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Gelatin and Gelatin/Rice Starch Coatings Affect Differently Fresh-Cut Potatoes and Colocasia Slices

Anastasia Bari [1] and Persephoni Giannouli [2,*]

[1] Department of Agriculture Crop Production and Rural Environment, School of Agricultural Sciences, University of Thessaly, Fytoko Street, 38446 Volos, Greece
[2] Department of Biochemistry and Biotechnology, School of Health Sciences, University of Thessaly, Viopolis, 41500 Larissa, Greece
* Correspondence: pergian@uth.gr; Tel.: +30-2410565208

Abstract: Traditional food packaging materials maintain food quality and safety during storage, but they cause significant environmental pollution. For this reason, there has been an increased demand in designing packaging materials from biodegradable ingredients such as edible proteins and polysaccharides. In the current study, biodegradable coatings from gelatin (Gel) or gelatin–rice starch (Gel-RS) mixtures were applied to fresh-cut Colocasia (*Colocasia esculenta*) and potato (*Solanum tuberosum*) samples, and main quality properties such as weight loss, firmness, breaking force, and color were evaluated during storage for seven days at 5 °C. Gel-coated potato samples kept moisture at higher levels compared to untreated samples or Gel-RS-coated samples (weight loss 41.40 ± 3.33%), while no differences in weight loss were observed for all fresh-cut Colocasia samples. Furthermore, the gelatin–rice starch coating increased the breaking force (1181.40 ± 159.73) and hardness (1609.6 ± 76.79) of fresh-cut potato samples during storage conditions. On the other hand, fresh-cut Colocasia coated with gelatin and gelatin/rice starch showed no significant differences in weight loss and texture characteristics. In conclusion, gelatin and gelatin/rice starch coatings provoke preservation of quality characteristics during storage of fresh-cut potatoes but have no preservation effects on fresh-cut Colocasia. This research enriches the knowledge of the effects of biodegradable coatings on fresh-cut starchy tubers.

Keywords: Colocasia; potato; color; texture; rice starch; gelatin

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1. Introduction

New approaches to packaging are essential today due to environmental impacts caused by aging-resistant synthetic polymers and plastics, which have become a serious threat to ecosystems. Plastic waste degradation generates microplastics (MPs), and today, there are serious problems raised from the detection of microplastics that are also derived from plastic packaging in all the environmental sections, such as air, soil, and water. Poor waste management systems led to a huge accumulation of plastic waste, and this release is well recognized as environmental contamination [1]. The effects of microplastics, besides the massive environmental problems, also have negative effects on human and animal health as they enter the food chain. Recent research showed that long-term exposure to microplastics could damage the digestive system and release toxic molecules in the body. Microplastics are a serious threat to health as they can be absorbed through pathways and accumulate in the liver, intestine, and kidneys [2]. In order to minimize the problems, researchers and industries introduce "green packaging", or bio-plastics, which are made from biodegradable polymers. The role of packaging is more complicated as the new materials should also satisfy consumer needs such as convenience, safety, and freshness of food products [3].

Packaging in the food market, except for its environmental impact, should give value to the product by maintaining its nutritional value and general quality characteristics, minimizing food preparation, and at the same time, increasing food shelf life. Nowadays, many techniques are available to give answers and solutions, especially concerning fresh food packaging [4]. The application of biopolymer edible coatings on fresh products is an area of research that has been extensively conducted due to its positive effects on products during storage [5]. Edible coatings reinforce fresh food as an additional layer leading to decreased weight loss, respiration rate, and delayed ripening process [6].

Starch and Gel are biopolymers that have been studied extensively due to their advantages, such as biodegradability and high availability in the market, which results in a lower cost of acquiring the raw material [7]. More specifically, rice starch (RS) has unique functional properties compared to the other starch botanical sources, such as a neutral taste and creamy texture, but when it is used as a coating on its own, it exhibits high water permeability (%) and low mechanical properties such as hardness (N) and breaking force (N) [8]. On the other hand, gelatin as a coating stands out compared to other proteins due to its low temperature of gelation (°C), optical properties, and high mechanical strength such as hardness (N) [9].

Biopolymer blending is a well-known process used for the development of innovative coating and film materials due to the optimization of biopolymer's functional properties, resulting in the development of new materials with better properties compared to their individual initial components [10]. An investigation is also necessary during biopolymer mixing due to possible disintegration levels, which could affect film thickness and homogeneity [11] and the coating's spreadability on fruit and vegetable surfaces. The mixing of biopolymers with, for example, high concentrations of starch, casein, and a low amount of gelatin, produces a biodegradable film with desirable thickness, opacity, solubility, and water loss due to increased hydrogen bonds between molecular chains. This type of film increased guava fruit self-life [4]. In another research mixture of gelatin protein from poultry waste and starch from the lotus stem developed an excellent coating for enhancing the self-life of cherry tomato fruits for 15 days of storage by enhancing UV barrier properties and reducing oxidation [12]. Further, a mixture of gelatin, different types of corn starch, and sorbitol as a plasticizer improved the appearance of Red Crimson grapes. The incorporation of gelatin in this type of starch increased the biofilm's mechanical strength and extended the grape's shelf–life due to significantly lower water vapor permeability storage under refrigerated conditions [13]. In addition, our recent research in gelatin coating demonstrated a high ability to preserve fresh-cut zucchini slices for seven days at 5 °C, but after mixing gelatin with rice starch, the zucchini slices showed increased weight loss, total color difference, and the maintenance of textural characteristics [14].

The quality of the packaged food is directly related to the food and packaging material attributes. Edible films and coatings are used for specific utilities in the conservation and improvement of various food products, but the biopolymers which construct films or coatings will behave differently when stored at different conditions, such as temperature and humidity. Furthermore, it is essential to underline that the effectiveness of coatings and films on quality and physiological aspects of food, e.g., coated fruits during storage, depends on food texture and constituents. In this sense, the application of edible coatings is carried out in different fruits or vegetables in order to control the exchange of moisture and gases between the crop and the environment during storage [15].

Two of the tubers that are well known for high carbohydrate content are Colocasia and potato, and both of them are processed in food markets for a large variety of products. The main component of Colocasia is starch 70–80% of the dry matter, which is responsible for the stick characteristics of Colocasia) [16]. Fresh potato tubers also contain a high quantity of starch, which varies according to the cultivars and the growth time. The percentage of starch within potato dry matter varies from 67.2 ± 1.4% to 80.4 ± 0.4%, but during storage, starch degradation takes place at low temperatures [17]. This phenomenon leads to changes in potato organoleptic characteristics [18,19]. Browning and texture are the main changes detected in fresh-cut potatoes, and until now, various methods have been applied to extend the slice's self-life at the refrigerator's temperature, such as the addition of additives or plant extracts [20] and different kinds of packaging such as modified atmosphere packaging [21]. The necessity of degradable packaging increases the research efforts for investigations for the best combinations of proteins and polysaccharides as coatings and films in the fresh-cut potato market.

In addition, there is little information on the effects of storage on the quality characteristics of fresh-cut Colocasia at refrigerator temperature. Only a few studies described investigations in order to extend storage time and increase the quality of fresh-cut Colocasia, such as the effects of the edible coating chitosan/starch or heating pre-treated techniques [22–24].

Gel and Gel-RS coatings could be eaten and have biodegradable characteristics, and it is the first time that they are used as coatings in fresh-cut starchy tubers in order to investigate their effects on their storage time and quality properties. The aim of this research is to investigate the effectiveness of gelatin, gelatin/rice starch coatings of fresh-cut Colocasia (*Colocasia esculenta*) and potato (*Solanum tuberosum*) in their quality characteristics such as weight loss, firmness, breaking force, and color during refrigerator temperature.

2. Materials and Methods

2.1. Preparation of Colocasia and Potato Samples

Colocasia (*Colocasia esculenta* L.) was donated by Agricultural Cooperative SEGIDEP SOTIRAS, Sotiras, Cyprus. Colocasia Sotiras is protected designation of origin and grown in Cyprus from the 12th century. Potato (*Solanum tuberosum* L.) tubers were purchased from a local market in Volos, Greece. The tubers were at commercial ripeness stage and were free of physical, mechanical, and microbiological damages and stored for 24 h at 5 °C before their processing. Colocasia and potato samples were washed with tap water; then, they were peeled, washed with distilled water, and dried with absorbent paper. After drying process, the tubers were cut into cylinders of 20 mm in height and 31 mm in diameter [14,25].

2.2. Preparation of Gelatin and Gelatin/Rice Starch Edible Coatings

Gelatin (Gel) edible coating solution was 3% *w*/*w* [26,27] (AppliChem GmbH, Darmstadt, Germany). The mixture of Gel-RS was prepared by mixing 3% *w*/*w* of gelatin and 5% *w*/*w* of rice starch Duchefa Biochemie B.V., Haarlem, The Netherlands) [14]. Furthermore, 1.5% *w*/*w* anhydrous glycerol (Sigma-Aldrich Co., St. Louis, MO, USA) was incorporated in the biopolymer's mixtures as a plasticizer [28].

The different biopolymers solutions were dissolved by simultaneous stirring and heating for 30 min at 85 °C [29]. When mixing took place, anhydrous glycerol was added to the mixtures. After this time, the coating solutions were left to cool at room temperature (∼20 °C). Coating took place by dipping the fresh-cut samples into the biopolymers mixture and left to dry at room temperature for 1 h. The control (Ctr) samples were left untreated.

The samples of treatments were placed in plastic disks and stored for 7 days at 5 °C, for the evaluation of the effect of the different coating treatments on their quality characteristics during the storage period [25]. The measurements took place on Days 0, 1, 2, 3, 4, and 7. All the experiments were conducted in triplicates [14].

2.3. Weight Loss Measurements

The effect of the different edible coatings on the weight loss of Colocasia and potato fresh-cut samples was evaluated during the storage period. On storage Days 0, 1, 2, 3, 4, and 7, treated and untreated samples were weighed using a laboratory scale high-precision digital weighing balance according to the standard method of AOAC [14].

The weight loss values were calculated as:

$$\text{Weight loss (\%)} = (\text{Wi} - \text{Wf})/\text{Wi} * 100 \quad (1)$$

where Wi (g) and Wf (g) are the initial and final sample weights, respectively. The measurements were performed in triplicate.

2.4. Texture Analysis

Texture characteristics of fresh-cut Colocasia and potato samples, such as firmness and breaking force, were also measured during the storage period for all treatments. Texture analysis was performed on Colocasia and potato on day samples 0, 1, 2, 3, 4, and 7 at 5 °C using an eXpert 5601 texture analyzer (ADMET, Norwood, MA, USA), with a probe of 3.1 mm in diameter [14]. The height and the diameter of the samples were 20 mm and 31 mm, respectively. A 70% compression of their initial height was performed on the samples, and the jog rate of the prob was 1 mm s^{-1}. For each treatment, three replications were analyzed and averaged.

2.5. Color Analysis

Color parameters such as L* (luminosity), a* (green–red), b* (yellow–blue), and Chroma (C*) or Chroma saturation index were measured for Days 0, 1, 2, 3, 4, and 7 of the storage period. The mean values of these parameters were obtained from three samples for every treatment. The color parameters values were determined by using a colorimeter (HunterLab MinScan XE Plus, Reston, VA, USA) with the illumining D75 and observation angle of 10°, calibrated with a standard white plate, in the CIELAB color space [14].

Numerical values of L*, a*, and b* parameters were employed to calculate Chroma (C*) or Chroma saturation index, Whiteness Index (WI), Hue*angle, and Total Color Difference (ΔE) of Colocasia and potato samples, by the following equations:

$$\text{Chroma}^* = \sqrt{(a^2 + b^2)} \quad (2)$$

$$\text{Hue}^*\text{angle} = \text{arctangent}(b^*/a^*) \quad (3)$$

$$\Delta E = \sqrt{([(L^* - L_o^*)^2 + (a^* - a_o^*)^2 + (b^* - b_o^*)^2])} \quad (4)$$

where L_o^*, a_o^*, and b_o^*, indicate the initial color parameters of fresh-cut Colocasia and potato slices on Day 0.

$$WI = 100 - \sqrt{[(100 - L^*)^2 + (a^*)^2 + (b^*)^2]} \quad (5)$$

For all measurements, three replications were obtained and averaged.

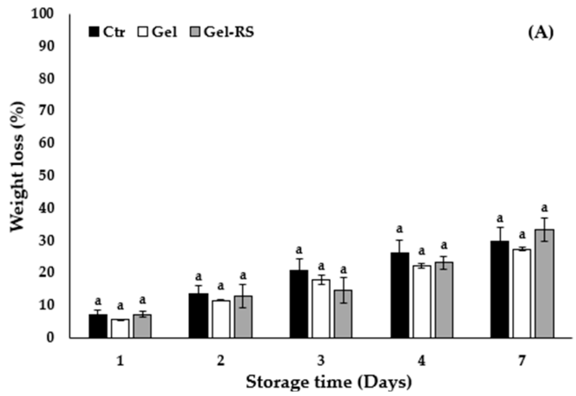
2.6. Statistical Analysis

All the measurements were repeated three times using three replicates for each sampling date. The results were expressed as means with standard errors of the triplicate determinations. One-way analysis of variance (ANOVA) and Least Significant Difference Test (LSD) were carried out to assess the effect of the independent variables of treatment and storage period on the different quality parameters of fresh-cut Colocasia and potato samples for each sampling date, using IBM SPSS Statistics 26 software. The level of significance was set at $p < 0.05$.

3. Results and Discussion

3.1. Weight Loss (%)

Water loss in fruits and vegetables is the main cause of the begging of deterioration. According to other studies, tubers tend to lose slower humidity than soft fruits and leafy vegetables [30]. In this research, the daily weight loss (%) of coated fresh-cut Colocasia and potato samples during a 7-day storage period in low-temperature conditions was determined (1), and the results are presented in Figure 1.



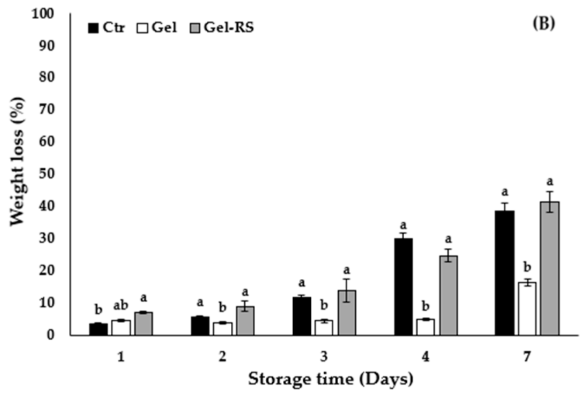


Figure 1. Daily weight loss (%) of coated fresh-cut Colocasia (**A**) and potato (**B**) samples during a 7-day storage period at 5 °C. Black columns indicate Ctr treatment; white columns indicate Gel treatment and grey columns indicate Gel-RS treatment. Different letters indicate statistical differences. Different letters within the columns indicate significant differences ($p < 0.05$) among the different treatments on every sampling date. Sample analysis was in triplicate.

As it is shown in Figure 1A, the weight loss (%) of fresh-cut Colocasia samples increased during the storage time, and the greatest values of weight loss were recorded on Day 7 for all treatments. The applications of the edible coatings of gelatin and gelatin–rice starch had no effect on the weight loss of fresh-cut Colocasia samples. Specifically, the coated samples showed slightly less weight loss (27.35 ± 0.47% and 33.35 ± 1.49%, for Gel and Gel-RS treatment, respectively) than the control samples (29.89 ± 1.20%), but no significant differences were noticed among the different treatments. The same results were found in starch/chitosan mixtures of different concentrations when they were applied to fresh-cut Colocasia samples. Colocasia samples lost 10.5% of their initial weight after 20 days of storage [23].

On the contrary, as it concerns weight loss (%) of fresh-cut potato samples, no significant differences were noticed among the different treatments until the second day of storage, as it is presented in Figure 1B. On the third day of storage, the weight loss of Gel treatment samples was found to be significantly lower compared to the other treatments, while on Day 7 of the storage period, no differences were noticed between the Ctr and Gel-RS treatments. Weight loss of Gel treatment samples was significantly lower compared to the other treatments. In general, the weight loss of fresh-cut potato samples showed an increase during the storage period, and the greatest weight loss values were observed on Day 7 for all coating treatments. The highest weight loss value recorded for Ctr treatment samples was 38.55 ± 2.64%; similar values were recorded for Gel-RS treatment (41.40 ± 3.33%). The highest weight loss of Gel treatment samples was 16.25 ± 1.04%.

Weight loss of gelatin-coated samples was found to be significantly lower compared to the other treatments, but the incorporation of rice starch in the coating mixture accelerated the process of water loss and weight expansion, and gelatin lost its protective role. In fact, during the last days of the storage period, the weight loss values were found to be the same for the Ctr treatment as well as for the Gel-RS treatment samples. Similar results were observed when an edible coating based on cactus extract was applied to fresh-cut potato samples, limiting the weight loss during long-term storage at 5 °C. The untreated potato samples lost 21.06% of their initial weight after five days of storage, while the coated samples lost only 9.04% of their weight [31]. Moreover, it was found that sodium alginate/CMC edible coatings improved the post-harvest life of potato samples as they prevented their dehydration [32]. It was also observed that the application of protective edible coatings based on MSE led to a lower weight loss of the samples (7.5%) after the fourth day of storage compared to the control treatment samples (16%) [33]. Furthermore, similar results were observed when chitosan and chitosan mixtures were applied to fresh-cut potato samples, where the different coating treatments showed lower or similar weight loss values than the control treatment (11.25%), respectively [34]. The weight loss of fresh-cut potato samples may be due to water loss from plant tissue transpiration and respiration but also from other physiological mechanisms [35]. The reduction in weight loss of the coated samples was due to the capacity of these coatings to form a semi-permeable barrier against gases such as oxygen, carbon dioxide, water, and other soluble substances, due to which it reduces respiration, moisture loss, and oxidation [36]. Moreover, it was found that mixtures of chitosan with proteins and polysaccharides were very effective in reducing the respiration rate and inhibiting water loss in potato tissues [37].

3.2. Texture Analysis

Texture characteristics are important quality parameters for fruits and vegetables. The application of Gel and Gel-RS edible coatings did not have an effect on the breaking force of fresh-cut Colocasia samples, as it is presented in Figure 2A. No significant differences were noticed among the treatments on every sampling date.

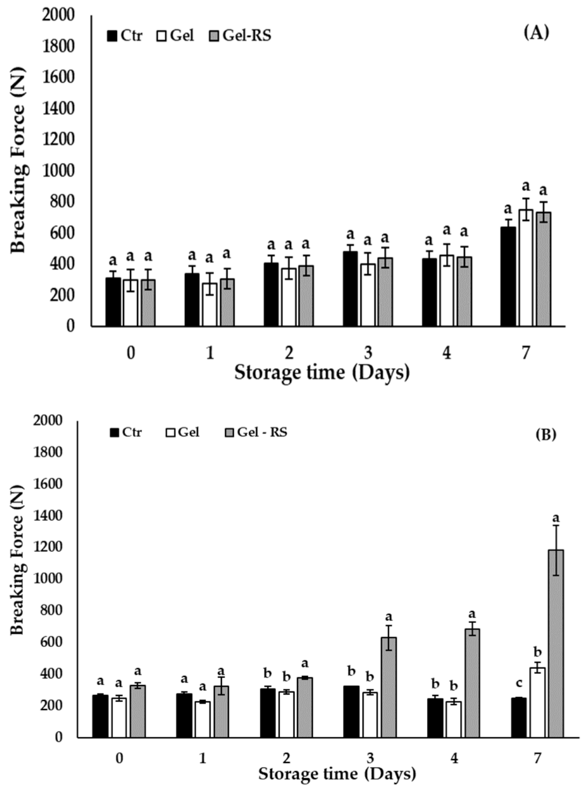


Figure 2. Breaking Force (N) of fresh-cut Colocasia (**A**) and potato (**B**) samples during a 7-day storage period at 5 °C. Black columns indicate Ctr treatment; white columns indicate Gel treatment and grey columns indicate Gel-RS treatment. Different letters indicate statistical differences. Different letters within the columns indicate significant differences ($p < 0.05$) among the different treatments on every sampling date. Sample analysis was in triplicate.

The highest values of freaking force for fresh-cut Colocasia were recorded on Day 7. The highest breaking force values recorded for the Ctr samples were 637.30 ± 20.14 N, for Gel-coated sample 753.21 ± 34.65 N and for Gel-RS-coated samples 734.10 ± 54.10 N, respectively. In general, there was an increase in breaking force and firmness values for all treated samples during the storage period at 5 °C.

On the contrary, Gel and Gel-RS showed different effects on fresh-cut potato samples, and the breaking force (N) of fresh-cut potato samples was affected by the different types of edible coating, as it is presented in Figure 2B. On Day 0 and Day 1 of the storage period, no significant differences were noticed among the two coating treatments, while from Day 2 to Day 4, the breaking force values of Ctr- and Gel-coated samples were similar but significantly different from the values of Gel-RS-coated fresh-cut potatoes. For all storage dates, except Day 0, the breaking force of Gel-RS-coated samples was significantly higher compared to fresh-cut potatoes Ctr and coated with Gel. For all treatments, the greatest breaking force values were observed on Day 7 and were 1181.40 ± 159.73 N, 444.20 ± 32.11 N, and 321.9 ± 1.94 N, referring to Gel-RS, Gel, and Ctr treatment, respectively.

In Figure 3, the effect of the different coating treatments on the firmness (N) of fresh-cut Colocasia and potato samples is presented.

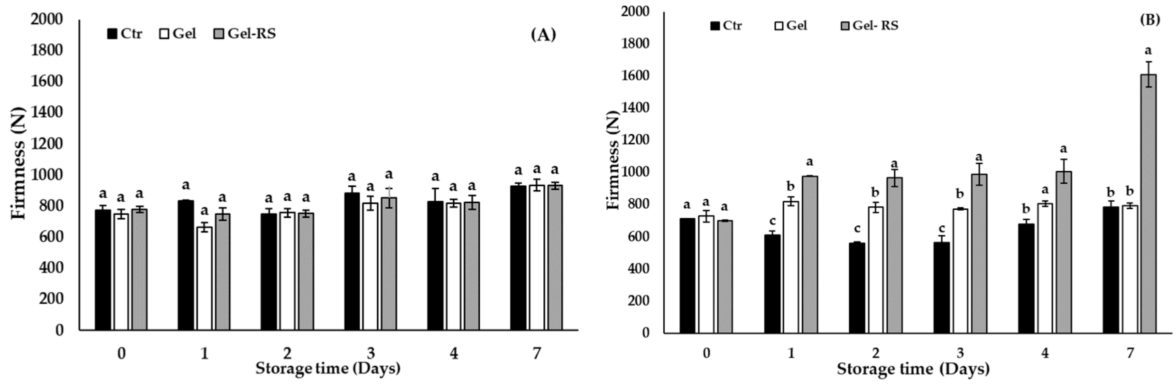


Figure 3. Firmness (N) of fresh-cut Colocasia (**A**) and potato (**B**) samples during a 7-day storage period at 5 °C. Black columns indicate Ctr treatment; white columns indicate Gel treatment and grey columns indicate Gel-RS treatment. Different letters indicate statistical differences. Different letters within the columns indicate significant differences ($p < 0.05$) among the different treatments on every sampling date. Sample analysis was in triplicate.

Firmness was also studied in this research. As it is shown in Figure 3A, Gel and Gel-RS edible coatings applied on Colocasia samples did not have effects on their firmness (N), and no differences were noticed compared to Ctr samples. The greatest values recorded for Ctr, Gel, and Gel-RS were 928.11 ± 19.66 N, 934.65 ± 38.00 N, and 931.88 ± 21.43 N, respectively, on Day 7 of storage.

Clearly, there was an increase in breaking force and firmness values for all the samples coated and uncoated during the storage period at 5 °C. It was reported that texture parameters of Colocasia samples, such as firmness and breaking force, increased during storage [38]. In other studies, the same results were observed when they studied the same characteristics in yam tubers (*Dioscorea dumetorum*) were studied just 72 h after their harvest [39]. Similarly, no differences were noticed in firmness values of fresh-cut Colocasia samples coated when they were coated with chitosan/starch mixtures [23]. The firmness values of the control treatment samples did not differ compared to the values of the coated samples, as Colocasia tubers contain a sticky substance characterized by high viscosity, rich in sugars such as arabinose and galactose [40], and the water-soluble gum formed on the surface of the tissue is able to make their structure stronger and, by extension, can increase the firmness values of the samples [41,42].

The increase in the firmness and breaking force values of Colocasia samples is due to the thickening of the cell wall, which takes place simultaneously with the lignification of the tissues during the storage period. The biochemical reactions between the components found inside Colocasia tubers, such as the hardening of pectin caused by the presence of calcium, but also the reduction of moisture content, lead to an increase in these parameters' values [38,39].

The application of different types of edible coatings had an effect on the firmness values of fresh-cut potato samples, as it is presented in Figure 3B. The firmness values of Gel-RS treatment samples were significantly higher than the values of Ctr and Gel coating treatments. Moreover, significant differences were observed between the firmness values of Ctr and Gel treatment. The highest firmness values were recorded on Day 7 of the storage period for all treatments. The greatest values recorded for each treatment were

1609.6 ± 76.79 N, 820.27 ± 29.27 N, and 784.32 ± 38.04 N, concerning the samples coated with Gel-RS, Gel, and the control, respectively.

The application of the Gel and Gel-RS biodegradable coatings applied in the current study affected the breaking force and the firmness values of the fresh-cut potato samples. Specifically, the application of the edible Gel-RS coating, apart from maintaining the characteristics of the structure of the samples, also led to an increase in their values. Furthermore, breaking force and firmness values of samples both coated with Gel and Gel-RS treatment samples increased during storage and showed significantly higher values than the control samples. Contrariwise, it has been observed that the firmness values of potato samples coated with chitosan coatings decreased during storage [33]. Moreover, they noticed that the coated samples had higher firmness values compared to the control samples at the end of the storage period. Hardness values in potatoes are related to the hardening of the tissues and the strengthening of the cell walls [43,44]. Similar results were found when the application of edible coatings on tomato samples during storage led to changes in their firmness [45]. Low levels of oxygen and high percentages of carbon dioxide can reduce the physical activity of enzymes, thus allowing the stability of samples to be maintained during storage [46]. Different results were found in another study where it was reported that coated potato samples lost 75% of their initial firmness at the end of a 12-day storage period [47]. The degree of blending of biopolymers and their possible disintegration levels are also very important for the textural properties of fruits and vegetables due to variations in the homogeneity and thickness of films or coatings thickness [11,48].

3.3. Color

3.3.1. L*, a*, b*, Chroma* and Hue*angle

Color parameters on food packaging materials are very important for product acceptability from the consumers, but even when a person characterizes two colors the same, slight differences could be found when measured with a color evaluating instrument. The color parameters, L*, a*, b*, Chroma* (2), and Hue*angle (3), of fresh-cut Colocasia samples during a storage period of seven days at 5 °C are presented in Table 1. Parameter L* is related to the intensity of light as its values increase. Positive values of parameter a* characterize red intensity while its negative values are related to the green color, and parameter b* shows yellow and blue intensity when its values are positive and negative, respectively [49]. In this research, it was found that the different types of coating had a direct effect on the color parameters of the fresh-cut Colocasia samples. Significant differences were observed for the values of L*, a*, and b* parameters among the different treatments. L* parameter values of Ctr samples were always higher, while the values of Gel-RS treatment were always lower compared to the other treatments for all sampling dates. The opposite was observed for the a* and b* parameters, where the highest values were observed for the Gel-RS treatment samples.

Furthermore, L* parameter values of fresh-cut Colocasia samples decreased as the values of a* and b*parameters increased during the storage period for all samples coated and uncoated with Gel and Gel-RS. Gel-RS and plasticizer form coating, which is more permeable on O_2. Furthermore, Colocasia slices had a protective mucilage which was secreted when the tuber tissue was cut. This mixture of biopolymers, plasticizer, and mucilage facilitates gas mobility and permeability in the specific coating, which could provoke color changes due to oxidation, which is related to L*'s decrease. The highest Chroma* values were observed for the samples of Gel-RS treatment and were significantly different compared to the values of Chroma* for Ctr and Gel-coated samples for every day of the storage period at 5°C. In general, it was observed a gradual increase in Chroma* values during storage time for all treatments. The highest Chroma* values were recorded on Day 7 and for all coating treatments.

Hue* angle values of all Colocasia samples were reduced during their storage at low temperatures. It was found that Gel-RS treatment samples had significantly lower Hue* values compared to the values of Ctr and Gel treatments ($p < 0.05$). On the contrary, the control samples for each maintenance day had the highest Hue* angle values compared to the other treatments ($p < 0.05$).

The highest parameter L* values were recorded for the Ctr treatment samples, as well as the lowest values of the a*, b*, and Chroma* parameters among the three coating treatments. The same results were also found when mixtures of chitosan and starch were applied to Colocasia samples [23]. Specifically, they observed small changes in the color parameters of the control samples during storage, and the saturation index (Chroma*) values were always lower compared to the coated samples for all sampling dates. This may be due to the presence of the mucilage that is secreted by the injured Colocasia tissue and creates a natural protective layer on the sample's surface.

Table 1. L*, a*, b*, Chroma* and Hue*angle of fresh-cut Colocasia samples during a storage period of 7 days on 5 °C.

Day	Treatment	L*	a*	b*	Chroma*	Hue*
0	Ctr	85.75 ± 0.02 a	1.68 ± 0.01 c	20.67 ± 0.01 b	20.73 ± 0.01 b	1.49 ± 0.00 a
	Gel	85.20 ± 0.48 a	2.10 ± 0.01 b	18.04 ± 0.02 c	18.16 ± 0.00 c	1.45 ± 0.00 b
	Gel-RS	77.74 ± 0.04 b	6.45 ± 0.01 a	21.91 ± 0.02 a	22.83 ± 0.01 a	1.28 ± 0.00 c
1	Ctr	85.54 ± 0.02 a	3.12 ± 0.01 c	20.05 ± 0.01 b	20.29 ± 0.01 b	1.44 ± 0.00 a
	Gel	81.86 ± 0.24 b	2.47 ± 0.02 b	19.21 ± 0.05 c	19.35 ± 0.02 c	1.42 ± 0.00 b
	Gel-RS	75.27 ± 0.07 c	6.85 ± 0.00 a	25.42 ± 0.04 a	26.31 ± 0.01 a	1.31 ± 0.00 c
2	Ctr	84.25 ± 0.35 a	2.81 ± 0.06 c	22.37 ± 0.01 c	22.54 ± 0.01 c	1.45 ± 0.00 a
	Gel	81.19 ± 0.58 b	4.35 ± 0.01 b	22.71 ± 0.02 b	23.12 ± 0.01 b	1.38 ± 0.00 b
	Gel-RS	73.94 ± 0.06 c	7.45 ± 0.01 a	25.68 ± 0.03 a	26.72 ± 0.01 a	1.29 ± 0.00 c
3	Ctr	83.47 ± 0.04 a	3.71 ± 0.02 c	21.37 ± 0.01 c	21.69 ± 0.01 c	1.40 ± 0.00 a
	Gel	79.25 ± 0.09 b	5.38 ± 0.02 b	23.14 ± 0.02 b	23.76 ± 0.01 b	1.34 ± 0.00 b
	Gel-RS	71.21 ± 0.14 c	7.98 ± 0.01 a	26.41 ± 0.02 a	27.58 ± 0.01 a	1.28 ± 0.00 c
4	Ctr	82.03 ± 0.68 a	4.29 ± 0.01 c	22.44 ± 0.06 c	22.85 ± 0.04 c	1.38 ± 0.00 a
	Gel	77.83 ± 0.21 b	6.99 ± 0.03 b	24.36 ± 0.06 b	25.31 ± 0.02 b	1.29 ± 0.00 b
	Gel-RS	70.99 ± 0.31 c	8.64 ± 0.02 a	27.21 ± 0.03 a	28.56 ± 0.02 a	1.26 ± 0.00 c
7	Ctr	76.77 ± 0.03 a	6.84 ± 0.01 c	25.10 ± 0.22 c	26.01 ± 0.15 c	1.30 ± 0.00 a
	Gel	69.94 ± 0.18 b	8.94 ± 0.01 b	26.17 ± 0.01 b	27.65 ± 0.00 b	1.26 ± 0.00 b
	Gel-RS	69.96 ± 0.20 b	9.48 ± 0.01 a	29.76 ± 0.03 a	31.22 ± 0.01 a	1.24 ± 0.00 c

Different letters within columns indicate statistically significant differences between samples of different treatments.

Generally, mechanical refrigeration, as a food preservation method, is widely used because it is effective in reducing the respiration rate of fruits and vegetables, which reduces their spoilage rate [50]. However, in several studies, it was observed that the storage of Colocasia samples at temperatures below 10 °C can cause fruit injuries and promote the breakdown of starch into reducing sugars [51,52]. In contrast, in some studies, it was reported that no chilling injury occurred in Colocasia samples when stored at 5 °C [53]. Reducing sugars are responsible for the appearance of the enzymatic browning effect, which is not desired by consumers [54]. Enzymatic browning in food is undesirable, as it leads to the formation of a group of carcinogens known as acrylamides, which result from the reaction of reducing sugars with the amino acid asparagine [55,56].

The degradation of starch granules occurs due to the increase in the activity of α-amylase, which hydrolyzes the α-glycosidic bonds of starch [32,57]. Moreover, it was found that starch granules stored for a long period of time undergo degradation [58]. Therefore, the storage of Colocasia samples in different storage environments may lead to changes in the physicochemical properties of its flour and starch due to the activity of temperature-sensitive α-amylase.

Similarly, color parameters L*, a*, b*, Chroma*, and Hue*angle of fresh-cut potato samples during a storage period of seven days at 5 °C are presented in Table 2.

Table 2. L*, a*, b*, Chroma*, and Hue*angle of fresh-cut potato samples during a storage period of 7 days on 5 °C.

Day	Treatment	L*	a*	b*	Chroma*	Hue*
0	Ctr	75.89 ± 0.08 b	3.09 ± 0.01 b	29.94 ± 0.02 c	30.10 ± 0.02 c	1.47 ± 0.00 c
	Gel	75.67 ± 0.04 b	3.47 ± 0.02 a	36.44 ± 0.03 b	36.47 ± 0.03 b	1.53 ± 0.00 a
	Gel-RS	79.62 ± 0.07 a	2.98 ± 0.03 c	41.31 ± 0.02 a	41.41 ± 0.02 a	1.50 ± 0.00 b
1	Ctr	75.71 ± 0.06 b	3.14 ± 0.02 c	31.42 ± 0.02 c	31.58 ± 0.02 c	1.47 ± 0.00 b
	Gel	73.50 ± 0.01 c	3.82 ± 0.01 a	36.29 ± 0.04 b	36.49 ± 0.04 b	1.47 ± 0.00 b
	Gel-RS	77.20 ± 0.02 a	3.36 ± 0.02 b	43.88 ± 0.08 a	44.01 ± 0.08 a	1.49 ± 0.00 a
2	Ctr	75.31 ± 0.08 b	3.28 ± 0.04 b	34.00 ± 0.02 c	34.16 ± 0.03 c	1.47 ± 0.00 a
	Gel	75.24 ± 0.11 b	3.30 ± 0.02 b	36.52 ± 0.01 b	36.67 ± 0.01 b	1.48 ± 0.00 a
	Gel-RS	76.14 ± 0.04 a	4.14 ± 0.03 a	44.33 ± 0.02 a	44.52 ± 0.02 a	1.48 ± 0.00 a
3	Ctr	75.21 ± 0.03 a	4.08 ± 0.02 b	36.89 ± 0.02 c	37.11 ± 0.02 c	1.46 ± 0.00 a
	Gel	73.49 ± 0.02 b	3.95 ± 0.05 c	37.33 ± 0.03 b	37.54 ± 0.03 b	1.47 ± 0.00 a
	Gel-RS	75.20 ± 0.04 a	4.85 ± 0.03 a	43.87 ± 0.05 a	44.52 ± 0.02 a	1.46 ± 0.00 a
4	Ctr	72.33 ± 0.09 b	4.59 ± 0.03 c	37.17 ± 0.03 c	37.45 ± 0.03 c	1.45 ± 0.00 b
	Gel	70.94 ± 0.01 c	5.10 ± 0.02 a	38.29 ± 0.02 b	38.63 ± 0.02 b	1.44 ± 0.00 c
	Gel-RS	74.45 ± 0.02 a	4.96 ± 0.02 b	43.42 ± 0.02 a	43.71 ± 0.05 a	1.46 ± 0.00 a
7	Ctr	70.94 ± 0.07 b	5.10 ± 0.02 c	38.29 ± 0.03 b	38.63 ± 0.03 b	1.44 ± 0.00 a
	Gel	62.80 ± 0.06 c	7.72 ± 0.03 a	36.12 ± 0.03 c	36.94 ± 0.03 c	1.36 ± 0.00 c
	Gel-RS	73.56 ± 0.02 a	6.02 ± 0.02 b	43.46 ± 0.03 a	43.88 ± 0.04 a	1.43 ± 0.00 b

Different letters within columns indicate statistically significant differences between samples of different treatments.

During the 7-day storage at 5 °C, various values of L*, a*, and b* parameters were observed between the control and treatment samples. The values of the brightness parameter L* were found to be higher in the samples of the Gel-RS treatment for all days of the storage period and were significantly different from the values of the other treatments. The same was observed for the values of the b* parameter, but the values of the a* parameter showed several fluctuations during the storage period. On the fourth and seventh days, the highest values were observed for the samples coated with the Gel coating. Gel-Rs showed a more compatible behavior with the potato slice's surface, and this coating played a protective role from biochemical processes such as enzymatic oxidation caused by polyphenol oxidase (PPO), which is responsible for the browning [59]. Furthermore, the rise in L* could be related to RS Whiteness [60].

The highest value of the Chroma* parameter was observed for the Gel-RS treatment, and it was significantly different from the control and the Gel treatment for each day of maintenance. A gradual increase in color with time was observed for all treatments. The highest values were recorded on the seventh day and were statistically different ($p < 0.05$) from the previous days. Finally, the Hue* angle values of potato samples decrease during storage at low temperatures. For each maintenance day studied, the values varied, and differences were observed between treatments ($p < 0.05$). On the seventh day of storage, the Ctr samples showed the largest Hue* angle values.

Regarding the changes in the color parameters studied, it was found that Gel-RS coating preserved the L* values of the fresh-cut potato samples. Similar values were also obtained for the a*, b*, and Chroma* parameters, where the highest values were observed for the Gel-RS treatment and were significantly different from the Ctr and Gel treatments. At the same time, a*, b*, and Chroma* values increased over time. This observation can be attributed to the phenomenon of enzymatic browning. Enzymatic browning is one of the most important problems of the food industry regarding the preservation and oxidation of phenolic compounds [47]. The results of this study are in accordance with the results of similar studies that observed an increase in formed pigments in food products during storage [33]. Similar results were obtained when coatings of sodium alginate and potato starch were applied to red potato samples and observed that the values of the Chroma* parameter increased compared to samples of the Ctr treatment [58]. These differences were characterized as significant. This is because the coatings provide a barrier against ethylene production and gas exchange between the samples and the environment, thus delaying losses from natural processes such as respiration and transpiration during storage. In addition, high CO_2 levels have been shown to reduce ethylene synthesis in tomatoes, which delays color changes [61]. Contrary to the results of the present study, it has been observed that applying chitosan coatings to freshly cut sweet potato samples maintained their color during storage [62]. It has also been reported that when they applied a coating based on cactus extract (1% *w*/*w*) on potato samples, it effectively suppressed the formation of unwanted brown color during storage at 5 °C [30].

3.3.2. Total Color Difference (ΔE)

The different types of edible coating affected the total ΔE (4) of fresh-cut Colocasia and potato samples, as it is shown in Figure 4. The ΔE values of Colocasia samples were greater compared to the values obtained from potato samples.

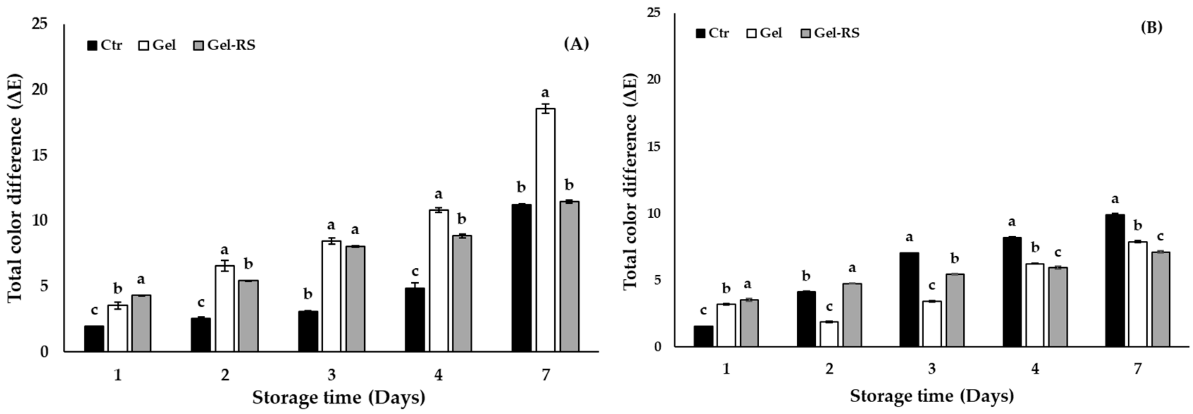


Figure 4. Total color difference (ΔE) values of fresh-cut Colocasia (**A**) and potato (**B**) samples during a 7-day storage period at 5 °C. Black columns indicate Ctr treatment; white columns indicate Gel treatment and grey columns indicate Gel-RS treatment. Different letters indicate statistical differences. Different letters within the columns indicate significant differences ($p < 0.05$) among the different treatments on every sampling date. Sample analysis was in triplicate.

As shown in Figure 4A, ΔE values of fresh-cut Colocasia samples coated with gelatin were significantly higher compared to the values of Ctr and Gel treatments. On the first four days of the storage period, ΔE of control samples were found to be significantly lower compared to the other treatments. The highest values of ΔE were recorded on Day 7 of storage for all treatments. The ΔE values of Colocasia samples recorded on that day were 11.26 ± 0.05, 18.57 ± 0.35, and 11.47 ± 0.12, concerning Ctr, Gel, and Gel-RS coating treatment, respectively. At the end of the storage period, the greatest values of ΔE were recorded for Gel treatment samples, while no differences were noticed between the Ctr and the Gel-RS treatment values.

ΔE values of the Ctr and Gel-RS treatment fresh-cut potato samples increased during storage, while ΔE (Gel) coated samples varied, as it is shown in Figure 4B. Moreover, significant differences were noticed among the three coating treatments for each day of storage. On Day 7, the Ctr treatment samples showed the highest color difference, followed by Gel and Gel-RS treatment samples. The highest values observed for each treatment were 9.92 ± 0.11 for the control treatment, 7.89 ± 0.10 for the Gel treatment, and 7.11 ± 0.09 for the Gel-RS treatment, respectively.

ΔE values of the Ctr and Gel-RS treatment samples increased progressively for each day of storage, while the values of the Gel treatment samples fluctuated. Similar results were found in some studies where the effect of two different coatings based on soy protein and chitosan on fresh potato samples was studied, respectively. The soy protein-based coating protected the samples from enzymatic browning [63,64].

Finally, in this study, both these two coatings reduced ΔE for fresh-cut potatoes compared to Ctr samples after seven days of storage at 5%. On the other hand, for fresh-cut Colocasia, Gel coating accelerates ΔE after the same period and temperature of storage compare to Ctr and to Gel-Rs coating. Interactions of coatings with samples surface could be responsible for the different behavior of tubers. Previous studies showed that the density and morphology of coatings affected fruit respiration and degradation [48,65]. In this research, it is shown that for potato fresh-cut slices, the surface of samples was more compatible with the coatings, but these coatings were not effective for Colocasia fresh-cut slices. Colocasia samples surface had the protective mucilage, which was secreted when the tuber tissue was injured during the preparation of the samples. This mucilage did allow Gel and Gel-Rs to act.

3.3.3. Whiteness Index (WI)

The different coating treatments had a direct effect on the Whiteness index (WI) (5) of Colocasia and potato fresh-cut samples, as is presented in Figure 5. Specifically, for both Colocasia and potato samples, WI values were increased during storage time, and the greatest values were recorded on Day 7.

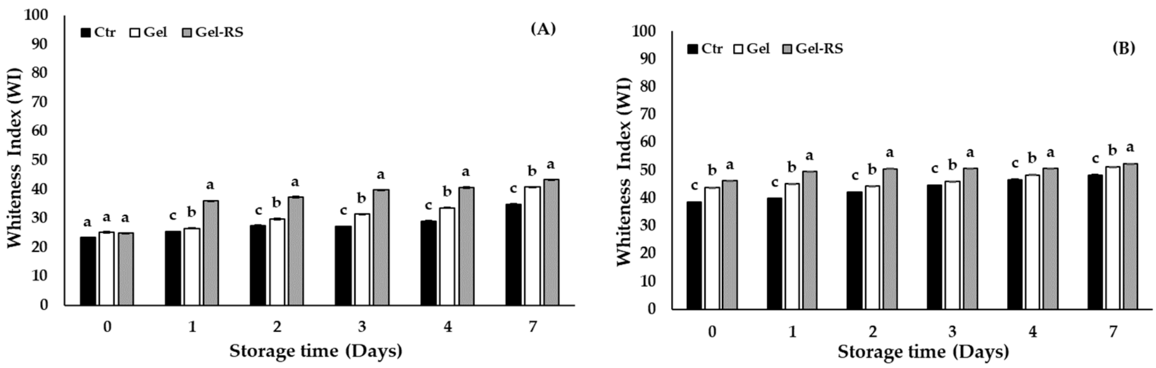


Figure 5. Whiteness Index (WI) of fresh-cut Colocasia (**A**) and potato (**B**) samples during storage period at 5 °C. Black columns indicate Ctr treatment; white columns indicate Gel treatment and grey columns indicate Gel-RS treatment. Different letters indicate statistical differences. Different letters within the columns indicate significant differences ($p < 0.05$) among the different treatments on every sampling date. Sample analysis was in triplicate.

The WI value of Colocasia samples was affected by the different coating treatments and storage times, as it is shown in Figure 5A. When Gel-RS edible coatings were applied to fresh-cut Colocasia samples, they retained the Colocasia sample's Whiteness. Moreover, WI values of Gel-RS-coated samples were found to be significantly higher compared to the Ctr and Gel treatments. The highest WI values recorded for Ctr, Gel, and Gel-RS treatments were 34.87 ± 0.11, 40.85 ± 0.09, and 43.34 ± 0.11, respectively. Significant differences were noticed among all treatments for all sampling dates. Significant differences were noticed among all treatments for all sampling dates. Nevertheless, the Whiteness index (WI) values of Colocasia samples were found to be significantly higher for the samples coated with Gel-RS, which may be due to the higher Whiteness values of the specific type of coating. Furthermore, the high Whiteness values observed in all treated samples can be attributed to the fact that Colocasia tubers are rich in starch, which has high Whiteness values (93.3–96.94) similar to the other type of starches [66]. Moreover, it has been found that storage of Colocasia samples at low temperatures did not cause any significant change in fruit color [67].

The same was also observed for fresh-cut potato samples, as it is shown in Figure 5B. The greatest WI values were observed for Gel-RS treatment samples, followed by the Gel and Ctr treatment samples, respectively. For all treatments, the greatest WI values were recorded on Day 7 and were 48.34 ± 0.06, 51.23 ± 0.07, and 52.42 ± 0.04, concerning the Ctr and samples coated with Gel and Gel-RS, respectively. The WI values of fresh-cut potato samples were significantly different among all samples for all sampling dates.

The Gel-RS-coated fresh-cut potatoes had the highest Whiteness values compared to the samples of the other treatments for all days of the storage period, while at the same time, they presented lower total color difference values. According to some studies, the enzymatic browning of a product can also be determined from the relationship between the Whiteness index and total color difference values [32]. High total color difference values with low Whiteness values indicate oxidative damage from enzyme action. Changes in Whiteness index values are associated with tissue water absorption in combination with storage conditions such as temperature and humidity [56]. Furthermore, the higher Whiteness values of Gel-RS treatment samples could be attributed to the functional properties of rice starch, such as high Whiteness values and higher hydrophilicity compared to gelatin coating [68]. Gel-RS coating had the same effect on WI values both for fresh-cut potatoes and fresh-cut Colocasia.

4. Conclusions

The current study provides novel information on the application of gelatin-based edible coatings on fresh-cut Colocasia and potato samples during their storage at 5 °C for seven days. Our data highlight that a combination of Gel and RS could be an interesting edible coating proposal for the development of biodegradable packaging in fresh potato products. In addition, the Gel and Gel-RS coating could not protect fresh-cut Colocasia slices due to the presence of the protective mucilage that is secreted when the tuber tissue is injured during the preparation of the samples. The compatibility of Colocasia fresh-cut surface with coatings should be further investigated. This investigation could be interesting in the food industry and, more specifically, in the quality maintenance of fresh-cut potatoes and Colocasia without using thermal processing technologies.

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