



## Article

# Application of *Opuntia ficus-indica* Mucilage and Aloe Gel-Based Edible Coating to Enhance Postharvest Quality and Microbiological Aspects of Fresh Figs (*Ficus carica* L.)

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**Abstract:** Fig is a widespread crop in southern Italy, highly valued for its sweet flavor. However, its consumption as a fresh product is limited to three to four days after harvest because of its high susceptibility to quality loss and microbial contamination. The combined use of low temperature and a modified atmosphere is the traditional preservation method. However, several studies have shown that the use of *Aloe arborescens* or *vera* and *O. ficus-indica* (OFI) mucilage as an edible coating could reduce the microbial load and water loss, respectively. Therefore, our study aimed to evaluate the synergistic effects of Aloe gel (AG) and *O. ficus-indica* mucilage (OM) on the quality and safety of two fig cultivars, 'San Giovanni' and 'Melanzana', during cold storage at 4 °C. The main results showed the effectiveness of edible coatings on both fig cultivars. An AG coating significantly reduced the microbial load, while the OM treatment showed the ability to preserve firmness and reduce weight loss. In addition, the combined OM + AG treatment showed the same effects as the individual coating formulations, also improving visual appearance. Thus, the use of the synergetic coating formulation could be a natural way to reduce the microbial load, extending fresh fig fruit's shelf life.

**Keywords:** *Aloe arborescens*; cactus pear cladodes; postharvest; fig fruits; coatings



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## 1. Introduction

Fig (*Ficus carica* L.), also known as milk berry or honey fruit, is a widely cultivated crop in the Mediterranean region. Most of the Italian production is concentrated in the southern regions [1–3]. Fig fruit can be consumed fresh or dried. Fig fruit represents an important source of fiber, carbohydrates, polyphenols, and vitamins. Figs with darker peel contain higher levels of health-promoting compounds, exhibiting greater antioxidant activity compared to those with green peel [4]. Renowned for their sweet flavor, figs are popular among consumers [5,6]. However, their consumption as fresh produce typically occurs close to the production areas, usually within three or four days after harvesting, due to their susceptibility to damage during transportation and handling [7].

During the ripening stage, both the fruit and its peel become highly susceptible to pressure and bruising, leading to potential breakage of the cuticle and peel detachment, which in turn favors bacterial infections. Furthermore, microbial decay can be facilitated by microorganisms entering through the ostiole. The post-harvest lifespan of figs depends significantly on handling practices that should be careful to minimize physical and microbiological damage and delay senescence [3]. Microbial contamination of fresh figs

originates from both environmental factors and production practices, resulting in loss of product quality and potential commercial losses. Yeasts, molds, and bacteria are primarily responsible for post-harvest deterioration, capable of altering the sensory qualities of fresh products and initiating fermentation processes.

Low-temperature storage is a widely adopted method for preserving figs, as they can be stored at temperatures below 2 °C without damage. Thus, cold storage, either alone or in combination with other treatments, represents the most effective technique for maintaining quality and controlling microbial deterioration over time [3]. Modified atmosphere packaging (MAP) represents the most applied technology for preserving fresh figs [7–13], although various preservation techniques have been reported in the literature. These include low-temperature storage [14], film coating or packaging [15,16], ozone treatment [17], chlorine and calcium treatments [18], fumigation [19], melatonin application [20], UVB irradiation [21], and the use of 1-methylcyclopropene (1-MCP) in conjunction with MAP [14]. An alternative to the aforementioned post-harvest technologies is the application of an edible coating (EC), offering a feasible approach. This method involves applying thin layers of edible materials to the surface of the product, creating a physical barrier against moisture, solutes, or gases emanating from the product. Thus, edible coatings provide a distinct means of developing a passive modified atmosphere due to their barrier properties.

The objective of applying edible coatings (ECs) is to mitigate product changes and prevent quality deterioration during storage, ultimately extending the shelf life of the product. Additionally, ECs facilitate the control of weight loss by reducing respiration and transpiration processes, thereby preserving the fruit's texture and nutritional properties. Moreover, ECs derived from renewable or natural sources are environmentally friendly and offer a potential alternative to mitigate plastic packaging usage and waste [22]. In recent years, several studies have been carried out regarding the application of natural edible coatings to prolong the shelf life of fresh figs [15,22,23].

There are potential alternatives to traditional chitosan-based coatings, namely, edible coatings derived from *Aloe* gel or *Opuntia ficus-indica* (OFI) mucilage. These alternatives have been tested on various fresh or fresh-cut products in recent years, including bananas [24], cherries [25], kiwifruits [26–28], and white peach [29]. OFI mucilage, sourced from the cladodes of *O. ficus-indica*, is gaining traction due to its complex polymeric structure, primarily consisting of carbohydrates with nutraceutical value. These substances swell when mixed with water or form colloidal suspensions, resulting in an EC that imparts a shiny appearance to the fruit surface. Moreover, they leverage their hydrophilic properties to create a barrier against water evaporation from the plant tissue, thus delaying weight loss and enhancing firmness [1,26].

*Aloe* gel, composed of sugars, polysaccharides, proteins, and vitamins, not only contributes to weight loss reduction but also provides microbial spoilage reduction benefits [28]. Studies have shown that combining OFI mucilage with *Aloe* gel yields superior results compared to individual treatments, leading to significant preservation of weight, firmness, and microbiological quality in fresh products. This combination has been found to mitigate physiological disorders and gas transpiration while maintaining total soluble solids and increasing antioxidant content. Even if the literature reports the effects of OFI mucilage or *Aloe* spp.-based coatings on fresh figs, there remains a need to investigate their combined effects. The application of OFI mucilage on breba figs can delay the reduction of the amino acid content during storage by increasing carbohydrates and other metabolites, showing a significant effect on fruit metabolism [2]. Research by Al-Hilifi et al. [30] demonstrated that *Aloe vera* gel-based EC effectively reduced weight loss and improved the qualitative characteristics of fig fruit. 'San Giovanni' and 'Melanzana' fig fruits are the most valuable cultivars in Italy, but since they are very perishable, the choice of an economical medium-value edible coating treatment was made to enhance their quality characteristics and to prolong their shelf-life.

Different research has studied the effects of *Aloe* on reducing microbiological growth, as well as the use of OFI on water loss and respiration rate control, but the effect of the use of both on postharvest whole fruit has not been studied.

Therefore, this research aimed to evaluate the individual and synergistic effects of applying two edible coatings based on *Aloe arborescens* gel and OFI mucilage on fresh figs. The coating application effects on the physicochemical and sensory quality of two fig varieties were studied. Two different fig varieties were tested to assess the potential presence of variety-specific treatment responses. Related microbiological safety aspects, which are the primary cause of deterioration and quality loss in fresh figs during their shelf life were also investigated.

## 2. Materials and Methods

### 2.1. Edible Coating Preparation

Mucilage was extracted from 2 kg of *O. ficus-indica* first-year cladodes following the method outlined by Allegra et al., 2016 [26]. The cladodes were harvested and transported to the University of Palermo. Cubes measuring 2 cm<sup>3</sup> were then homogenized in distilled water at a concentration of 20% (*w/v*) with a water-to-cubes ratio of 1:1.5. This mixture was maintained at a temperature of 40 ± 1 °C for 90 min, followed by centrifugation at 3000 rpm for 20 min. The supernatant was boiled until the volume reduced by 50%, and 99% ethanol was added in a 1:2 ratio to minimize alcohol usage during precipitation. The solution was then stored at 4 ± 1 °C for 48 h to enhance mucilage aggregation. After supernatant removal, the pure mucilage was obtained. For the preparation of *Aloe* gel (AG), 1 kg of ripe *Aloe arborescens* leaves were harvested at the experimental field of the University of Palermo. The outer margin of the leaves was removed and they were then longitudinally cut to separate the parenchyma from the epidermis. The gelatinous parenchyma was homogenized using an Ultra-Turrax (Ika Labortechnik, Staufen, Germany) at 24,500 rpm for 5 min, resulting in a mucilaginous gel. Subsequently, the gel was filtered to remove the fibrous part [29].

### 2.2. Plant Materials and Coating Application

Figs (*F. carica* L.) of 'San Giovanni' (light green peel and great size) and 'Melanzana' (purple peel and great size) cultivars were harvested at the end of August 2022 from a commercial orchard in Sicily, Italy. Immediately after harvest, fruits were transported to the University of Palermo post-harvest laboratory. Subsequently, they were immersed in sanitized water (100 ppm of free chlorine) for 360 s. Any defective fruits, showing signs of bruising, physical damage, unusual coloration, or improper maturity, were discarded, and the remaining were used for the experiment. Following the preparation of the previously described edible coatings (as detailed in Section 2.1), the coating treatments were applied as follows: (i) a mixture of 30 g of pure *O. ficus-indica* mucilage extract (OM), 500 mL of distilled water with 2% *A. arborescens* (AG) and 50 mL of glycerol as a plasticizer (OM + AG); (ii) 30 g of *A. arborescens*, 500 mL of distilled water, 50 mL of glycerol (OM); and (iii) 500 mL of distilled water with 2% *A. arborescens* and 50 mL of glycerol as a plasticizer (AG).

The coating process followed the method described by Sortino et al. [28]. Figs were dipped in the coating solution for 60 s, excess coating was drained, and then the coated fruits were dried in a forced-air dryer at 20 °C for 5 min. Control samples (CTRL) consisted of figs dipped in distilled water. The treated figs were then placed in macroperforated polystyrene (PS) bags (Carton Pack S.p.A., Rutigliano, Italy) and stored at 4 ± 0.5 °C with 85% RH for up to 12 d [1]. For each of the three coated treatments and the uncoated CTRL sample, and for each storage time, 144 fruits (2 fruit × 36 bags × 2 variety) were used. Quality parameters, as described below, were determined immediately after dipping (day 0) and at 2, 5, 8, and 12 d of storage (microbiological analyses), or 3, 5, 7, and 10 d for physicochemical and sensory determination.

### 2.3. Total Soluble Solids (TSSs), Titratable Acidity (TA), and Maturation Index

The total soluble solids content was determined on fig fruit before the treatments and on the 10th day of storage with a hand-held refractometer (Atago Palette PR-32, Atago Co., Tokyo, Japan). The titratable acidity (expressed g citric acid 100 g<sup>-1</sup> fresh weight) was determined by titrating with 0.1 M NaOH to an endpoint of pH 8.10. The maturation index (MI) was calculated as the TSS (°Brix) to TA (g citric acid 100 g<sup>-1</sup> fresh weight) ratio.

### 2.4. Color

The color of the peel was measured with a portable colorimeter (Minolta CR 400 HEAD, Minolta, Osaka, Japan) equipped with an 8-mm measuring head, and a C illuminant (6774 K) was used.

### 2.5. Firmness

Fruit firmness was measured before the treatments and on the 10th day using a fruit texture analyzer (Instron 5564, Instron Corporation, Norwood, MA, USA) adapted with a flat tip. Fig fruit was compressed on the cheek with a 2.5 cm flat tip at a speed of 5 mm s<sup>-1</sup> to a depth of 4 mm, and the maximum value of the force was expressed in newtons (N).

### 2.6. Microbiological Analyses

Microbiological analyses were conducted on fig samples to assess the levels of total mesophilic microorganisms (TMMs), as well as yeasts and *Pseudomonas* count, as described below. Initially, 25 g of fruit tissue was suspended in a 1:10 ratio (fruit to diluent) in Ringer's solution (Sigma-Aldrich, Milan, Italy). The suspension was homogenized for 2 min using a stomacher (BagMixer1 400, Interscience, Saint Nom, France) and then serially diluted. For the enumeration of TMMs, cell suspensions were plated on plate count agar (PCA) and incubated aerobically at 30 °C for 72 h. *Pseudomonas* counts were conducted by inoculating the dilutions on *Pseudomonas* Agar Base (PAB) supplemented with cetrimide and incubated for 48 h at 25 °C. Yeasts counts were performed on yeast potato dextrose (YPD) agar and incubated aerobically at 25 °C for 48 h [1]. All media and supplements were obtained from Oxoid (Milan, Italy) and plate counts were carried out in duplicate for each trial.

### 2.7. Total Polyphenol Content

The total polyphenol content was determined following the method described in [31], using the Folin–Ciocalteu reagent (FC). Thirty grams of fresh fig fruit tissue were homogenized with methanol (in a ratio of 1:10, *w/v*). After filtration, the methanolic extracts were concentrated under reduced pressure, and the resulting residue was suspended in a solution of 50% (*v/v*) aqueous methanol. This suspension was then utilized for the determination of the phenolic content. The results were expressed as gallic acid equivalent (mg kg<sup>-1</sup> fresh weight), with the analyses performed in triplicate for each sample.

### 2.8. Visual Appearance Score

The visual appearance score at each storage time was evaluated by six trained judges, using a 5 to 1 scale, according to [32], where 5 = very good, 4 = good, 3 = fair (limit of marketability), 2 = poor (limit of usability), and 1 = very poor (inedible). Panelists assessed changes in flesh color and brightness, the occurrence of mold, and the presence of any surface flaws.

### 2.9. Weight Loss

Weight loss was measured on samples after the treatment (day 0) and after 3, 5, 7, and 10 days of storage, as a percentage of the initial fresh weight.

### 2.10. Statistical Analysis

The experimental design consisted of three edible coating treatments (OM, AG, and OM + AG) and the untreated control, with observations made at 0, 2, 5, 8, and 12 d, or 3, 5, 7, and 10 d after coating for physicochemical and sensory evaluation. For each treatment, six fruits were analyzed at each sampling time, as single replicates. Analysis of variance and correlation were applied to the obtained results and Systat 13.0 for Windows was used as the statistical software. Significant differences ( $p \leq 0.05$ ) were measured by Fisher's test.

## 3. Results

'San Giovanni' and 'Melanzana' fig fruit were harvested in August with different mean firmness values but similar TSS and TA contents and maturation indexes, although they are different cultivars (Table 1).

**Table 1.** Chemical and physical characteristic of 'San Giovanni' and 'Melanzana' varieties at harvest.

	'San Giovanni'	'Melanzana'
Firmness (N mm <sup>-1</sup> )	22.3 ± 1.1	21.7 ± 2.1
TSS (%)	15.5 ± 3.2	14.5 ± 1.9
TA (g citric acid 100 g <sup>-1</sup> fresh weight)	0.3 ± 0.04	0.3 ± 0.05
Maturation index (TSS/TA)	51.6 ± 6.1	48.3 ± 1.5
L*	72.2 ± 6.3	42.7 ± 2.9
a*	-16.1 ± 1.5	29.1 ± 3.5
b*	36.4 ± 4.5	23.2 ± 6.1

The physicochemical mean values of the 'San Giovanni' and 'Melanzana' cultivars are shown on the 10th day of storage (Table 2). Regarding firmness, it is observed that fruit subjected to the OM and AG + OM treatments had a greater firmness compared to CTRL and AG in both cultivars. This suggests that the use of the edible coating based on OFI mucilage contributed to improving fruit firmness, slowing down their natural deterioration. The TSS mean values of 'San Giovanni' fig fruit have a generally higher average compared to the 'Melanzana' cultivar. Therefore, on the 10th day of storage, the TSS and TA contents of the untreated and treated samples remained stable. The maturation index showed different results between treatments and cultivars. Indeed, San Giovanni fig fruit treated with the AG treatment showed higher mean values than the other treatments, while CTRL 'Melanzana' fig fruit had the highest mean values. On the 10th day of storage, L\* (lightness) showed a decrease in the untreated and treated 'San Giovanni' and 'Melanzana' cultivar samples but the untreated ones had worse results than the OM, AG, and OM + AG treatments. The indexes a\* and b\* slightly changed between the treatments after 10 days of cold storage. Untreated samples lost approximately half of the initial values of firmness in both cultivars, while the OM and OM + AG treatments showed the best results in terms of firmness. These mean values were correlated with visual score values, shown below showing a high index ( $R^2 = 0.985$ ), meaning that the loss of firmness is one of the key factor determining consumers' acceptance.



**Table 2.** Chemical and physical characteristic of ‘San Giovanni’ and ‘Melanzana’ cultivar fresh figs coated with edible coating made of *O. ficus-indica* cladode pure mucilage (OM); with *Aloe arborescens* (AG); with OFI mucilage + *Aloe arborescens* (OM + AG); and not treated (CTRL) on 10th day of storage at 4 °C. Data are means of three replicates for each sampling time, error bars represent standard deviation.

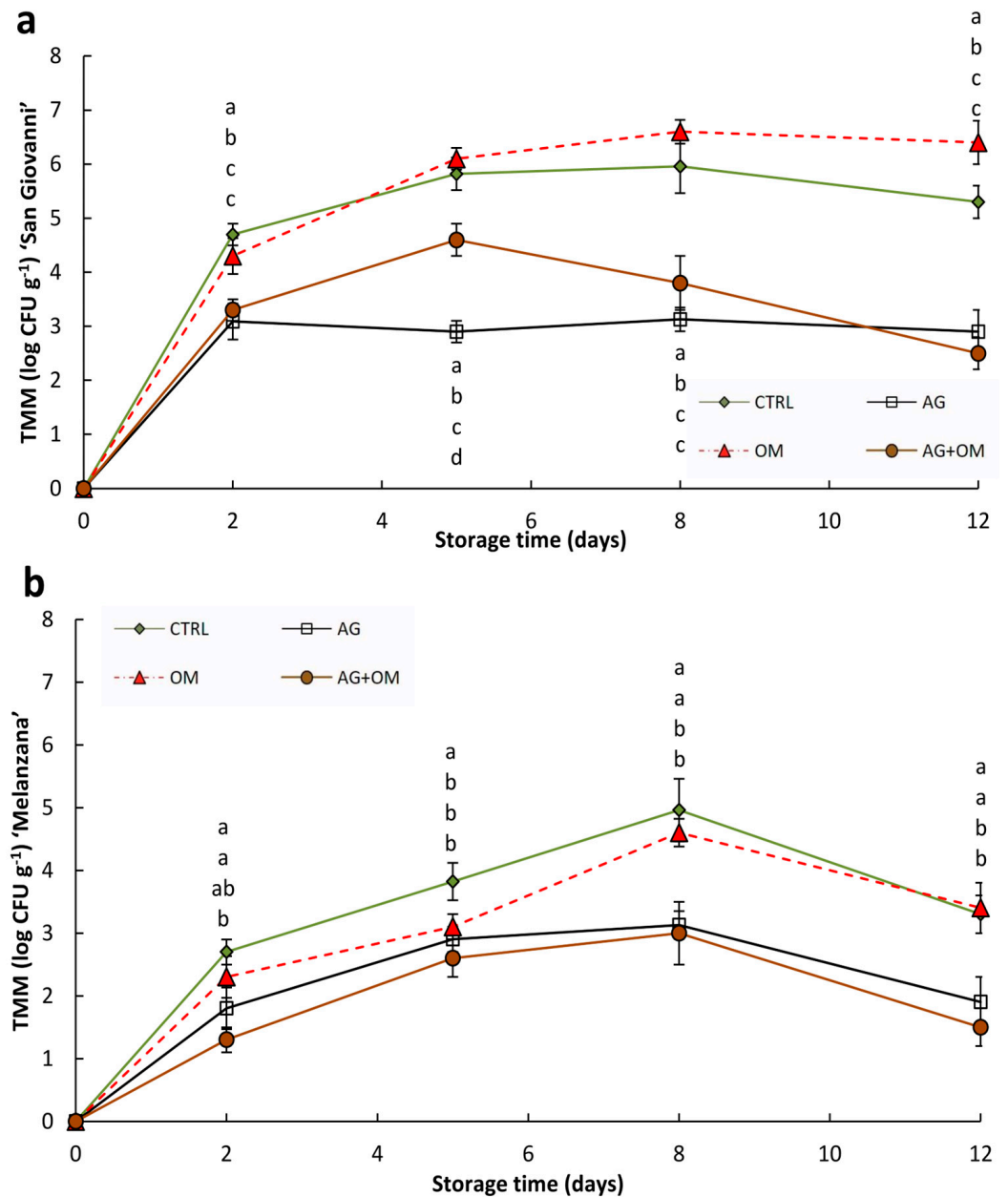
Cultivar	Treatment	Firmness (N mm <sup>-1</sup> )	TSS (%)	TA (g Citric Acid 100 g <sup>-1</sup> Fresh Weight)	Maturation Index (TSS/TA)	L*	a*	b*
‘San Giovanni’	CTRL	13.68 ± 1.9	15.5 ± 3.2	0.2 ± 0.04	77.5 ± 6.4	51.2 ± 8.1	−13.1 ± 1.5	37.7 ± 2.5
	AG	17.55 ± 1.2	13.6 ± 2.7	0.1 ± 0.02	97.1 ± 3.6	55.5 ± 6.3	−15.1 ± 1.2	37.2 ± 1.2
	OM	18.82 ± 1.5	14.1 ± 2.4	0.3 ± 0.02	47.0 ± 2.7	59.3 ± 5.1	−15.6 ± 1.1	36.9 ± 1.9
	AG + OM	18.01 ± 1.5	14.5 ± 2.7	0.2 ± 0.01	72.5 ± 4.9	58.6 ± 7.6	−15.7 ± 1.4	36.5 ± 1.6
‘Melanzana’	CTRL	11.79 ± 1.2	13.1 ± 2.9	0.1 ± 0.03	87.3 ± 5.1	27.1 ± 4.5	29.1 ± 3.5	25.3 ± 3.1
	AG	15.23 ± 1.7	13.8 ± 1.4	0.2 ± 0.01	69.0 ± 6.5	32.1 ± 4.1	29.1 ± 3.6	24.4 ± 1.5
	OM	19.47 ± 1.4	13.3 ± 0.9	0.2 ± 0.01	66.5 ± 2.7	37.7 ± 5.7	29.1 ± 3.7	25.5 ± 2.9
	AG + OM	19.90 ± 1.3	13.5 ± 1.5	0.2 ± 0.02	67.5 ± 2.8	37.2 ± 4.3	29.1 ± 3.8	24.6 ± 2.7

### 3.1. Microbiological Aspects

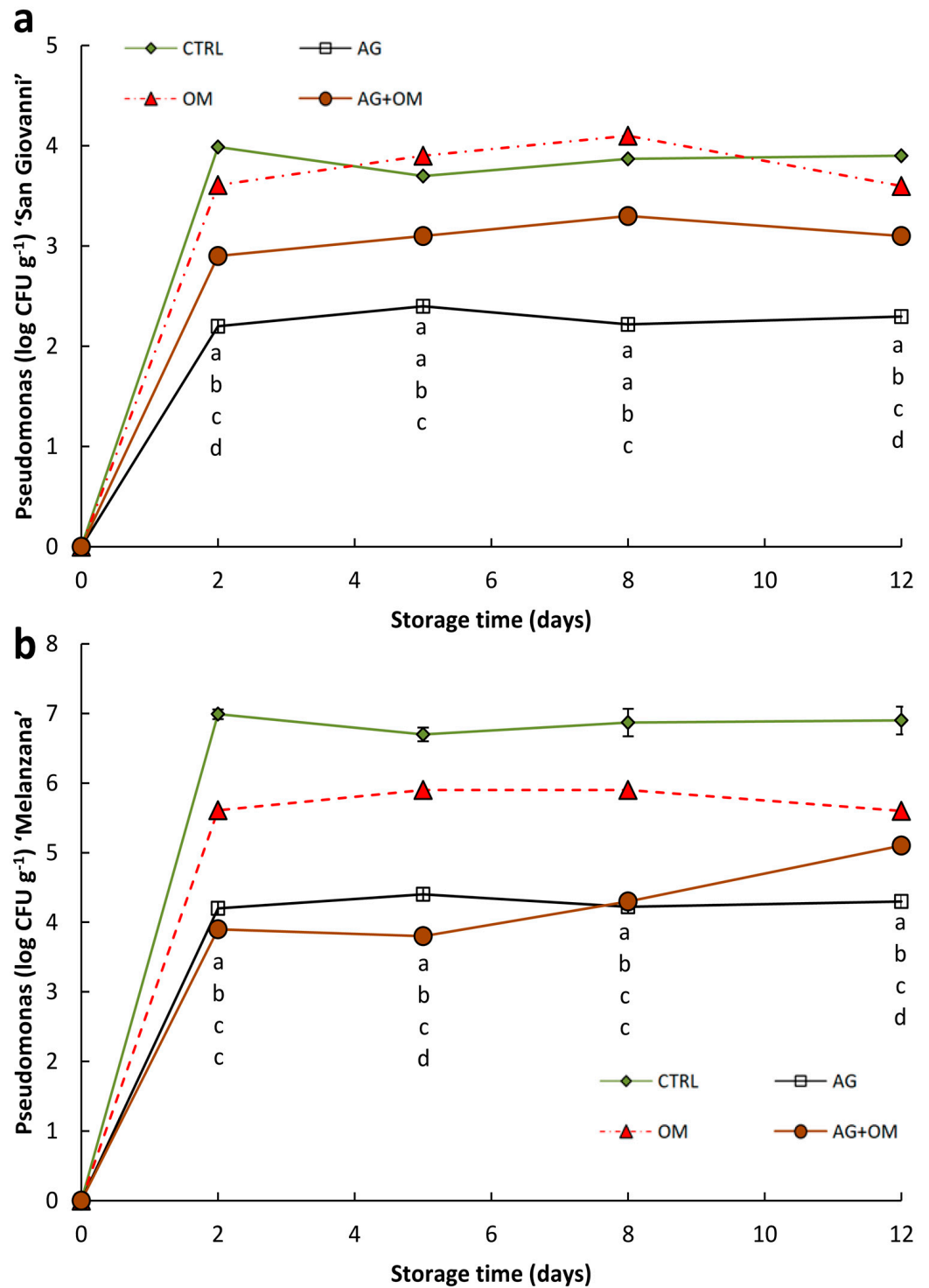
A similar trend that demonstrated a progressive rise in microbial populations during the storage period emerged in both fig varieties. AG samples for the ‘San Giovanni’ cultivar (Figure 1a) had the lowest total mesophilic load after storage, staying constant at almost 3 log CFU g<sup>-1</sup>. Samples coated with both ECs (AG + OM) showed levels between 3 and 4 log CFU g<sup>-1</sup> from days 8 and 12, which were statistically equivalent to AG. On the other hand, the microbial loads in the control samples and those that were just coated with OM showed greater levels of microbial growth, amounting to about 5–6 log CFU g<sup>-1</sup> at the end of storage. A similar trend was observed for the ‘Melanzana’ variety (Figure 1b), although with lower absolute values compared to ‘San Giovanni’. Throughout storage, the CTRL and OM samples significantly differed from AG and AG + OM, with final average microbial loads of 4 log CFU g<sup>-1</sup> and 2 log CFU g<sup>-1</sup>, respectively.

Similarly, regarding the presence of *Pseudomonas* spp. on the external surface of fresh figs, it was observed that the inclusion of *Aloe* in the edible coating significantly decreased the *Pseudomonas* spp. load throughout the entire refrigerated storage period. From the 2nd day of storage onward, all samples exhibited an increase in microbial load, albeit reaching different levels depending on the type of coating applied (Figure 2a,b).

In the ‘San Giovanni’ cultivar, *Pseudomonas* spp. levels remained around 2 log CFU g<sup>-1</sup> for the AG-coated sample and 3 log CFU g<sup>-1</sup> for the AG + OM coating until day 12 (Figure 2a). On the other hand, in the dark ‘Melanzana’ cultivar, these values were approximately double, yet still statistically lower than those of the other treatments, with the control samples showing the highest values for both varieties (Figure 2b). Concerning the yeast count for the ‘San Giovanni’ variety, the OM coating of cactus pear cladodes was more effective in controlling yeast growth, maintaining yeast levels of 1 log unit lower than the AG and AG + OM treatments for up to 12 days of storage. In the ‘Melanzana’ variety, at the end of the storage period the AG, OM, and AG + OM treatments showed statistically similar values (approximately 4 log CFU g<sup>-1</sup>), contrasting with the value exceeding 6 log found in the CTRL sample (Figure 3).

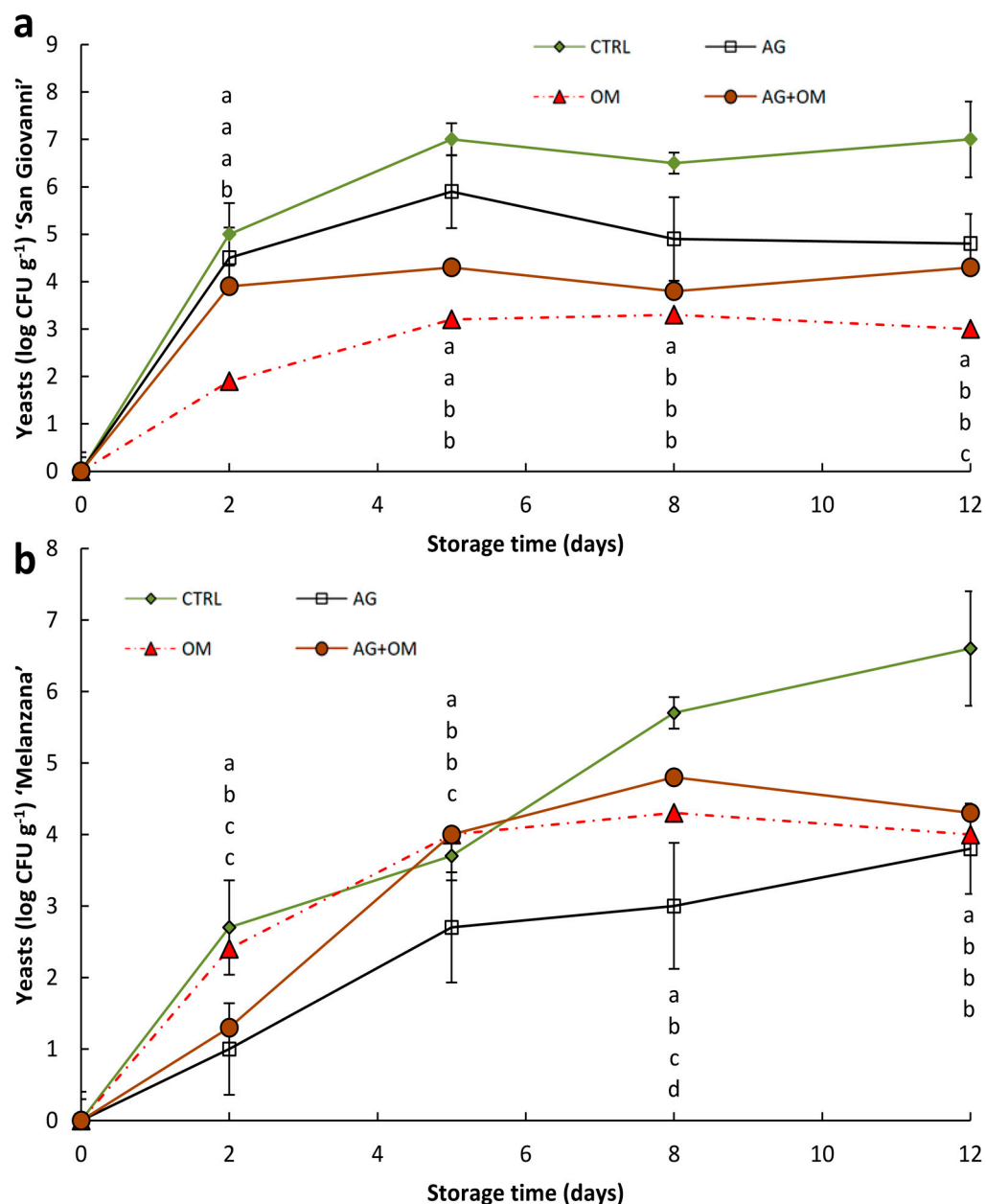


**Figure 1.** Total mesophilic microorganisms (TMMs) load of (a) ‘San Giovanni’ and (b) ‘Melanzana’ cultivar fresh figs coated with edible coating made of *O. ficus-indica* cladode pure mucilage (OM); with *Aloe arborescens* (AG); with OFI mucilage + *Aloe arborescens* (OM + AG); and not treated (CTRL), just after being coated (0) and after being stored for 2, 5, 8, and 12 days at 4 °C. Data are means of three replicates for each sampling time; error bars represent standard deviation. Means with different letters at the same time of storage are significantly different according to Fisher’s test ( $p$  value  $\leq 0.05$ ).



**Figure 2.** *Pseudomonas* spp. load of (a) 'San Giovanni' and (b) 'Melanzana' fresh fig cultivars coated with edible coating made of OFI mucilage (OM); with *Aloe arborescens* (AG); with OFI mucilage + *Aloe arborescens* (OM + AG); and not treated (CTRL), just after being coated (0) and after being stored for 2, 5, 8, and 12 days at 4 °C. Data are means of three replicates for each sampling time; error bars represent standard deviation. Means with different letters at the same time of storage are significantly different according to Fisher's test ( $p$  value  $\leq 0.05$ ).

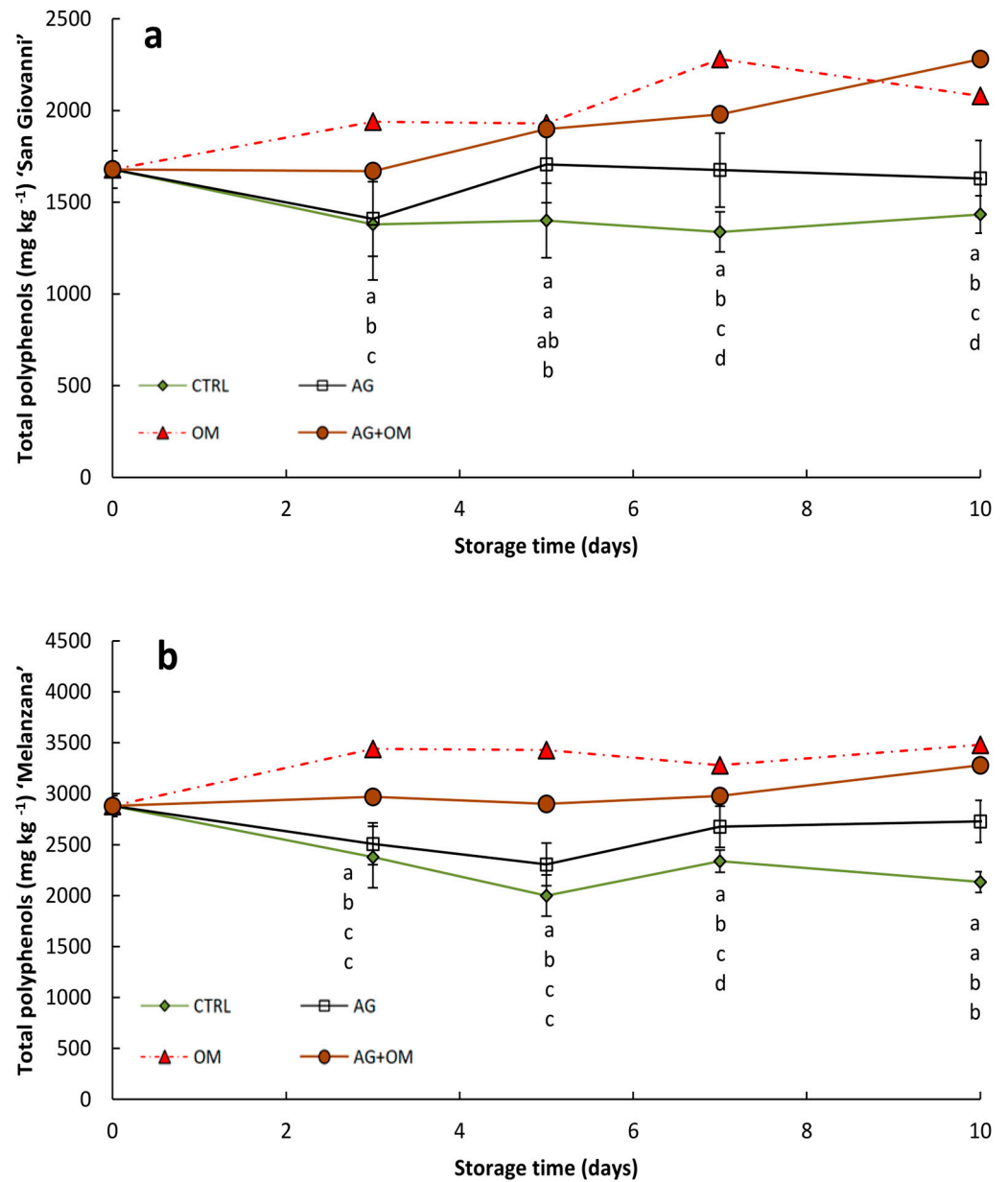




**Figure 3.** Yeasts load of (a) 'San Giovanni' and (b) 'Melanzana' fresh fig cultivars coated with edible coating made of OFI mucilage (OM); with *Aloe arborescens* (AG); with OFI mucilage + *Aloe arborescens* (OM + AG); and not treated (CTRL), just after being coated (0) and after being stored for 2, 5, 8, and 12 days at 4 °C. Data are means of three replicates for each sampling time; error bars represent standard deviation. Means with different letters at the same time of storage are significantly different according to Fisher's test ( $p$  value  $\leq 0.05$ ).

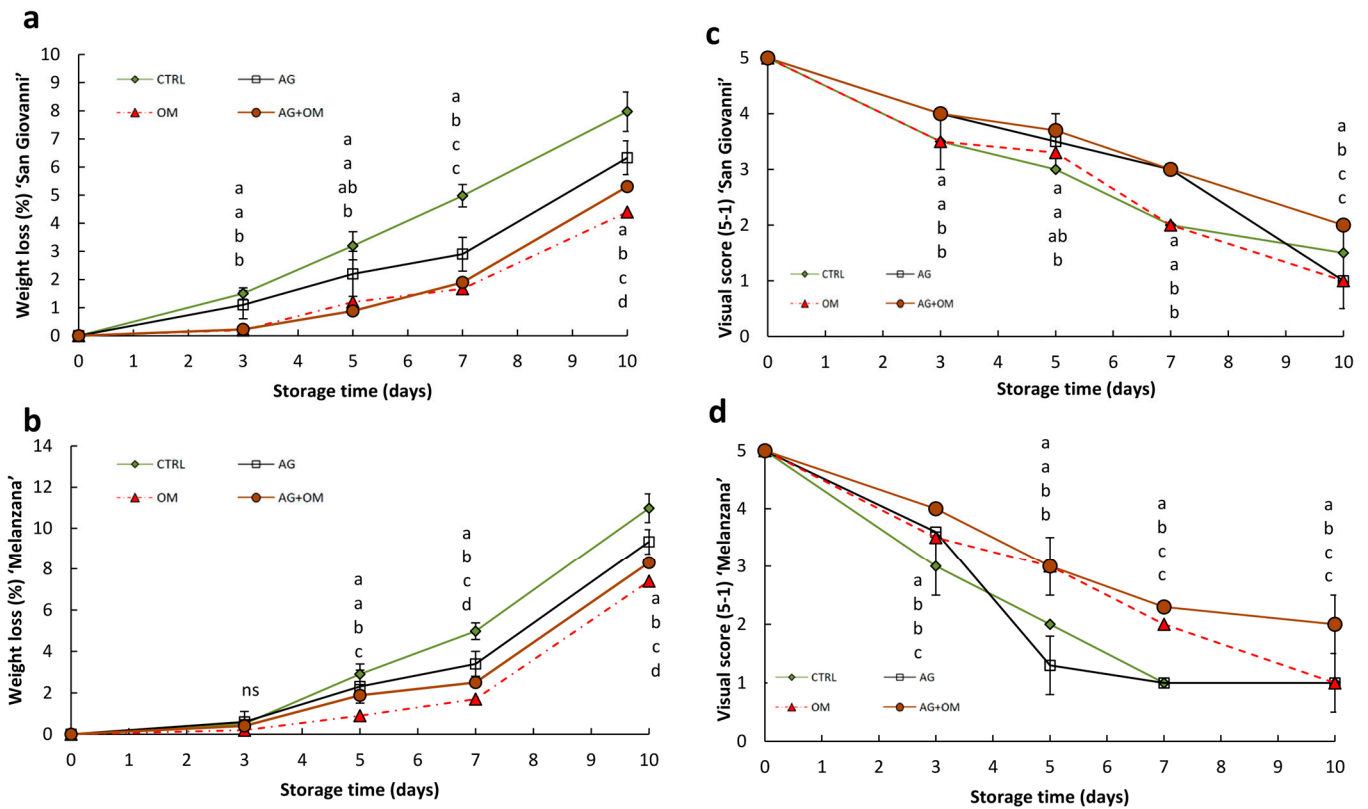
### 3.2. Physicochemical and Sensory Aspects

The evolution of the total polyphenol content of fresh figs during storage time exhibited a similar trend in both varieties, with 'San Giovanni' figs demonstrating the highest mean values (Figure 4a,b). Generally, the phenolic content remained relatively stable over time. However, the type of EC significantly impacted this parameter from the initial days of storage. Specifically, the OM and AG + OM treatments facilitated the maintenance of higher values for both varieties studied. Although the 'Melanzana' variety displayed differences between treatments like those of the other variety, it notably exhibited significantly higher values of these compounds, approximately double compared to 'San Giovanni'.



**Figure 4.** Total polyphenol content of fresh figs of (a) 'San Giovanni' and (b) 'Melanzana' cultivars coated with edible coating made of OFI mucilage (OM); with *Aloe arborescens* (AG); with OFI mucilage + *Aloe arborescens* (OM + AG); and not treated (CTRL), just after being coated (0) and after being stored for 3, 5, 7, and 10 days at 4 °C. Data are means of three replicates for each sampling time; error bars represent standard deviation. Means with different letters at the same time of storage are significantly different according to Fisher's test ( $p$  value  $\leq 0.05$ ).

Coating application significantly influenced both weight loss (Figure 5a,b) and the visual appearance of fresh fig fruit (measured by visual score, Figure 5c,d). Throughout the 10-day storage period, a physiological increase in weight loss was observed, with noticeable differences among the treatments. Specifically, the OM and AG + OM treatments resulted in lower weight loss, ranging between 3 and 4% for the 'San Giovanni' variety and approximately 8% for the 'Melanzana' variety. Fig fruits coated with *Aloe* gel displayed intermediate behavior, while the absence of an edible coating (CTRL sample) led to the highest weight loss, reaching a maximum value of 10% for 'Melanzana' figs.



**Figure 5.** Visual score (a–c) and weight loss (b–d) of ‘Melanzana’ and ‘San Giovanni’ cultivar fresh figs coated with edible coating made of OFI mucilage (OM); with *Aloe arborescens* (AG); with OFI mucilage + *Aloe arborescens* (OM + AG); and not treated (CTRL), just after being coated (0) and after being stored for 3, 7, and 10 days at 4 °C. Data are means of three replicates for each sampling time; error bars represent standard deviation. Means with different letters at the same time of storage are significantly different according to Fisher’s test ( $p$  value  $\leq 0.05$ ).

The evolution of the visual score for both varieties over storage time, as shown in Figure 5c,d, revealed distinct trends. The CTRL samples exhibited a rapid decline in visual scores, while the other treatments displayed slightly fluctuating patterns, gradually decreasing but without a consistent trend. Notably, the AG + OM samples consistently maintained significantly higher visual scores than the other treatments, maintaining a positive appearance rating for up to 10 days. AG + OM-treated figs’ visual appearance remained above the marketability threshold (score of 3) for up to 5 days of storage, gradually declining afterward, reaching indicative values around 2.5, 7, and 10 d. In contrast, the visual appearance of the other samples at day 10 approached the usability limit. Visual score data were correlated with firmness results, showing a high correlation index ( $R^2 = 0.985$ ).

#### 4. Discussion

OM and AG were mixed due to the difficulty of OFI preserving microbial growth due to the high presence of carbohydrates in *Opuntia* mucilage, which was slowed down by AG due to the known antimicrobial properties of *Aloe*. As previously discussed by [28], *Aloe* and mucilage-based edible coating application was proven to be effective in controlling different quality aspects of fresh-cut fruit, even if the effectiveness itself was subject to the different compositions of the constituents of both *Aloe* and the OFI mucilage. The microbiological quality of fig fruit subjected to different coating treatments was evaluated over a 12-day storage period to understand the effect of the edible coating on reducing microbial contamination. Due to the wide range of constituents of both matrixes, microbial growth was controlled. Significant effects were observed across all the microbial groups considered due to the presence of one or both coatings. However, as previously noted

by [1], the application of an OFI mucilage coating to fresh figs did not entirely prevent microbial decay but rather mitigated its development. On the other hand, the presence of *Aloe arborescens* gel was responsible for reducing microbial loads, given its different constituents known for inhibiting the growth of both Gram+ and Gram– bacteria [28]. Similarly, findings reported by [28] regarding fresh-cut kiwifruit showed that the presence of EC, particularly Aloe gel, resulted in a more effective microbial reduction, especially concerning bacteria and yeasts. *A. arborescens* demonstrated efficiency in reducing microbial activity, likely due to its higher aloin content compared to other *Aloe* species; in particular, *A. arborescens* is much richer in phenolics and total antioxidant activity and poorer in terms of putrescine and spermidine compared to *A. vera* [33]. The combined coating formula application did not notably enhance the treatment effectiveness, indicating that the antimicrobial activity is primarily attributable to the *Aloe* gel.

Overall, the application of coatings improved the safety aspects of the fruit, as also observed in the application of EC based on active polysaccharides on figs [22]. The hypothesis suggests that indigenous microflora present on figs' surfaces did not find suitable conditions for growth after the coating application. Regarding polyphenol content, no significant variations were observed compared to the initial value, aligning with a similar trend reported in [1] for 'Dottato' breba figs, with absolute values comparable to those of 'San Giovanni' and 'Melanzana' figs. However, after 5 days of storage, the phenols content increased by about 37%. Generally, increases in phenol content can be promoted by wounding stress, which determines the accumulation of phenolic compounds [34]. Indeed, Figures 1a and 2a show an increase in *Pseudomonas* spp. and total mesophilic microorganisms on the 7th day of storage only for the 'San Giovanni' cultivar, probably due to its higher value of TSS than the 'Melanzana' cultivar (Tables 1 and 2).

Fresh figs are particularly susceptible to losing their organoleptic and external characteristics. Therefore, results regarding external appearance and weight loss are particularly pertinent. The thin peel of figs allows for rapid water loss, exacerbating tissue aspect deterioration and leading to increased weight loss, particularly during cold storage, especially for the CTRL samples (Figure 4a,b). Coatings form a thin, transparent layer on the fig peel surface, effectively slowing down the dehydration process responsible for the fruit's weight loss. Similar results were obtained with different types of coating. For instance, Adiletta et al. [7] observed that a chitosan coating significantly delayed fruit weight loss, while control samples experienced a notably higher percentage of weight loss (22.2%) after nine days of storage. Similarly, lower weight loss percentages were observed in 'Dottato' figs coated with *Opuntia ficus-indica* mucilage [1,2].

Moreover, postharvest treatments using natural antimicrobial compounds, such as defatted soybean meal extract combined with macro- or microperforated films, slowed down weight loss in 'Cuello Dama Blanco' and 'Cuella Dama Negro' fig cultivars during 14 days of cold storage at 0 °C [10]. Maintaining the cold chain after harvest can also help in reducing weight loss in fresh figs [7]. An *Aloe* gel-based coating also contributed to reducing weight loss after 10 days of storage (<2.94%) compared to uncoated control samples, as reported by [30]. However, in our study, the primary responsibility for weight loss reduction is attributed to OFI mucilage (treatments OM and AG + OM; Figure 4), as confirmed by the experiment on kiwifruit slices by Allegra et al. [28]. Several other studies regarding the application of edible coatings based on OFI mucilage on different fruit types have further confirmed this behavior [24–29].

Many of the parameters considered, for example, TSS/TA ratio maturity index, used as an index of consumer acceptability and fruit quality [35], were proven to be higher in 'San Giovanni' AG-treated fig fruit, especially compared with CTRL fruit. It was in fact observed that single coatings were more effective than the combination of both. However, for the visual score, it was the AG + OM treatment that had a significant effect (Figure 5c,d). The combined coating led to better maintenance of the visual score for both varieties, although by the end of the storage period, no treatment allowed it to remain above the marketability limit (score = 3). A similar trend was observed for minimally processed

kiwifruit treated with both OFI mucilage and *Aloe* gel, which had the best visual score up to 7 d of storage [1,28].

## 5. Conclusions

This study aimed to assess the synergistic effects of combined edible coatings comprising *Aloe arborescens* and OFI mucilage on the postharvest quality of two varieties of fresh figs, focusing particularly on safety aspects and physicochemical parameters. Our result showed that both varieties detected a progressive increase in microbial populations during the storage period, with a lower microbial load in samples treated with an edible coating based on *Aloe* gel (AG) compared to control samples and those treated only with OFI mucilage (OM), particularly evident regarding the presence of *Pseudomonas* spp. and total mesophilic microorganisms groups. OFI mucilage (OM) was more effective in controlling weight loss in both varieties until 10 days of storage. Overall, the AG + OM treatment improved safety and appearance on the 7th day, showing the best results. The use of *Aloe arborescens* and OFI mucilage coatings reduced bacterial growth and weight loss, enhancing the quality of fresh figs, offering the potential to extend shelf life while maintaining product quality. Further research can optimize fig preservation and appearance.

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