

**Improvement of quality, sensory properties and shelf life of
 fresh cut oranges by using a bilayer cocoa-sodium alginate
 coating**

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3 1 **Improvement of quality, sensory properties and shelf life of fresh cut oranges by**
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6 2 **using a bilayer cocoa-sodium alginate coating**
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9 3 **RUNNING TITLE: IMPROVEMENT OF QUALITY OF FRESH CUT**
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12 4 **ORANGES BY USING A BILAYER COATING**
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55 21 *alginate, cocoa and a bilayer alginate-cocoa coating on the quality of fresh-cut oranges during storage*, by
56 22 *Virginia Glicerina, Lorenzo Siroli, Ester Betoret, Giada Canali, Marco Dalla Rosa, Rosalba Lanciotti,*
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58 21 *Santina Romani*, which is published in its final version in JOURNAL OF THE SCIENCE OF FOOD AND
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Abstract

BACKGROUND

Fresh-cut products are ready-to-use goods which retain the fresh characteristics of raw produce. However, numerous factors restrict the quality and shelf-life of fresh-cut products. One of the most promising, convenient and safe technologies to preserve the quality and to prolong the shelf-life of fresh fruits and vegetables is the application of edible coatings.

RESULTS

The aim of this study was to investigate the effects of different coatings (alginate-based, cocoa-based and a combination of them) on physico-chemical, microbiological and sensory characteristics of fresh-cut oranges during storage. Preliminary rheological analyses were performed on coatings in order to characterize them. The three different coated orange samples were packaged in polyethylene terephthalate trays under atmospheric conditions and stored for 10 days at 6°C. During storage, all samples were analysed for water activity, moisture, colour, texture, microbiological analyses and sensory quality. Orange samples coated with sodium alginate maintained the highest quality characteristics in terms of texture and microbiological properties, but not from a sensory point of view. Samples coated only with cocoa presented very high sensory attributes, but the lowest microbiological and textural quality. Samples covered in both alginate and cocoa demonstrated the best quality parameters throughout the whole storage period, including high sensory characteristics and the lowest microbiological cell loads (yeast and mesophilic aerobic bacteria under the threshold limit of 6.0 log cfu/g).

CONCLUSIONS

The bilayer coating represented the best solution in order to develop a new ready to eat fresh oranges with both high textural and sensory attributes and prolonged shelf life

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3 50 **Keywords:** edible coating, double coating, cocoa, alginate, oranges, rheology, shelf-life.
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8 53 **INTRODUCTION**

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11 54 Fresh-cut products are ready-to-use goods which retain the fresh characteristics of raw produce.¹ Raw
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13 55 and minimally-processed fruits and vegetables are sold to consumers in a ready-to-use or ready-to-
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15 56 eat form. This type of product does not generally contain preservatives or antimicrobial substances
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17 57 and rarely undergoes any heat processing before consumption.² The food market evolves with new
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19 58 products and changing trends, but fresh-cut ones remain at the top of the list of products that meet the
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21 59 needs of many consumers.³ However, numerous factors restrict the quality and shelf-life of fresh-cut
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23 60 products. During storage, in fact, they undergo significant deteriorations and as a consequence decay
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25 61 of their sensory (e.g. flavour, colour, texture) and nutritional value. Water loss is the primary factor
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27 62 that involves deterioration of fruits and vegetables and may result in soft texture, translucency and
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29 63 loss of nutritional value and sensory attributes.^{4,5} Researches aimed to retard the quality loss of fresh-
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31 64 cut fruits, maintaining their safety in terms of microbial growth are of great interest for companies
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33 65 involved in their production and distribution.^{6,7} Different approaches have been employed to preserve
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35 66 fresh-cut product quality during shelf-life, including modified atmosphere packaging, chemical
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37 67 treatments such as calcium dips and physical treatments such as gamma irradiation, pulse light, ozone,
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39 68 cold plasma, and high pressure pre-treatment combined with vacuum impregnation.^{8,9,10} One of the
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41 69 most promising, convenient and safe technologies to preserve the quality and to prolong the shelf-life
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43 70 of fresh fruits and vegetables is the application of edible coatings.¹¹ These coatings are formed from
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45 71 a suspension of a thickening agent, which after application on the product forms a film that acts as a
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47 72 barrier to gas exchange and water loss by modifying the atmosphere and slowing fruit ripening.¹²
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49 73 Edible coatings can be classified in three categories with regards to the nature of their components:
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51 74 polysaccharides (alginate, gellan, etc...), lipids (paraffin, beeswax, chocolate, etc..), proteins (corn
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53 75 zein, wheat gluten, etc...) and composites, made up from combining substance from previous

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3 76 categories (e.g. gelatin and fatty acids, methylcellulose and fatty acids, etc.). ¹³In recent years
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5 77 researches are focused on the application of alginate as edible coating on fresh-cut fruits, for its
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7 78 characteristics of good transparency and resistance to gas exchange. ¹²A lot of studies have been
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10 79 performed on the influence of alginate coating alone or in combination with other substances on the
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12 80 chemico-physical and microbiological characteristics of different type of fresh-cut fruit, such as
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14 81 pineapple,¹⁴ pears,¹⁵ apples,^{16,17,18} mango, ¹⁹papaya,²⁰ tomato fruit, ²¹ melon^{22,23} and blueberries.²⁴
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17 82 However, to our knowledge, no studies have been performed on the influence of edible coating
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19 83 alginate on the physico-chemical, sensory and microbiological properties of fresh cut orange
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21 84 products. Fresh cut oranges were selected as samples to cover, considering their high nutritional
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23 85 values and quality that undergoes to significative loss, during storage, because of their sensitive to
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25 86 microbiological growth, water loss and to low temperature, especially after cutting. For this reason,
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27 87 in the first part of this study, the influence of a sodium alginate-based coatings on the main quality
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29 88 characteristics of orange fresh-cut products is evaluated. However, the application of coatings without
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31 89 compromising sensory attributes of fresh-cut fruits is not always achieved, and therefore needs further
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33 90 studies.²⁵ Moreover, companies requested innovative products, with improved sensorial
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35 91 characteristics, maintaining high quality parameters for longer storage times, for this reason, in
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37 92 addition, cocoa as an alternative edible coating was examined. To our knowledge, few studies were
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39 93 focused on the possibility to use cocoa based coatings, normally used in the bakery and confectionery
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41 94 industries, to preserve fresh cut fruits. In the 1988, Biquet and Labuza²⁶ performed a research with
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43 95 the purpose to evaluate the moisture permeability properties of a cocoa coating without any kind of
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45 96 applications on food system. Recently Khan²⁷ et al., and Meza et al. 2018²⁸ reported some studies
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47 97 respectively focused on the efficacy and the deposition behaviour of a cocoa coating applied by
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49 98 electro spraying, and on its rheological and adsorption properties. Only two **works** deal with the
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51 99 application of cocoa coatings on fruits products, where in the first one Gounga et al. 2008,²⁹ applied
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53 100 two cocoa coatings on dried chestnut and analysed them for nutritional and microbiological properties
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55 101 only after covering. While Glicerina et al., 2019³⁰ applied two cocoa based coating on fresh cut fruits
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3 102 (apples and grapes) and their influence on the main quality characteristics, during storage, was
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5 103 evaluated. However, obtained results showed that in comparison to uncoated samples, cocoa based
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7 104 coatings gave a positive effect only on the sensory properties of fresh cut fruit samples during storage,
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10 105 showing a shelf-life very similar to uncoated ones; even if grapes maintained better quality properties
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12 106 than apples probably because the presence of their natural skin that promoted a protective effect.

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15 107 The absence of an intermediate coating between fruit and cocoa did not contribute to extend the shelf
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17 108 life; to fill the mentioned gap in the present research two layers of coating were used. For this reason,
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20 109 in this study, the effects of different coatings, alginate-based, cocoa-based and a combination of them
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23 110 (as double coating), on the physico-chemical, microbiological and sensory characteristics of fresh-
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25 111 cut oranges during storage were evaluated.

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31 113 **MATERIALS AND METHODS**

34 114 **Raw materials**

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37 115 Fresh-cut oranges were obtained from the consortium Agribologna (Bologna). The variety of orange
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39 116 was *Navel*. The oranges had a refractive index of 11.3 °Brix and an acidity of 0.83 ml/ 100 ml citric
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41
42 117 acid. Two types of coatings were employed to cover fresh-cut orange samples; one sodium alginate
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44 118 based, the other cocoa based. The formulations of sodium alginate coating, obtained in laboratory by
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46 119 adding calcium ascorbate and solved in distilled water, and that made with a commercial cocoa
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48 120 realized with Cocoa Butter substitutes (CBS) are reported in Table 1. The sodium alginate formulation
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51 121 was realized according to Zhong et al.,³¹ and Fu et al.,³²

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125 **Sample preparation**

126 The orange fruits were manually peeled and subsequently obtained slices were separated and
127 subjected to a peroxiacetic acid solution dip (200 ppm) to prevent microbial contamination. After
128 drying at 4°C for 10 minutes, slices were divided in three parts of irregular shape. Subsequently, the
129 orange pieces were covered with the different coatings: cocoa cream (Co), sodium alginate (Al) and
130 both combined (Co+Al). This last coating type were made by covering each orange slice with a first
131 layer of alginate and after drying (at 4°C for 30 minutes) a second one of cocoa cream, preliminary
132 obtained by melting dark chocolate substitute in a microwave at 750 watts for 1 minute. These
133 conditions were chosen after preliminary trials, in order to avoid modification in the product structure,
134 in accordance with Stortz & Marangoni³³ and Glicerina et al.,³⁴ 2 grams of sodium alginate solution
135 plus 2 g of melted cocoa coating were used to cover each piece of fruit. In all coated fruits the single
136 coating layer had a thickness of 1.0 ± 0.1 mm. Each orange piece was completely dipped in each
137 coating type, removed with tweezers and left to dry in a cold room at 4°C for 15 minutes. After
138 cooling, approximately 100 g of each orange sample was packed in different PET trays closed with
139 polypropylene (PP) film at medium barrier to oxygen. In specific, the PET tray had a thickness of 3
140 mm, an oxygen transmission rate (OTR) of 60 cm³/m²/day/atm and a water transmission rate of 27
141 cm³/m²/ day/atm, while the PP film presented a thickness of 30 µm and an oxygen and a water
142 transmission rate respectively of 860 cm³/m²/ day/atm and 19 cm²/m²/ day/atm, in both cases
143 measured at 23°C. All samples were stored at 6°C for 10 days. Three trays of each sample were
144 analysed at six different times: after 0 (T0), 1 (T1), 2 (T2), 3 (T3), 6 (T6) and 8 (T8) days, chosen
145 after preliminary trials. Control sample was represented by orange pieces without coating, processed
146 and stored at the same conditions. Samples were named: Orange C, control without coating; Orange
147 Al, coated with sodium alginate; Orange Co, coated with cocoa cream; and Orange Al+Co, coated
148 with double layer of sodium alginate and cocoa cream.

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8 9 152 **METHODS**

10 11 12 153 **Rheological analysis on fruit coatings**

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15 154 Rheological measurements were carried out on both cocoa and alginate coatings in order to
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17 155 characterize them. Measurements were performed at 40 °C using a controlled stress–strain rheometer
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20 156 (MCR 300, Physica/Anton Paar, Ostfildern, Germany) equipped with a system of coaxial cylinders
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22 157 (CC27). The rheological behaviour of coatings was analysed in steady state conditions. After a pre-
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24 158 shearing of 500 s at 5 s⁻¹, viscosity was measured by increasing shear rate from 2 to 50 s⁻¹ within 180
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26 159 s and taking 18 measurements at different points.³⁵ The obtained flow curves, on the basis of
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29 160 preliminary trials, were fitted according to the Casson model that showed the best fit, compared
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31 161 against other rheological models. The Casson model is a structure-based model derived from the
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33 162 analysis of a structure and its kinetic change, usually employed to study the rheological behaviour of
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36 163 food matrices characterized by the presence of a yield stress.^{36,37}

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39 164 This model is described by the following equation:

$$40
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42 165 \tau^{0.5} = \tau_0^{0.5} + \eta_{PL} \gamma^{0.5} \quad (1)$$

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45 166 where τ_0 is the yield stress at the zero point and η_{PL} is the so-called plastic viscosity³⁴

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49 50 51 168 **Moisture and Water Activity**

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54 169 Moisture content and water activity were determined at each storage time, separately on the fruit
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56 170 samples and cocoa coatings (after removing it from each fruit piece), in order to evaluate possible
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58 171 migration phenomena between them. In samples coated with sodium alginate analyses were
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60 172 performed on the whole fruit because of it was not possible to separate the coating from the fruit

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3 173 pieces because of the high tackiness of the sodium alginate. Moisture content was determined
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5 174 gravimetrically by difference in weight before and after oven drying at 70 °C, until constant weight
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8 175 was reached. The moisture content was calculated as follows:

$$11 \text{ 176 } \text{Moisture content \%} = 100 - ((W_f - W_d / W_f) * 100)$$

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14 177 W_f = weight fresh sample

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17 178 W_d = weight dry sample

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20 179 The water activity values of ground fruits and cocoa coatings were obtained by using a dew point
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22 180 hygrometer, AquaLab-Water Activity Meter (mod. SERIES 3TE. Decagon Device, Inc., Nelson
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24 181 Court, NE). Three measurements were carried out from each sample (Orange C, Orange AI, Orange
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26 182 Co, Orange AI+Co) and their respective cocoa coating, when present, after separation from fruit
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29 183 pieces, at each storage interval for both moisture and water activity analyses.

30 31 32 184 33 34 35 185 **Textural analysis**

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38 186 Evaluation of firmness and fracturability was conducted with a penetration test by means of a Texture
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40 187 Analyser mod. TA-HDi500 (Stable Micro Systems, Surrey, Godalming, UK), equipped with a 5 Kg
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42 188 load cell and a 6 mm diameter stainless steel probe. Test speed was 1 mm s⁻¹ with a 6 mm depth of
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45 189 penetration.³⁸ The maximum peak of the curve, obtained during penetration, was used as the firmness
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47 190 value F (N). The distance between the origin of curve till the point until the end of the penetration, is
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49 191 an index of the fracturability (N*s/mm). Results were expressed as the average of ten measurements
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52 192 for each sample.

196 **Microbiological analysis**

197 Microbiological analyses were performed after 1, 3, 6 and 9 days of storage. For each type of sample,
198 30 g of whole product were placed in sterile bags and with 60 mL of sterile saline solution (0.9%
199 NaCl) and subsequently homogenized for 2 minutes in Stomacher (model Lab Blender Seward,
200 London, UK). Subsequently, the samples were serial diluted into sterile physiological solution
201 according to the expected microbial cell loads of the samples. The total loads of lactic bacteria, yeasts,
202 molds, total mesophilic aerobic bacteria, total psychrotrophic aerobic bacteria and total coliforms
203 were determined. In particular, yeasts were counted on Yeast extract Peptone Dextrose medium
204 (YPD) (Oxoid Ltd, Basingstoke, United Kingdom), total coliforms on Violet Red Bile Agar (Oxoid
205 Ltd, Basingstoke, United Kingdom), lactic acid bacteria on De Man Rogosa and Sharpe (MRS)
206 (Oxoid Ltd, Basingstoke, United Kingdom), total aerobic mesophilic and psychrotrophic bacteria on
207 Plate Count Agar (PCA) (Oxoid Ltd, Basingstoke, United Kingdom) and mold on Malt Extract Agar
208 (MEA) (Oxoid Ltd, Basingstoke, United Kingdom). In particular, yeasts, molds and total aerobic
209 mesophils were incubated at 30 °C for 48h, total coliforms and lactic bacteria were incubated at 37
210 °C for 24h, while psychrotrophic aerobic bacteria were incubate at 10 °C for 7 days.

212 **Sensory analysis**

213 A panel composed by 80 tasters (female and male, aged from 25 to 52 years) was asked to evaluate
214 the four samples and to rate their preference using a 9-point hedonic scale (1 = extremely dislike; 9
215 = extremely like),³⁹ immediately after treatment (T0) and after 3 days of storage. The others storage
216 times were not considered due to the limit of microbiological acceptability, according to
217 microbiological analysis results. The attributes rated were: external and inner appearance, smell,
218 firmness, flavour and overall acceptability. The test was performed in laboratory scale and conducted
219 in individual booths.⁴⁰ Orange samples were served to the panellist in a randomized order.

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56 222 **STATISTICAL ANALYSIS**
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9 223 Analysis of variance (ANOVA) and the test of mean comparisons according to Fisher's least
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11 224 significant difference (LSD) with a 0.05 level of significance were applied to find out significant
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13 differences among the different samples. The statistical package STSG Statistica for Windows,
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16 226 version 6.0 (Statsoft Inc., Tulsa, OK, USA) was used.
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2122 228 **RESULTS AND DISCUSSION**
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2425 229
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2728 230 **Rheological characteristics of coatings**
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31 231 In Figure 1 the flow curves of the two different edible coatings, sodium alginate and cocoa, are
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33 232 showed. In both samples, apparent viscosity decreases with the increase of the shear rate, indicating
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35 233 pseudoplasticity. This behaviour can be explained by the structural breakdown of the molecules due
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37 to the hydrodynamic forces generated and to the increased alignment of the constituent molecules.⁴¹
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40 235 Alginate coating presents the highest viscosity, with initial values around 50.000 mPa, cocoa coating
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42 236 had an initial apparent viscosity values around 5.000 mPa. Moreover, in order to better explain the
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44 237 rheological values obtained by the flow curves, the Casson yield value and the Casson plastic
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46 viscosity parameters were calculated applying the Casson model, results are reported in Table 2. All
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49 239 data were well fitted by the Casson model, providing high determination coefficients (R^2), comprising
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51 240 between 0.98 and 0.99. Alginate coating presented highest yield stress and viscosity values compared
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53 to cocoa one, underlining how the amount of energy needed to start flow was the highest in the former.
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56 242 Sodium alginate is made up of d-mannuronic and l-guluronic acids and contains numerous
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58 243 hydrophilic molecular groups.^{42, 31}When water is added to sodium alginate, strong bonds between
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60 244 molecules are created, giving arise to a tighter and more compact structure. High sodium alginate

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3 245 viscosity values may also be achieved through the addition of calcium ascorbate which, as has been
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5 246 demonstrated previously³², causes high matrix aggregation due to its crosslinking effects that
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8 247 strengthen alginate solution bonds. Nevertheless, Skurtys et al.,¹³ and Zhong et al.³¹ have shown that
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10 248 sodium alginate solutions with high viscosities, such as those observed in their study (around 100
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12 249 mPa*s), may be appropriate for its use in edible coatings, especially if applied by a dipping method;
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15 250 while those with low viscosity can provide processing advantage during spraying methods. Cocoa
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17 251 coating showed lower yield stress and viscosity values than alginate one, this can be attributed to its
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19 252 lipid- based formulation.⁴³ However, according with literature,^{44,28} the yield stress and viscosity
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22 253 values of the used cocoa coating make them suitable for coating purposes, being high enough to
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24 254 prevent gravity effects (sagging and dripping) but sufficiently low to allow capillarity-driven levelling.
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30 256 **Moisture and Water Activity**

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33 257 In Figure 2 moisture changes during the storage of coated fresh-cut orange samples as well as the Co
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35 258 and Co+Al cocoa coatings alone (after removal from fruit pieces) are shown. In both mono and bilayer
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37 259 alginate covered fruits, a constant trend with a slight reduction in moisture content at the end of
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40 260 storage was observed, while in C and Co samples a more pronounced moisture reduction was
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42 261 highlighted during storage. Orange samples Al maintained the highest moisture content during the
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44 262 entire storage period. This behaviour is probably due to the water barrier effect induced by sodium
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46 263 alginate that limited the water migration, keeping the fruit pieces more hydrated than in the other
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49 264 samples.^{4,24} The calcium ascorbate, present in the sodium alginate coating formulations, caused a
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51 265 molecular cross-linking effect, thereby strengthening the chemical bonds among sodium alginate
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53 266 components and further promoting the water migration barrier effect of the coating.⁴⁵ The sodium
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56 267 alginate water barrier effect, which has also been reported in the studies of Meza et al.,²⁸ is
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58 268 underscored by the fact that the Orange Co sample underwent the highest moisture loss during
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60 269 storage, that was parallel to an increase in the moisture content of its cocoa coating (Coating Co).

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3 270 This behaviour, according with Johanson and Bergensthal,⁴⁶ can be probably attributed to a water
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5 271 exchange between the fruits and the cocoa characterized by different water amount. Furthermore
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8 272 (Figure 2) a similar behaviour was observed in Orange Co+Al, even if with lower intensity, thereby
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10 273 confirming the role of sodium alginate as moisture barrier. The control sample Orange C lost more
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12 274 water compared to samples Al and Co+Al.⁴⁷ but less than sample Orange Co, having only the fruit's
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15 275 natural skin as barrier against dehydration.

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18 276 In Figure 3 results related to the water activity changes in fresh-cut orange samples and in the different
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20 277 cocoa coatings after their removal at each storage time are reported. Also in this case a reduction in
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22 278 water activity values was observed for all samples during storage. This reduction was parallel to an
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25 279 increase in the respective cocoa coating of samples Al+Co and Co, as previous observed for moisture.
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27 280 This trend may be a further confirmation of water exchange between fruit and coating, as previously
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29 281 seen in moisture results, and also of the barrier effect conferred by sodium alginate coating. Moreover,
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31 282 water activity results, showed how Al and Co+Al samples had the lowest a_w values compared to C
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34 283 and Co orange ones. These low values can be probably attributed to a water binding stronger in Al
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36 284 and Co+Al coatings than Co one, in fact Al and Co+Al coating formulations were rich in sodium
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38 285 alginate that promoted hydrogen bonds.⁴⁸

44 287 **Textural properties**

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47 288 In the Figures 4 and 5 the firmness and fracturability results of orange samples during storage are
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49 289 shown respectively. Coated Al sample presented the highest firmness values compared to the other
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52 290 ones, showing an increase of this parameter during storage. High firmness values in samples fruit
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54 291 coated with sodium alginate (Orange Al), can be attributed to the alginate network structure.²⁴
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56 292 Uncoated samples firmness values were intermediate between Al and samples coated with Co
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58 293 (Orange Co+Al and Orange Co), showing a constant trend during all storage times. For what concern
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60 294 Co+Al and Co samples, lower firmness values were observed compared to Al and C ones, this trend

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can be probably attribute in part to the moisture exchange occurred between cocoa coatings and fruit and between coating and the surrounding environment as previous stated in the moisture section, that involved a softening effect. Moreover, a further softening effect can be attributed to the presence of fat in the cocoa coating formulation.

For what concern fracturability (Fig. 5), Al sample showed the statistically highest values compared to other samples at each storage time, while sample Co+Al presented intermediate values between Al and the other two samples (C and Co), even if not always statistically different from them. These values are a further confirmation of the barrier effect conferred by the sodium alginate coating, that maintained orange pieces more hydrated and more structured. Moreover, according with literature (Tapia et al., 2008)¹⁶ the presence of Ca²⁺⁺ improve the fruit resistance to the softening, probably because of the stabilization of membrane systems and the formation of Ca pectates, which increase rigidity of the middle lamella and cell wall.

Microbiological analysis

In Table 3, the cell loads of mesophilic aerobic bacteria, psychrotrophic aerobic bacteria and yeasts are respectively reported. The growth of mesophilic and psychotrophic aerobic bacteria resulted affected by the coating types of the samples. Since day 1 of storage, control samples C showed a significant higher cell loads, of both the microbial groups, than the other samples. Both mesophilic and psychotrophic aerobic bacteria rapidly increased their cell loads after 3 days of storage in controls and samples covered by cocoa cream (Co) that showed significantly higher cell loads than the other samples. After 6 days of storage also samples coated with alginate alone (Al) significantly increased the total aerobic loads, while samples coated by both cocoa and alginate showed significant lower cell loads that the other samples. The total microbial viable count represents an important criterion for the evaluation of food quality.^{49,50} The international criteria of ready to eat fruit report as satisfactory levels of aerobic colony count cell loads below 6.0 log cfu/g, acceptable levels when the

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3 320 cell loads ranged between 6.0-7.0 log cfu/g and unsatisfactory levels when the cell loads are higher
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5 321 than 7.0 log cfu/g.^{51,52} The results obtained showed that control sample overcame the level of 7.0 log
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7 322 cfu/g, both for mesophilic and psychotrophic bacteria, after 6 days of storage. The samples coated with
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10 323 alginate or cocoa alone never exceed the load of 6.0 log cfu/g after 9 days of storage with regard to
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12 324 mesophilic aerobic bacteria while both these samples exceed the acceptable limit of 7.0 log cfu/g for
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14 325 psychotrophic bacteria but only after 9 days of storage. The sample double coated (Co+Al) showed the
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17 326 best quality for the whole period of storage. In fact, the detected cell loads of mesophilic and
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19 327 psychotrophic bacteria after 9 days resulted 4.93 and 6.07 log cfu/g respectively. Yeasts load represents
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21 328 an important quality criterion for ready to eat fruits since they are one of the main spoilage in this
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23
24 329 food category.⁵³ Also in this case C sample showed a significant higher cell load compared to the
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26 330 other samples for the whole period of storage. Until the third day of storage the Al sample showed
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28 331 the lowest yeasts load. Nevertheless, from the sixth day both the samples Al and Al+Co showed the
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31 332 lowest yeasts loads. However, the international criteria on ready to eat fruit report as unsatisfactory
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33 333 yeast level when the cell load overcome 6 log cfu/g.⁵² In this study, only control samples overcame
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35 334 the reported yeast limit after 9 days of storage. On the contrary, the other samples remained below
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38 335 this limit showing, after 9 days of storage, cell loads of 5.33, 4.77 and 4.70 log cfu/g respectively for
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40 336 the samples Co, Al and Al+Co. Furthermore, microbiological results agree with a_w values since Al
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42 337 and Co+Al samples, that showed lowest a_w values, highlighted the lowest cell load. ⁵⁴ Lactic acid
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44 338 bacteria, total coliforms and moulds (data not shown) never exceed 3.5, 2.0 and 1.7 log cfu/g in all
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47 339 samples for the whole period of storage. However, they do not represent the main microbial category
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49 340 of microbial spoilage for this kind of product.⁵³ Overall obtained results are in agreement with
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51 341 literature data that report an antimicrobial effect of alginate coating on different fruit typology such
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54 342 as fresh-cut water melon ⁵⁵⁻²³ fresh-cut pineapple ¹⁴, pears, ¹⁵apples ^{16,17} and blueberries.²⁴ Moreover,
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56 343 these results suggest a synergistic effect of alginate and cocoa coatings when combined, as
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58 344 demonstrated by the lowest growth kinetics of microorganisms in samples subject to this coating.
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345 **Sensory analysis**

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3 346 Results of sensory analysis carried out in all samples at 0 and 3 days of storage are reported in Table
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5 347 4. At 0 day of storage all samples were judged quite similar, obtaining high scores for all evaluated
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8 348 attributes. Orange Al and Co+Al, were more appreciated for texture attribute, while the Orange Co
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10 349 obtained slightly higher scores than Co+Al for smell and flavour attributes; the others were judged
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12 350 similar. After 3 days of storage a reduction in the score of all sensory attributes was registered in all
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15 351 samples, but covered ones maintained scores over the acceptability limit, also after this time. In
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17 352 particular, after 3 days of storage, orange Co was the more appreciated from panellist compared to
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19 353 other samples, except that for the visual appearance and firmness, for which sample Al reached
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22 354 highest scores, followed by Co+Al one. In particular, double coated samples, presented intermediate
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24 355 flavour and overall acceptability values, between Co and Al. Control samples reached the lowest
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26 356 score compared to coated one except that for the visual appearance and firmness, that were judged
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29 357 higher than Co one.

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34 359 CONCLUSIONS

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38 361 The present study has demonstrated that a sodium alginate coating can preserve the firmness, moisture
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40 362 content, and product shelf-life of fresh-cut orange. After three days of storage, however, sodium
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42 363 alginate-coated fruits were deemed less appealing with regards to their flavour and smell. On the
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45 364 contrary, samples with cocoa coating maintained superior sensory attributes in terms of flavour, smell
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47 365 and overall acceptability, after three days of storage, but presented lower firmness and higher
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49 366 microbiological load than other coated samples. Control samples manifested the lowest quality of the
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52 367 study group across the main evaluated attributes.

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54 368 Oranges with the double coating (sodium alginate and cocoa), seems to be the more promising
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56 369 solution in order to obtained fresh cut oranges with the lowest microbial load and at the same time
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59 370 high-quality characteristics. The results of this study suggest that the use of a double sodium alginate
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3 371 and cocoa coating would lead to both high sensory attributes and extended shelf-life of ready-to-eat,
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5 372 fresh-cut oranges.

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12 13 14 375 **ACKNOWLEDGEMENTS**

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27 28 29 381 **REFERENCES**

30
31
32 382
33
34
35 383 1 Ranjitha K, Rao DS, Shivashankara KS, Oberoi HS, Roy TK and Bharathamma H, Shelf-life
36
37 384 extension and quality retention in fresh-cut carrots coated with pectin. *Innovative Food Sci &*
38
39 385 *Emerging Technol* **42**: 91-100 (2017).

40
41
42 386

43
44
45 387 2 Lanciotti R, Gianotti A, Patrignani F, Belletti N, Guerzoni ME and Gardini F, Use of natural aroma
46
47 388 compounds to improve shelf-life and safety of minimally processed fruits. *Trends in food sci &*
49
50 389 *technol* **15 (3-4)**: 201-208 (2004).

51
52
53 390

54
55
56 391 3 Marquez GR, Di Pierro P, Mariniello L, Esposito M, Giosafatto CV and Porta R, Fresh-cut fruit
57
58 392 and vegetable coatings by transglutaminase-crosslinked whey protein/pectin edible films. *LWT-Food*
59
60 393 *Sci and Technol* **75**: 124-130 (2017).

- 1
2
3 394
4
5
6 395 4 Nunes CN and Emond JP, Relationship between weight loss and visual quality of fruits and
7
8 396 vegetables. *Proc. Fla. Stat*
9
10
11 397
12
13
14 398 5 Yousuf B, Qadri OS and Srivastava AK, Recent developments in shelf-life extension of fresh-cut
15
16 399 fruits and vegetables by application of different edible coatings: A review. *LWT-Food Sci and*
17
18 *Technol* (2018).
19 400
20
21
22 401
23
24
25 402
26
27
28 403 6 Mastromatteo M, Mastromatteo M, Conte A and Del Nobile MA, Combined effect of active coating
29
30 404 and MAP to prolong the shelf life of minimally processed kiwifruit (*Actinidia deliciosa* cv. Hayward).
31
32 405 *Food Research Int* **44(5)**: 1224-1230 (2011).
33
34
35 406
36
37
38 407 7 Medina MS, Tudela JA, Marín A, Allende A and Gil MI, Short postharvest storage under low
39
40 408 relative humidity improves quality and shelf life of minimally processed baby spinach (*Spinacia*
41
42 *oleracea* L.). *Post Biol and Technol* **67**: 1-9 (2012).
43 409
44
45
46 410
47
48
49 411 8 Manzocco L, Rumignani A and Lagazio C, Emotional response to fruit salads with different visual
50
51 412 quality. *Food Qual and Preference* **28(1)**: 17-22 (2013).
52
53
54 413
55
56
57 414 9 Denoya GI, Vaudagna SR and Polenta G, Effect of high-pressure processing and vacuum packaging
58
59 415 on the preservation of fresh-cut peaches. *LWT-Food Sci and Technol* **62(1)**: 801-806 (2015).
60

1
2
3 416
4
5

6 417 10 Palekar MP, Taylor TM, Maxim JE and Castillo A, Reduction of Salmonella enterica serotype
7
8 418 Poona and background microbiota on fresh-cut cantaloupe by electron beam irradiation. *Int J of Food*
9
10
11 419 *microbiol* **202**: 66-72 (2015).

12
13
14 420
15

16
17 421 11 Mantilla N, Castell-Perez ME, Gomes C and Moreira RG, Multilayered antimicrobial edible
18
19 422 coating and its effect on quality and shelf-life of fresh-cut pineapple (*Ananas comosus*). *LWT-Food*
20
21 423 *Sci and Technol* **51(1)**: 37-43 (2013).

22
23
24 424
25

26
27 425 12 Andrade da Silva D, Krieger Oliveira J, Santos CM, Souza Bery CC, Almeida Castro A and
28
29
30 426 Belarmino Santos JA, The use of sodium alginate-based coating and cellulose acetate in papaya post-
31
32 427 harvest preservation. *Acta Scientiarum. Technol* **36(3)** (2014).

33
34
35 428
36

37
38 429 13 Skurtys O, Acevedo C, Pedreschi F, Enronoe J, Osorio F and Aguilera JM, *Food hydrocolloid*
39
40 430 *edible films and coatings*. Nova Science Publishers, Incorporated (2014).

41
42
43 431
44

45
46 432 14 Azarakhsh N, Osman A, Ghazali HM, Tan CP and Adzahan NM, Lemongrass essential oil
47
48 433 incorporated into alginate-based edible coating for shelf-life extension and quality retention of fresh-
49
50
51 434 cut pineapple. *Post Biol and Technol* **88**: 1-7 (2012).

52
53
54 435
55

56
57 436 15 Oms-Oliu G, Soliva-Fortuny R and Martín-Belloso O, Edible coatings with antibrowning agents
58
59 437 to maintain sensory quality and antioxidant properties of fresh-cut pears. *Post biol and Technol* **50(1)**:
60
438 87-94 (2008).

- 1
2
3 439
4
5
6 440 16 Rojas-Graü MA, Tapia MS, Rodríguez FJ, Carmona J and Martin-Belloso O, Alginate and gellan-
7
8 441 based edible coatings as carriers of anti-browning agents applied on fresh-cut Fuji apples. *Food*
9
10 442 *Hydrocolloids* **21(1)**: 118-127 (2007).
11
12
13
14 443
15
16 444 17 Chiabrando V and Giacalone G, Effect of essential oils incorporated into an alginate-based edible
17
18 445 coating on fresh-cut apple quality during storage. *Quality Assurance and Safety of Crops and Foods*
19
20 446 **7(3)**: 251-259 (2014).
21
22
23
24 447
25
26
27 448 18 Kapetanakou AE, Nestora S, Evageliou V and Skandamis PN, *Sodium alginate–cinnamon*
28
29 449 *essential oil coated apples and pears: Variability of Aspergillus carbonarius growth and ochratoxin*
30
31 450 *A production*. *Food Research International* (2018). Available:
32
33 <https://doi.org/10.1016/j.foodres.2018.10.072>
34
35
36
37 452
38
39
40 453 19 Salinas-Roca B, Soliva-Fortuny R, Welti-Chanes J and Martin-Belloso O, Combined effect of
41
42 454 pulsed light, edible coating and malic acid dipping to improve fresh-cut mango safety and quality.
43
44 455 *Food Control* **66**: 190-197 (2016).
45
46
47
48 456
49
50 457 20 Tapia MS, Rojas-Graü MA, Carmona A, Rodríguez FJ, Soliva-Fortuny R and Martin-Belloso O,
51
52 458 Use of alginate-and gellan-based coatings for improving barrier, texture and nutritional properties of
53
54 459 fresh-cut papaya. *Food Hydrocolloids* **22(8)**: 1493-1503 (2008).
55
56
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56
57
58
59
60

- 461 21 Zapata PJ, Guillén F, Martínez-Romero D, Castillo S, Valero D and Serrano M, Use of alginate
462 or zein as edible coatings to delay postharvest ripening process and to maintain tomato (*Solanum*
463 *lycopersicon* Mill) quality. *J of the Sci of Food and Agricul* **88(7)**: 1287-1293 (2008).
- 464
- 465 22 Raybaudi-Massilia RM, Mosqueda-Melgar J and Martín-Belloso O, Edible alginate-based coating
466 as carrier of antimicrobials to improve shelf-life and safety of fresh-cut melon. *Intl J of Food*
467 *Microbiol* **121(3)**: 313-327 (2008).
- 468
- 469 23 Poverenov E, Danino S, Horev B, Granit R, Vinokur Y and Rodov V, Layer by-Layer electrostatic
470 deposition of edible coating on fresh cut melon model: Anticipated and unexpected effects of
471 alginate–chitosan combination. *Food Bioprocess Technol* **7**: 1424–1432 (2014).
- 472
- 473 24 Mannozi C, Cecchini JP, Tylewicz U, Siroli L, Patrignani F, Lanciotti R, ... and Romani S, Study
474 on the efficacy of edible coatings on quality of blueberry fruits during shelf-life. *LWT-Food Sci and*
475 *Technol* **85**: 440-444 (2017).
- 476
- 477 25 Ma L, Zhang M, Bhandari B and Gao Z, Recent developments in novel shelf life extension
478 technologies of fresh-cut fruits and vegetables. *Trends in Food Sci and Technol* **64**: 23-38 (2017).
- 479
- 480 26 Biquet B and Labuza TP, Evaluation of the moisture permeability characteristics of chocolate
481 films as an edible moisture barrier. *J of Food Sci* **53(4)**: 989-998 (1988).

1
2
3
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53
54
55
56
57
58
59
60

483 27 Khan MKI, Maan AA, Schutyser M, Schroën K and Boom R, Electrospraying of water in oil
484 emulsions for thin film coating. *J of Food Engineering* **119**: 776–780 (2013).

485
486 28 Meza BE, Carboni AD and Peralta JM, Water adsorption and rheological properties of full-fat and
487 low-fat cocoa-based confectionery coatings. *Food and Bioproducts Processing* **110**: 16-25 (2018).

488
489 29 Gounga ME, Xu S and Wang Z, Nutritional and microbiological evaluations of chocolate-coated
490 Chinese chestnut (*Castanea mollissima*) fruit for commercial use. *J Zhejiang University of Sci B*. **9**
491 **(9)**: 675-683 (2008).

492
493 30 Glicerina V, Tylewicz U, Canali G, Siroli L, Dalla Rosa M, Lanciotti R and Romani S, Influence
494 of two different cocoa-based coatings on quality characteristics of fresh-cut fruits during storage.
495 *LWT-Food Sci and Technol*, **101**: 152-160 (2019).

496
497 31 Zhong Y, Cavender G and Zhao Y, Investigation of different coating application methods on the
498 performance of edible coatings on Mozzarella cheese. *LWT-Food Sci and Technol* **56(1)**: 1-8 (2014).

499
500
501 32 Fu S, Thacker A, Sperger DM, Boni RL, Buckner IS, Velankar S and Block LH, Relevance of
502 rheological properties of sodium alginate in solution to calcium alginate gel properties. *Aaps*
503 *Pharmscitech* **12(2)**: 453-460 (2011).

1

2

3 505 33 Stortz TA and Marangoni AG, Ethylcellulose solvent substitution method of preparing heat
4
5 506 resistant chocolate. *Food research int* **51(2)**: 797-803 (2013).

7

8 507
9

10

11 508
12

13

14 509 34 Glicerina V, Balestra F, Dalla Rosa M and Romani S, Microstructural and rheological
15
16 510 characteristics of dark, milk and white chocolate: A comparative study. *J of Food Engineering* **169**:
17
18 511 165-171 (2016).

20

21

22 512
23

24

25 513 35 International Confectionery Association (ICA), 2000. Viscosity of Cocoa and Chocolate Products.
26
27 514 Analytical Method 46. Available from: CAOBISCO, rueDefacqz 1, B-1000 Bruxelles, Belgium.

28

29

30 515
31

32

33 516 36 Rao A (ed). *Rheology of Fluid, Semisolid, and Solid Foods*, Springer, New York (2014).

34

35

36 517
37

38

39 518 37 Glicerina V and Romani S, Advances in Yield Stress Measurements for Chocolate, *in Advances*
40
41 519 *in Food Rheology*, ed. by J. Amhed, Elsevier, UK, pp.459-481 (2017).

42

43

44 520
45

46

47 521 38 Beirão-da-Costa S, Steiner A, Correia L, Empis J and Moldão-Martins M, Effects of maturity
48
49 522 stage and mild heat treatments on quality of minimally processed kiwifruit. *J of Food Engineering*,
50
51 523 **76(4)**: 616-625 (2006).

53

54

55 524
56

57

58 525 39 Stone H, Bleibaum R and Thomas HA, Test strategy and design of experiments. *Sensory*
59
60 526 *evaluation practices* 117-157 (2012).

- 1
2
3 527
4
5
6 528 40 ISO, U. 8589. *Analisi sensoriale “Criteri generali per la progettazione di locali destinati*
7
8 529 *all’analisi” Ente Nazionale Italiano di Unificazione. Milano, Italia (2007).*
9
10
11 530
12
13
14 531 41 Izidoro DR, Scheer AP, Sierakowski MR, Haminiuk CWI, Influence of green banana pulp on the
15
16 532 rheological behaviour and chemical characteristics of emulsion (mayonnaises). *LWT- Food Sci and*
17
18 *Technol* **41**: 1018–1028 (2008).
19 533
20
21
22 534
23
24
25 535 42 Davidovich-Pinhas M and Bianco-Peled H, A quantitative analysis of alginate swelling.
26
27 536 *Carbohydrate Polymers* **79(4)**: 1020-1027 (2010).
28
29
30 537
31
32
33 538 43 Glicerina V, Balestra F, Pinnavaia GG, Dalla Rosa M and Romani S, Rheological characteristics
34
35 539 of nut creams realized with different types and amounts of fats. *J of Food Quality* **36(5)**: 342-350
36
37 540 (2013).
38
39
40
41 541
42
43
44 542 44 Peressini D, Bravin B, Lapasin R, Rizzotti C and Sensidoni A, Starch–methylcellulose based
45
46 543 edible films: rheological properties of film-forming dispersions. *J of Food Engineering* **59(1)**: 25-32
47
48 544 (2003).
49
50
51 545
52
53
54 546 45 Embuscado ME and Huber KC (eds). *Edible films and coatings for food applications*. Springer,
55
56 547 New York (2009)
57
58
59 548
60

- 1
2
3 549 46 Johansson D and Bergenståhl B, The influence of food emulsifiers on fat and sugar dispersions in
4
5 550 oils. III. Water content, purity of oils. *J of the American Oil Chemists' Society* **69(8)**: 728-733 (1992).
6
7
8 551
9
10
11 552 47 Yaman Ö and Bayındırlı L, Effects of an edible coating and cold storage on shelf-life and quality
12
13 of cherries. *LWT-Food Sci and Technol* **35(2)**: 146-150 (2002).
14 553
15
16
17 554
18
19
20 555
21
22
23 556 48 Hou L and Wu P, Exploring the hydrogen-bond structures in sodium alginate through two-
24
25 557 dimensional correlation infrared spectroscopy. *Carbohydrate polymers* **205**: 420-426 (2019).
26
27
28 558
29
30
31 559 49 Jeddi MZ, Yunesian M, Gorji MEH, Noori N, Pourmand MR and Khaniki GRJ, Microbial
32
33 560 evaluation of fresh, minimally-processed vegetables and bagged sprouts from chain supermarkets.
34
35 561 *Jof health, population, and nutrition* **32(3)**: 391 (2014).
36
37
38 562
39
40
41 563 50 Cardamone C, Aleo A, Mammina C, Oliveri G and Di Noto AM, Assessment of the
42
43 564 microbiological quality of fresh produce on sale in Sicily, Italy: preliminary results. *Jof Biological*
44
45 *Research-Thessaloniki* **22(1)**: 3 (2015).
46 565
47
48
49 566
50
51
52 567 51 Health Protection Agency. Guidelines for assessing the microbiological safety of ready-to-eat
53
54 568 foods placed on the market (2009). Available:
55
56 569 http://www.hpa.org.uk/web/HPAwebFile/HPAweb_C/1259151921557
57
58
59 570
60

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2
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4
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42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

571 [52 FSAI, Guideline Microbiological Criteria \(2016\). Available:](#)

572 https://www.fsai.ie/food_businesses/micro_criteria/guideline_micro_criteria.html

573
574 53 Siroli L, Patrignani F, Serrazanetti DI, Tabanelli G, Montanari C, Tappi S, Rocculi P, Gardini F
575 and Lanciotti R, Efficacy of natural antimicrobials to prolong the shelf-life of minimally processed
576 apples packaged in modify atmosphere. *Food Control* **46**: 1-9 (2014).

577
578 54 Nyhan L, Begley M, Mutel A, Qu Y, Johnson N and Callanan M, Predicting the combinatorial
579 effects of water activity, pH and organic acids on *Listeria* growth in media and complex food matrices.
580 *Food microbiol* **74**: 75-85 (2018).

581
582 55 Sipahi RE, Castell-Perez ME, Moreira RG, Gomes C and Castillo A, Improved multilayered
583 antimicrobial alginate-based edible coating extends the shelf life of fresh-cut watermelon (*Citrullus*
584 *lanatus*). *LWT-Food Sci and Technol* **51**: 9–15 (2013).

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Table 1. Alginate and Cocoa based coating formulations.

Ingredients (g/100 g)	Alginate Coating	Cocoa Coating
Non -hydrogenated fats	-	45.0 g
Sugars	-	41.0 g
Cocoa powder	-	7.0 g
Skimmed milk powder	-	6.0 g
Soy lecithin	-	0.4g
Stabilizer	-	0.4g
Vanille flavour	-	0.2g
Distilled water	80.0 g	-
Calcium ascorbate	10.0 g	-
Sodium alginate powder	10.0 g	-

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Table 2. Yield stress and plastic viscosity values of alginate and cocoa based coating obtained by applying the Casson model.

Samples	Yield Stress (mPa)	Plastic Viscosity (mPa)
Alginate Coating	98660.5±1817.9 ^a	951.2 ±4.90 ^a
Cocoa Coating	3344.5±209.5 ^b	519.5±13.8 ^b

^{a-b}Values followed by different letters differ significantly at P<0.05 level.

Table 3. Cell loads expressed as log CFU/g of mesophilic and psychrotrophic aerobic bacteria and yeasts of non-coated sample (C), sample coated by sodium alginate (Al), by cocoa cream (Co) and covered by both coatings (Co+Al) during 9 days of refrigerated storage.

Samples	Mesophilic aerobic bacteria (log CFU/g)			
	day 1	day 3	day 6	day 9
C	4.82±0.14 ^a	5.93±0.11 ^a	7.14±0.09 ^a	7.39±0.04 ^a
Al	3.05±0.45 ^{bc}	3.93±0.41 ^c	5.14±0.05 ^b	5.83±0.11 ^b
Co	3.24±0.13 ^c	4.61±0.14 ^b	4.83±0.08 ^c	5.51±0.20 ^b
Co+Al	3.66±0.18 ^b	3.86±0.16 ^c	4.22±0.25 ^d	4.93±0.13 ^c
Samples	Psychrotrophic aerobic bacteria (log CFU/g)			
	day 1	day 3	day 6	day 9
C	5.15±0.09 ^a	6.85±0.10 ^a	8.06±0.17 ^a	8.66±0.12 ^a
Al	3.49±0.35 ^c	5.16±0.39 ^c	6.22±0.15 ^c	7.02±0.08 ^b
Co	4.65±0.12 ^b	5.91±0.16 ^b	6.76±0.22 ^b	7.05±0.17 ^b
Co+Al	4.71±0.19 ^b	4.95±0.60 ^c	5.20±0.26 ^d	6.07±0.18 ^c
Samples	Yeasts (log CFU/g)			
	day 1	day 3	day 6	day 9
C	3.49±0.12 ^a	4.83±0.83 ^a	5.51±0.14 ^a	6.13±0.12 ^a
Al	2.36±0.13 ^c	2.61±0.08 ^c	3.71±0.13 ^c	4.77±0.29 ^c
Co	3.05±0.11 ^b	3.68±0.31 ^{ab}	4.82±0.14 ^b	5.33±0.12 ^b
Co+Al	3.02±0.06 ^b	3.15±0.53 ^b	3.27±0.27 ^c	4.70±0.14 ^c

^{a-d}Values followed by different letters differ significantly at P<0.05 level.

Table 4. Sensory attributes of non-coated sample (C), sample coated by sodium alginate (Al), by cocoa cream (Co) and covered by both coatings (Co+Al) at 0 and 3 days of storage.

Time (days)	Sample	External visual appearance	Inner visual appearance	Smell	Flavour	Firmness	Overall Acceptability
0	C	8.11±0.29 ^a	8.46±0.35 ^a	8.23±0.22 ^c	8.25±0.06 ^c	8.21±0.26 ^b	8.19±0.31 ^b
	Al	8.43±0.32 ^a	8.64±0.23 ^a	8.00±0.14 ^c	8.15±0.09 ^c	8.83±0.18 ^a	8.13±0.15 ^b
	Co	8.50±0.23 ^a	8.80±0.29 ^a	9.00±0.16 ^a	8.70±0.13 ^a	7.82±0.31 ^c	8.95±0.13 ^a
	Co+Al	8.35±0.38 ^a	8.70±0.24 ^a	8.66±0.11 ^b	8.48±0.09 ^b	9.00±0.36 ^a	8.73±0.17 ^a
3	C	6.02±0.10 ^b	6.04±0.07 ^b	4.90±0.09 ^c	4.94±0.21 ^d	6.00±0.06 ^c	5.41±0.31 ^d
	Al	6.42±0.20 ^a	6.47±0.15 ^a	6.46±0.17 ^b	5.70±0.10 ^c	6.56±0.17 ^a	6.23±0.07 ^c
	Co	5.83±0.16 ^c	5.66±0.19 ^c	6.85±0.15 ^a	6.80±0.19 ^a	5.65±0.11 ^d	6.65±0.16 ^a
	Co+Al	6.13±0.18 ^b	6.33±0.17 ^a	6.57±0.13 ^b	6.58±0.11 ^b	6.35±0.16 ^b	6.44±0.12 ^b

^{a-d} Values followed by different letters differ significantly at P<0.05 level.

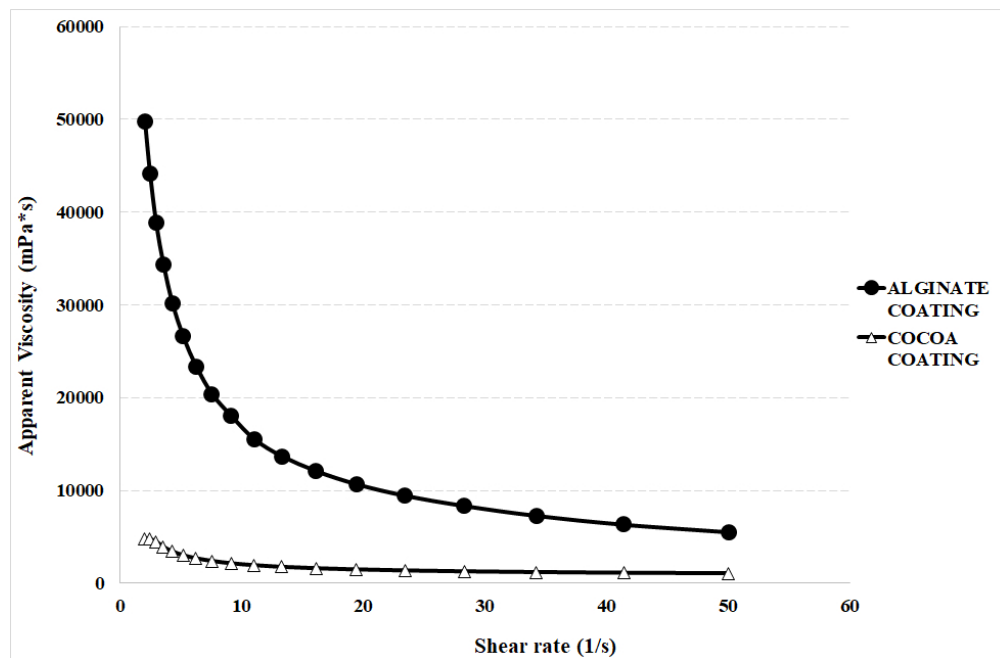


Figure 1. Flow curves of alginate and cocoa based coating evaluated by increasing the shear rate from 2 to 50 s⁻¹.

258x169mm (96 x 96 DPI)

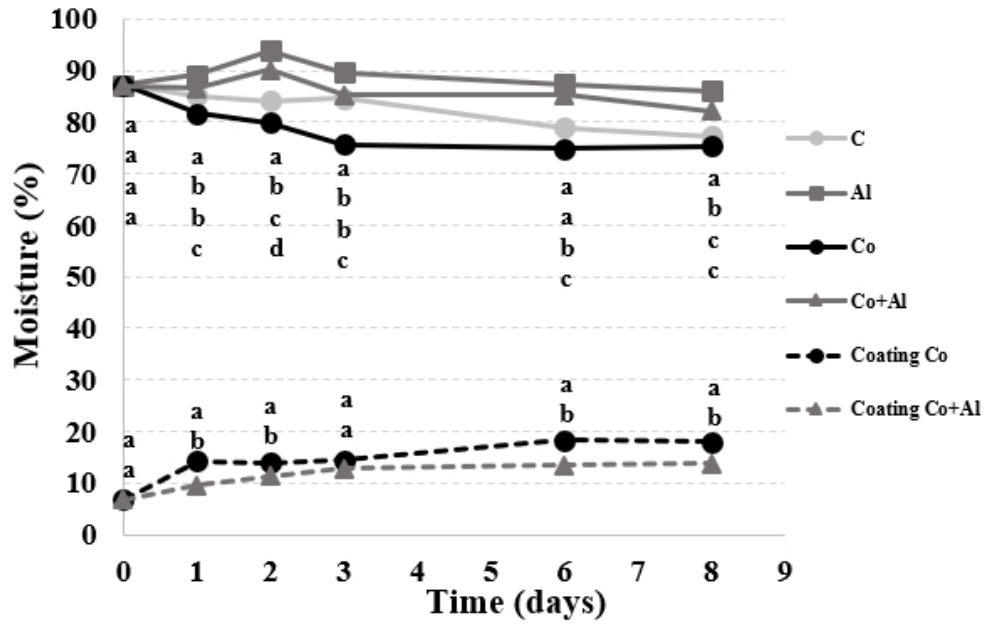
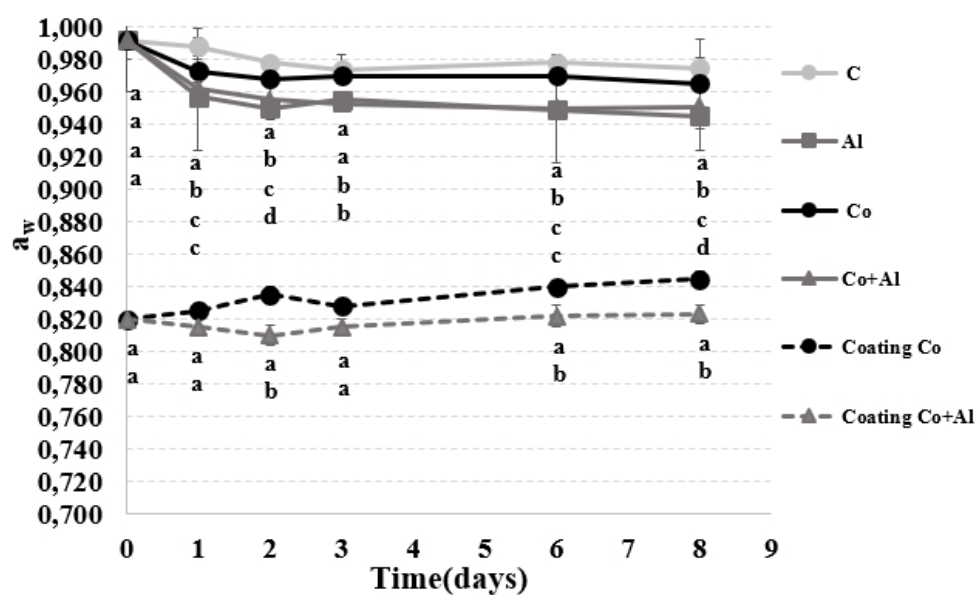


Figure 2. Moisture of orange samples evaluated during storage. a-d Values followed by different letters differ significantly at P<0.05 level

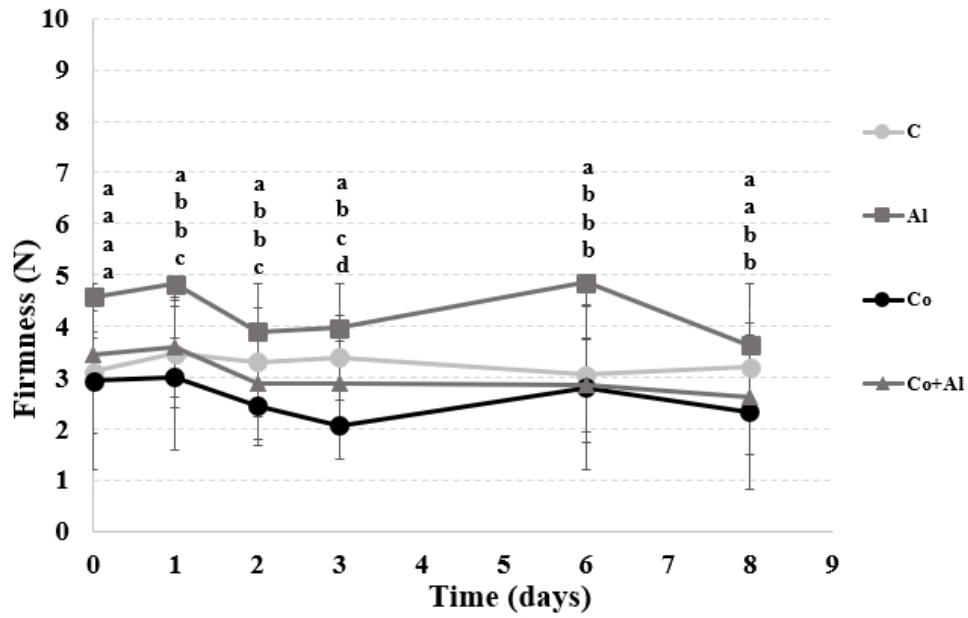
157x101mm (96 x 96 DPI)



Water activity (a_w) of orange samples evaluated during storage.
a-d Values followed by different letters differ significantly at $P < 0.05$ level

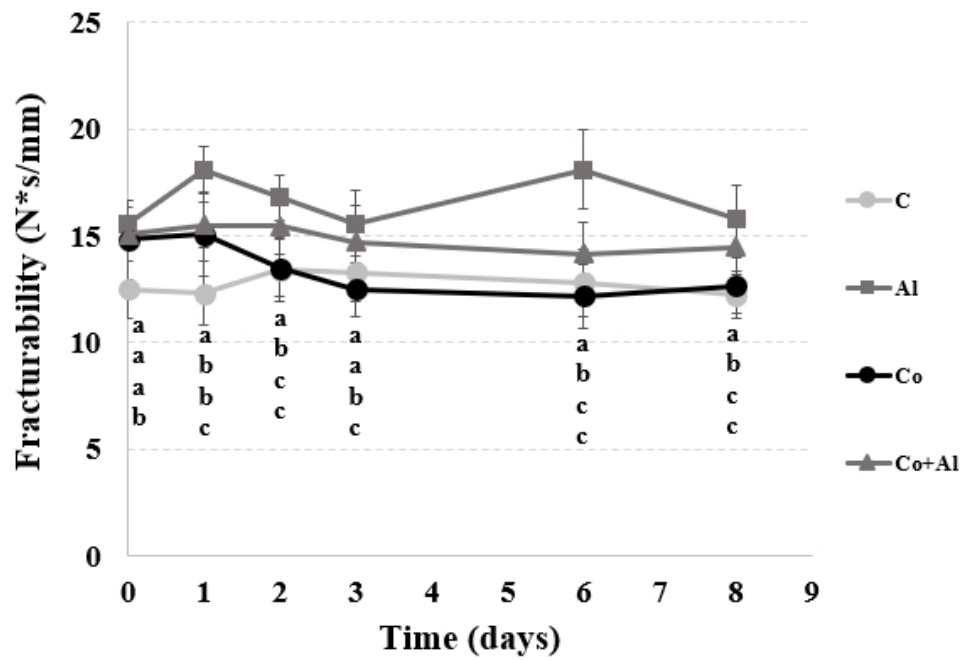
171x106mm (96 x 96 DPI)

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Firmness of orange samples evaluated during storage.
a-d Values followed by different letters differ significantly at P<0.05 level

174x114mm (96 x 96 DPI)



Fracturability values of orange samples during storage
a-c Values followed by different letters differ significantly at $P < 0.05$ level

156x111mm (96 x 96 DPI)