)$$

where $\%T$ is transmittance percentage, and δ is the film thickness (mm).

### 2.4 Participants

The study was realized in 2020 with Brazilian consumers. All declared to use plastic packaging for food. No specific knowledge of biodegradable packaging was required. All participants declared to be 18 years of age or older at the time of the survey. They agreed to participate in this survey before voluntarily answering the online questionnaire. Participants were also informed that they could leave the questionnaire online at any time.

### 2.5 Images

Five Pec and WPI-based films made by extrusion/thermo-compression were photographed using a 4-megapixel digital camera in a white cabinet under artificial white light. The films were cut into 3 x 1.5 cm pieces. The camera and the films were positioned at 19.5 cm from each other, and the images were obtained using 4.0X magnification. The images were not submitted to digital treatment, to keep the colors as close as possible to the true colors of the films. The images are shown in Figure 1.

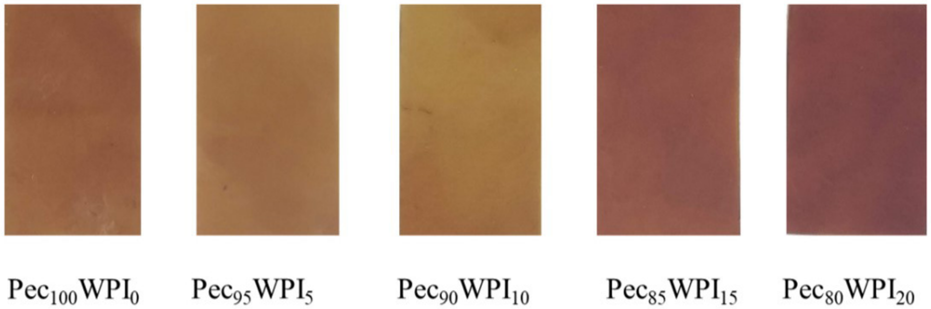


**Figure 1.** Images of thermo-plasticized Pec and WPI-based films.

### 2.6 Online questionnaire

Participants were asked to respond to an online questionnaire conducted on Google Docs, with an average response time of 10 min. Participants were contacted via email, social media, and smartphone communication apps. After accepting to participate in the research, participants were instructed to adjust the brightness of the monitor or device by 80% to standardize and minimize possible differences between monitors and devices. The choice for an online questionnaire was due to the restrictions imposed by the COVID-19 pandemic.

The consumers evaluated five different films, and the experiment was conducted with a completely balanced block design. All recruited consumers stated that they consume food packed in plastic packaging.

The questionnaire was divided into sessions. The first session contained questions: participants' age and education; packaging consumption habits; concept and consumption of biodegradable packaging; and the degree of importance of biodegradable packaging, color, appearance, and resistance of the packaging.

In the second session, the five images of Pec and WPI-based films were presented to the participants in a monadic way. The images were not identified so as not to influence the responses. The first questions were about the acceptance and the purchase intention. Then, consumers were asked to correlate the samples with previously selected attributes. After that, participants were informed about the origin and biodegradability of the materials used to produce the films, and, again, they were invited to answer about their purchase intention.

The third and final session included questions about participants' preferences and the foods or beverages they would package using the films.

It is noteworthy that all participants evaluated all films, and information was not provided on the material concentrations (Pec and WPI), so as not to interfere in the analysis of the images.

### 2.7 Data analysis

The results of the characterization of the films were analyzed by Analysis of Variance (ANOVA), using the SISVAR Software (version 5.6)[19] with a significance level of $p < 0.05$, and the results were compared using the Tukey's test. Three samples of each film were used, in three repetitions.

For the questionnaires, a descriptive and exploratory analysis of data was initially carried out to extract information about the consumption habits of the participants. Then, Tukey's test ($p < 0.05$) was performed to analyze the degree of importance of biodegradable packaging, color, resistance, and appearance at the time of purchase; acceptance of films; and the intention to purchase a packaged food using the featured films. To compare purchase intentions with or without further information about the material's biodegradability, a T-test was also performed at $p<0.05$. A 7-point scale ranging from "unimportant" on the left to "very important" on the right was used for the degree of importance. A 7-point scale ranging from "I really disliked it" on the left to "I really liked it" on the right of the scale was also used in the acceptance analysis. For the purchase intent test, a 5-point scale was used, ranging from "certainly would not buy" on the left to "certainly buy" on the right of the scale.

Then, correspondence analysis (Check-All-That-Apply, CATA) was performed to determine the association between the films and the descriptors. In this analysis, consumers are invited to choose all possible attributes from a previous list of attributes raised by a focus group[20] composed of consumers of conventional packaging (non-biodegradable) and consumers of biodegradable packaging. Focus group was developed according to the methodology proposed by Krueger and Casey[21] and members consumers of biodegradable packaging. Focus group members only had access to the images that make up the questionnaire. The following attributes were listed: light brown, dark brown, dark, woody, natural, unprocessed, smooth, rough, shiny, transparent, opaque, yellowish, thin, thick, tough, fragile, in addition to the term "others", in which consumers could report other attributes observed.

A hierarchical grouping was also performed using the same ones used for CATA, that is, without treatment.

In the preference ordering test, consumers were asked to rank the films according to the order of preference, with samples sorted from most preferred to least preferred. The samples were identified with random 3-digit numbers and were presented randomly, that is, without ascending or descending order of WPI concentration. Of the 556 consumers who responded to the online questionnaire, only 434 responded to the order of preference. Scores were used according to the order of preference, ranging from 5 for the most preferred sample and 1 for the least preferred sample. Thus, considering the total number of consumers who responded to the order of preference, the highest sum of possible scores for a sample was 2170, while the lowest possible score was 434. The sum values of each sample demonstrate how preferred the sample was by the survey respondents. The samples were also submitted to the Friedman test ($p < 0.05$), which is a non-parametric bi-directional analysis of variance to compare several related samples, using the rows rather than raw data for statistical calculation[20].

Finally, consumers were asked to suggest possible foods and beverages that could be packaged using the studied films. For that, a list of foods and beverages made by the same focus group of the CATA analysis was presented. The list also contained the term "others", in which consumers could include any food or beverage not mentioned on the list. In addition, consumers could mark as many items on the list as they deemed necessary. Data analysis was performed using the R software version 3.5.2.

## 3. Results and Discussions

### 3.1 Characterization of the films

As can be seen in Table 1, the addition of WPI led to a reduction in film thickness probably due to the crosslinking effect resulting from the Maillard reaction[22]. Concerning the mechanical properties of the films, no difference was observed between the parameters Tensile Strength (TS), Modulus of Elasticity (ME), and Elongation at Break (E).

These results demonstrate that the addition of WPI and, consequently, the Maillard reaction was not able to negatively affect the mechanical properties. WPI-based films showed mechanical parameter values greater than or equal to the films without the addition of WPI ($Pec_{100}WPI_0$). These results are due to the increase in intermolecular interactions provided by the thermo-compression process and the protein cross-linking promoted by the Maillard reaction[22-24].

Table 2 presents the results of the optical parameters and transparency of extruded/thermo-compressed Pec and WPI-based films. The L* values (luminosity) indicate an intermediate luminosity, that is, films are neither black nor white. The C* values (Chroma) characterize films with high color saturation, while positive a* and b* values indicate reddish and yellowish samples[17]. In the present study, significant differences were observed for the color parameters (L*, C*, a*, and b*) only for the sample $Pec_{100}WPI_0$ ($p < 0.05$) when compared with the other treatments. This result may be due to the Maillard reaction, due to the presence of an amino group of protein from WPI, and the reducing sugar of the polysaccharide (Pec) +under controlled conditions of dry heating[25].

According to Ramos and Gomide[17], ΔE values above 5 are easily detectable to the human eye, and values between 3.0 and 5.0 show "very easy" perception. Thus, the results of ΔE showed that the color difference between the films can be perceived by the naked eye.

Although the Transparency (T) values were relatively low, it was possible to visualize the product packaged by the films under study. As observed for the other colorimetric parameters, the transparency was affected by the addition of WPI and, consequently, by the Maillard reaction, which is a non-enzymatic browning reaction.

### *3.2 Social analysis and consumer habits*

The social characteristics of the participants and the frequencies (sex, age, and education status) are described in Figure 2. Most of the individuals who answered the questionnaire were female (72.3%), aged from 26 to 50 years (61.1%), and completed post-graduate degree (49.1%).

Table 3 presents the profile of the participants concerning their habit of consuming biodegradable packaging. The results showed that 60.5% of the participants consumed plastic packaging at least once a day. This high frequency is confirmed by the high annual worldwide consumption of plastics, which are largely used as packaging material[1-4].

Almost all consumers (94.2%) stated that they knew about biodegradable packaging. When asked about the meaning of the expression "biodegradable packaging", they showed knowledge about the concept. Many of them reported that it may be packaging that decomposes quickly and naturally, with no adverse effects on the environment. These results can be explained by the unlimited access to information with the popularization of the internet[12]. Most consumers who responded to the online questionnaire had higher education and postgraduate degrees, with greater access to information, in addition to being able to understand several concepts such as biodegradable packaging.

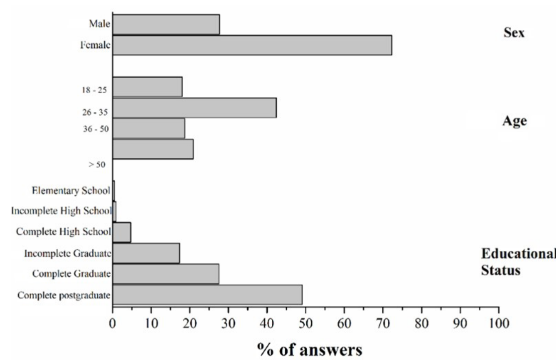


**Figure 2.** Social characteristics of consumers.

**Table 1.** Thickness, Tensile Strength (TS), Modulus of Elasticity (ME), and Elongation at Break (E) of extruded/thermo-compressed Pec/WPI-based films.

| Samples | Thickness (µm) | TS (MPa) | ME (MPa) | E (%) |
|---|---|---|---|---|
| $Pec_{100}WPI_0$ | 0.435 ± 0.008 $^a$ | 4.89 ± 0.87 $^a$ | 0.40 ± 0.01 $^a$ | 282.93 ± 7.51 $^a$ |
| $Pec_{95}WPI_5$ | 0.394 ± 0.027 $^{ab}$ | 6.30 ± 0.63 $^a$ | 0.44 ± 0.15 $^a$ | 276.85 ± 4.07 $^a$ |
| $Pec_{90}WPI_{10}$ | 0.381 ± 0.046 $^b$ | 6.07 ± 0.39 $^a$ | 0.42 ± 0.03 $^a$ | 281.37 ± 5.52 $^a$ |
| $Pec_{85}WPI_{15}$ | 0.376 ± 0.035 $^b$ | 5.76 ± 1.01 $^a$ | 0.41 ± 0.15 $^a$ | 284.37 ± 14.91 $^a$ |
| $Pec_{80}WPI_{20}$ | 0.371 ± 0.010 $^b$ | 4.88 ± 1.22 $^a$ | 0.39 ± 0.15 $^a$ | 282.96 ± 8.86 $^a$ |

Means observed in the column with the same letter do not differ statistically ($p < 0.05$).

**Table 2.** Optical parameters (L*, C*, a*, b*, ΔE) and Transparency (T) of extruded/thermo-compressed Pec/WPI-based films.

| Samples | L* | C* | a* | b* | ΔE | T (%) |
|---|---|---|---|---|---|---|
| $Pec_{100}WPI_0$ | 66.46 ± 0.31 $^b$ | 34.03 ± 2.59 $^a$ | 5.75 ± 0.34 $^a$ | 33.54 ± 3.40 $^a$ | - | 4.14 ± 0.14 $^{bc}$ |
| $Pec_{95}WPI_5$ | 56.78 ± 0.09 $^a$ | 41.83± 3.37 $^b$ | 11.60 ± 0.41 $^b$ | 40.19 ± 4.11 $^b$ | 4.71 ± 0.82 $^a$ | 4.29 ± 0.12 $^c$ |
| $Pec_{90}WPI_{10}$ | 59.29 ± 0.32 $^a$ | 43.59 ± 2.46 $^b$ | 11.06 ± 1.26 $^b$ | 42.16 ± 2.65 $^b$ | 4.59 ± 0.64 $^a$ | 4.40 ± 0.29 $^c$ |
| $Pec_{85}WPI_{15}$ | 54.17 ± 1.29 $^a$ | 52.88 ± 1.31 $^b$ | 16.58 ± 1.37 $^b$ | 50.21 ± 3.27 $^b$ | 6.31 ± 0.78 $^c$ | 3.70 ± 0.14 $^a$ |
| $Pec_{80}WPI_{20}$ | 54.09 ± 0.97 $^a$ | 45.49 ± 1.93 $^b$ | 14.21± 2.59 $^b$ | 43.21 ± 5.87 $^b$ | 5.52 ± 0.91 $^b$ | 3.95 ± 0.14 $^{ab}$ |

Means observed in the column with the same letter do not differ statistically ($p < 0.05$).

When analyzing the consumer behavior at the time of purchase, only 22.7% of the consumers observed whether the food packaging was biodegradable. On the other hand, 71.9% of consumers responded that knowledge about biodegradable packaging positively affects product choice. When asked the reasons for such influence, consumers reported that they were aware of the environmental benefits generated by the consumption of biodegradable packaging when compared to traditional non-biodegradable packaging. However, the high price of biodegradable packaging and the lack of clear information about the material's biodegradability were reported as limiting factors at the time of purchase.

This consumer behavior may be due to greater visibility about the impact of non-biodegradable plastic packaging on the environment[26]. Another important factor is the greater association of plastic packaging with environmental problems when compared to other materials, such as cellulosic and glass packaging[27]. Thus, although consumers have reported that biodegradable packaging would influence the purchase intention, they may not purchase a product packaged in this type of packaging. Consumer awareness is not limited to environmental awareness, which is also related to the consumers' engagement in the subject[27].

Figure 3 showed the degree of importance that consumers reported for the parameters of color, resistance, appearance, and biodegradability of the packaging when purchasing a product. The package color had the lowest score and, thus the lowest degree of importance at the time of purchase. While the attributes of resistance and appearance showed a similar degree of importance. The use of biodegradable packaging had the highest degree of importance, with values close to the maximum score of 7. This result corroborates the findings in Table 3.

### 3.3 Consumers' acceptance and purchase intention

Table 4 presents the results of the acceptance test and the purchase intention for Pec and WPI-based films. The acceptance varied with the WPI concentration, with higher scores for the WPI-based films, which can be associated with the results of the optical parameters (L*, C*, a*, and b*) and transparency (T). The presence of WPI and, consequently, the occurrence of the Maillard reaction significantly affected the optical and transparency values of the films. Thus, the consumers' acceptance may be related to the color and transparency of the samples. Consumers prefer clearer and more transparent packaging, with less saturated colors.

A significant difference in statistics was observed for the purchase intent without knowledge of the packaging's biodegradability between the films. Reinforcing the importance of perceived visual attributes. Similar results were observed for the acceptance, once the films with higher acceptance scores also exhibited higher purchase intent scores and *vice versa*.

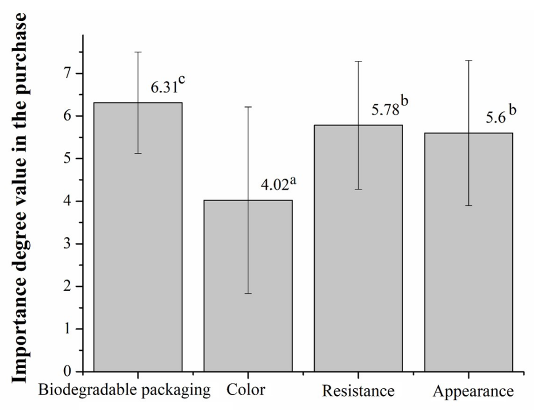


**Figure 3.** Degree of the importance of attributes when purchasing a product. Means observed with the same letter do not differ statistically ($p < 0.05$).

**Table 3.** Biodegradable packaging consumption habit.

| Biodegradable Packaging Consumption Habit | % of answers |
|---|---|
| Frequency of consumption of plastic packaging | |
| > once a day | 39.6 |
| once a day | 20.9 |
| 3 to 4 times a week | 16.9 |
| 1 to 2 times a week | 14.2 |
| Fortnightly | 3.1 |
| Monthly | 3.1 |
| Rarely | 3.6 |
| Know what biodegradable packaging is | |
| Yes | 94.2 |
| No | 5.8 |
| When purchasing, check if the packaging is biodegradable | |
| Yes | 22.7 |
| No | 77.3 |
| Biodegradable packaging influences the purchase of a product | |
| Yes | 71.9 |
| No | 28.3 |

Concerning the purchase intent test with knowledge about biodegradability, an increase in purchase intent was observed without knowledge of the material's biodegradability, with values close to the maximum allowed score (5). Furthermore, no significant difference statistic was observed between the films, showing that biodegradability prevailed over the visual aspects. This result corroborates the high degree of importance observed for the biodegradable packaging and reinforces those consumers are aware of environmental issues arising from the use of biodegradable packaging.

Table 4 shows the results of the T-test, with a significant difference statistic observed in the purchase intention for all samples when the biodegradability information was provided to the consumer. Therefore, biodegradability is a predominant factor over the visual aspects. The information provided by the packaging is an extrinsic factor that can affect consumer behavior[28], and can be an opportunity to encourage the consumption of biodegradable packaging. This result corroborates the report of consumers, who stated that the evident absence of specific information about the biodegradability of the packaging material makes the choice difficult when compared to traditional non-biodegradable packaging (Table 3). In addition, the results of purchase intention with the biodegradability information are important. Biodegradable polymers add value to industries, which drives sustainable development and, consequently, reinforces the green economy[2].

### *3.4 CATA test*

Figure 4 shows the correspondence analysis established by consumers. The first and second dimensions accounted for 94.9% of the data variance, with 87.3% and 7.6%, respectively. The films $Pec_{100}WPI_0$, $Pec_{95}WPI_5$, and $Pec_{90}WPI_{10}$ were classified as unprocessed, natural, light brown, yellowish, smooth, glossy, thin, and brittle. In turn, the films $Pec_{85}WPI_{15}$ and $Pec_{80}WPI_{20}$ were classified as dark brown, dark, woody, wrinkled, opaque, tough, and thick. Therefore, the results allowed for establishing correlations between the attributes' darker color and opacity with the attributes' resistance and thickness. In contrast, a correlation between light, yellow, and bright colors with fine, fragile, natural, and unprocessed was observed. These correlations were not confirmed by the instrumental analyses of film thickness, mechanical properties, and transparency.

Figure 5 shows the hierarchical clustering analysis of CATA data. The samples can be grouped into two clusters, corresponding to one group of samples with 0, 5, and 10% WPI and another group with samples containing 15 and 20% WPI. When analyzing the hierarchical clustering, the correspondence established by consumers in the CATA test (Figure 5), and the sample characterization (Tables 3 and 4), it was evident that these two groups differed in the descriptors' color and transparency. The group with lower WPI concentrations was characterized by the descriptors yellowish, light brown, and natural, and the group of samples with higher WPI concentrations was characterized by the descriptors dark brown, dark, and opaque.

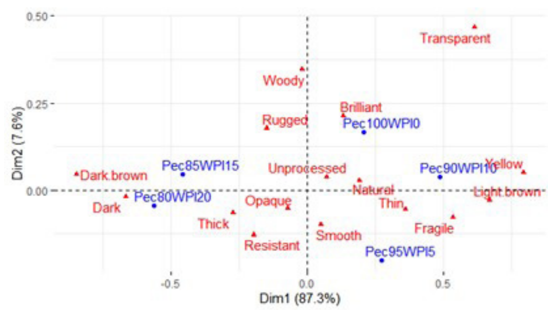


**Figure 4.** CATA results for the films made with different Pec and WPI concentrations.

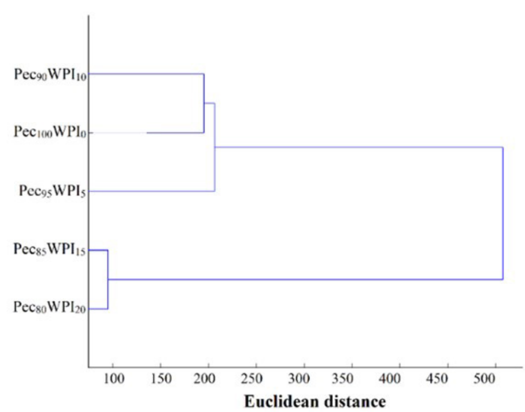


**Figure 5.** Hierarchical clustering of CATA data for the films made with different Pec and WPI concentrations.

**Table 4.** Acceptance and purchase intention of Pec and WPI-based films.

| Samples | Acceptance | Purchase intent without information that the films were biodegradable* | Purchase intention with the information that the films were biodegradable* | Preference ordering sum** |
|---|---|---|---|---|
| $Pec_{100}WPI_0$ | 4.50 ± 1.49$^{bc}$ | 3.39 ± 1.04$^{aA}$ | 4.18 ± 0.94$^{aB}$ | 1307$^{ab}$ |
| $Pec_{95}WPI_5$ | 4.63 ± 1.48$^{bc}$ | 3.57 ± 1.08$^{aA}$ | 4.48 ± 0.76$^{aB}$ | 1429$^{a}$ |
| $Pec_{90}WPI_{10}$ | 4.71 ± 1.49$^{c}$ | 3.56 ± 1.02$^{bA}$ | 4.28 ± 0.88$^{aB}$ | 1418$^{a}$ |
| $Pec_{85}WPI_{15}$ | 4.09 ± 1.46$^{a}$ | 3.40 ± 1.02$^{bA}$ | 4.25 ± 0.91$^{aB}$ | 1263$^{b}$ |
| $Pec_{80}WPI_{20}$ | 4.40 ± 1.43$^{b}$ | 3.47 ± 1.07$^{abA}$ | 4.31 ± 0.91$^{aB}$ | 1091$^{c}$ |

*Means observed in the column with the same lowercase letter do not differ statistically ($p < 0.05$) according to Tukey's test. Means observed in the same line with the same capital letter do not differ statistically ($p<0.05$) according to the T test; **Lines with the same letter do not differ statistically ($p <0.05$) according to the Friedman test.

Although no significant difference was observed for L*, C*, a*, and b* values between the WPI-based films, significantly different ΔE values were observed for the formulations $Pec_{85}WPI_{15}$ and $Pec_{80}WPI_{20}$ when compared with the others, with scores greater than 5, which represents a greater ability to distinguish color by the naked eye[17]. Furthermore, these formulations had the lowest transparency values and, thus the highest opacity. Although WPI may have contributed to the Maillard reaction, which is a non-enzymatic browning reaction, significant differences between the color parameters were not detected, despite a total difference in color and transparency being perceived by consumers.

### 3.5 Preference ordering

The results of the preference ordering and Friedman rank-sum test were presented in Table 4, which showed that the formulations $Pec_{100}WPI_{0}$, $Pec_{95}WPI_{5}$, and $Pec_{90}WPI_{10}$ were the most and equally preferred by consumers, while the formulations $Pec_{85}WPI_{15}$ and $Pec_{80}WPI_{20}$ were the least preferred.

When comparing the results of preference ordering and acceptance tests, the most preferred samples also exhibited the highest acceptance scores. By correlating these values with CATA results (Figure 4), hierarchical clustering (Figure 5), and film characterization (Tables 3 and 4), the formulations with greater acceptance and preference were lighter, more transparent, with less saturated color. Therefore, both the preference and acceptance were directly related to the color and transparency of the films and referred to the descriptors thin, fragile, natural, and unprocessed, which was not confirmed by the analytical determinations.

### 3.6 Application of the films

As shown in Figure 6, approximately 55% of the consumers suggested applications in coffee, chocolates, grains, cereals, bread, and nuts, and 20% corresponded to coffee and chocolates. Therefore, this response pattern showed the consumers' acceptance of biodegradable films as packaging material for a wide range of foods and beverages.

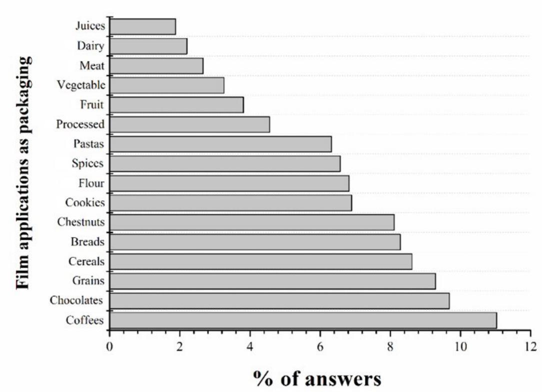


**Figure 6.** Consumer responses on possible applications of films made with different Pec and WPI concentrations for food and beverage packaging.

This is an important approach, as it encourages the use of biodegradable packaging for food and beverages, which are essential for sustainable development and strengthening the green economy[2]. And it was also observed by some studies, as reported by Udayakumar et al.[29].

## 4. Conclusions

The present results showed that the vast majority of consumers (77.3%) did not observe the biodegradability of the packaging during purchase, although they reported that biodegradable packaging can positively affect the purchase decision (71.9%). The acceptance, the purchase decision, and the preference for biodegradable films were affected by the visual impression. In addition, the consumers established a correspondence between the parameters of color and transparency with thickness and resistance, considering 94.9% of the data variance. The results showed acceptance of the promising application of biodegradable packaging, especially in food and beverages, with approximately 55% of consumers suggesting applications in coffee, chocolates, grains, cereals, bread, and nuts. The application of these films as food and beverage packaging can lead to sustainable development and enhance the green economy.

Future studies are necessary to verify the effective application of these biogeneratable packaging in food and beverages, especially with regard to maintaining the physicochemical and microbiological properties of both the food and beverages and the packaging.

## 5. Author's Contribution

- **Conceptualization** – Ana Carolina Salgado de Oliveira.
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- **Formal analysis** – Ana Carolina Salgado de Oliveira; Michele Nayara Ribeiro.
- **Funding acquisition** – Soraia Vilela Borges.
- **Investigation** – Ana Carolina Salgado de Oliveira.
- **Methodology** – Ana Carolina Salgado de Oliveira; Michele Nayara Ribeiro.
- **Project administration** – Soraia Vilela Borges.
- **Resources** – Soraia Vilela Borges.
- **Software** – NA.
- **Supervision** – Soraia Vilela Borges.
- **Validation** – Julio Cesar Ugucioni; Roney Alves da Rocha.
- **Visualization** – Ana Carolina Salgado de Oliveira; Roney Alves da Rocha.
- **Writing – original draft** – Ana Carolina Salgado de Oliveira; Julio Cesar Ugucioni.
- **Writing – review & editing** – Julio Cesar Ugucioni; Soraia Vilela Borges.

## 6. Acknowledgements

The authors would like to thank the Coordination for the Improvement of Higher Education Personnel (CAPES), the National Council for Scientific and Technological Development (CNPq), the Minas Gerais State Research Support Foundation (FAPEMIG), the Federal University of Lavras (UFLA) for financial support.

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*Received: Aug. 10, 2023*
*Revised: Oct. 23, 2023*
*Accepted: Nov. 30, 2023*