Research article

http://www.revistas.unal.edu.co/index.php/refame

Revista Facultad Nacional de Agronomía

Pysicochemical properties and application of edible coatings in strawberry *Fragaria* × *Ananassa*) preservation

Propiedades fisicoquímicas y aplicación de recubrimientos comestibles en la conservación de fresa (*Fragaria* x *Ananassa*)

doi: 10.15446/rfnam.v71n3.73548

Sandra G. Barrazueta-Rojas[1]*, José F. Falconí[2], Marcelo N. Navarro Ojeda[2], Julio M. Oleas-López[2] and Guillermo X. Mendoza-Zurita[2]

ABSTRACT

The strawberry is one of the most economically important fruit in the Ecuadorian Highlands. Diseases are the main cause of post-harvest losses, causing damage to color, firmness and fruit quality. The main objective of this work was to evaluate the effect of three edible coatings based on gelatin, pectin and beeswax in the post-harvest conservation of the strawberry variety "Oso Grande" from the Chambo canton, Chimborazo province, Ecuador. The process was developed by using a completely random design with factorial arrangement: at room temperature and cooling First, the fruit was selected considering the degree of maturation, size, shape, health of the fruit, and uniform color. Next, it was separated into four groups, washed, and sanitized. Finally, the edible coatings based on gelatin, pectin and beeswax, all enriched with clove essential oil, were applied. The presented physical-chemical changes were evaluated in the two study temperatures. With the obtained results, it could be verified that the use of edible coatings affected statistically in the physical-chemical characteristics of the strawberry. The gelatin coating is the one with the best results, with a lower weight loss of 5.26%, firmness 9.92 N, soluble solids 7.49%, pH 3.69, acidity 0.73% and a shelf life of 5 days. The cost of production for obtaining the gelatin coating was the most economical with a price of $11.10/kg USD. The results show the efficiency of the edible coatings and the storage temperature in the extension of the shelf life of the strawberry.

Keywords:
Physico-chemical properties
Strawberries
Edible coating
Fruit conservation

RESUMEN

La fresa es una de las frutas económicamente más importante en la sierra ecuatoriana. Las enfermedades son las principales causas de pérdidas postcosecha, generando daños en el color, la firmeza y calidad del fruto. El principal objetivo de este trabajo corresponde a la evaluación del efecto de tres recubrimientos comestibles a base de gelatina, pectina y cera de abeja, en la conservación postcosecha de la fresa variedad Oso Grande proveniente del cantón Chambo provincia de Chimborazo-Ecuador. El proceso se llevó a cabo utilizando un diseño completamente al azar con arreglo factorial: a temperatura ambiente y de refrigeración. Los frutos fueron seleccionados en función del grado de maduración, tamaño, forma, sanidad de las frutas, y color uniforme; posteriormente se separó en cuatro grupos; se lavaron, desinfectaron y finalmente se aplicó el recubrimiento comestible a base de gelatina, pectina y cera de abeja, todos ellos enriquecidos con aceite esencial de clavo de olor. Se evaluaron los cambios físico-químicos presentados a las dos temperaturas de estudio. Con los resultados obtenidos se pudo comprobar que el empleo de recubrimientos comestibles afectó estadísticamente en las características físico-químicas de la fresa; siendo el recubrimiento de gelatina el que presenta los mejores resultados, con una menor pérdida de peso 5,26%, firmeza 9,92 N, sólidos solubles 7,49%, pH 3,69, acidez 0,73% y una vida de anaquel de 5 días. El costo de producción para la obtención del recubrimiento de gelatina fue el más económico con un precio de $11,10/kg USD. Los resultados obtenidos demuestran la eficacia de los recubrimientos comestibles y la temperatura de almacenamiento en la prolongación de la vida de anaquel de la fresa.

Palabras clave:
Propiedades fisicoquímicas
Fresas
Recubrimientos comestibles
Conservación de frutas

[1] Facultad de Informática y Electrónica. Escuela Superior Politécnica de Chimborazo. Panamericana Sur km 11/2 Riobamba, Ecuador.
[2] Facultad de Ciencias Pecuarias. Escuela Superior Politécnica de Chimborazo. Panamericana Sur km 11/2 Riobamba, Ecuador.
* Corresponding author: <gabybarrazueta@yahooo.es>

Received: June 7, 2017; Accepted: October 30, 2017
Rev. Fac. Nac. Agron. Medellín 71(3): 8631-8641. 2018 ISSN 0304-2847 / e-ISSN 2248-7026

FAO (2009) indicates that the post-harvest losses causes are very diverse. These include the collection at an inappropriate time in the ripening process. Also, the excessive exposure to rain, drought or extreme temperatures, contamination by microorganisms and physical damage contribute to reduce the product value (whose estimates are between 15% and up to 50% of production in developing countries). This is mainly because farmers do not have the knowledge and skills to apply good agricultural practices and much less about post-harvest manipulation.

The strawberry is a bright red fruit, succulent and fragrant that is obtained from the plant that receives the same name. Studies, like those of Barquero (2007), point out that the problem lies in the post-harvest losses (reaching up to 50% of production); and is usually caused by microorganisms. Since a strawberry is harvested in full maturation and maintained at room temperature, it deteriorates by 80%, in only 8 h (Wang and Gao, 2013). Works carried out by Bestfleisch *et al.* (2014), show that diseases are the main causes of post-harvest losses in the strawberry. The most frequent disease is the one caused by *Botrytis cinerea* (gray mold).

Pérez *et al*. (sf) say that new storage techniques have been developed in recent years, which make it possible to prolong the lifetime of fruits; one of these techniques is the use of edible coatings.

Edible coatings are defined as wrappers that cover the product, creating a semi-permeable barrier to gases (O_2 and CO_2) and water vapor; these improve the mechanical properties, helping to maintain the structural product integrity and to retain volatile compounds. One coating inside the fruit create a modified atmosphere that reduces the speed of respiration, and therefore delays the process of senescence (cell aging) (Pérez *et al*., sf). They also improve the mechanical properties, helping to maintain the structural product integrity that they cover, to retain volatile compounds and can contain food additives (antimicrobial agents, antioxidants, etc.) (Barquero, 2007; Anjum and Akhtar, 2012; Ruiz, 2015; Shao *et al*., 2015).

This research was carried out with the aim of improving the post-harvest management of the strawberry, using natural edible coatings such as gelatin, pectin and beeswax, combined with clove essential oil (the latter compound is very appreciated in the food industry because of its attributed antimicrobial and antifungal properties).

Former researches indicate that clove essential oil has proven very effective against *Penicillium digitatum* (Shao *et al*., 2015; Hall and Fernandez, 2004; Anjum and Akhtar, 2012). According Vesaltalab *et al.* (2012), similar results were obtained when used clove essential oil against *Botrytis cinerea*. Eugenol is the main chemical component of clove oil that has shown greater efficacy against several pathogens (Chaieb *et al*., 2007). Eugenol (4-allyl-2-methoxyphenol) presents antimicrobial properties, antioxidants, antifungal and antiviral activity. These can contribute to major alterations in the hyphal morphology, the alteration of the cell membrane and the release of cellular material from various fungi resulting in the death of these microorganisms (Shao *et al*., 2015).

The coatings used in the investigation are natural, do not cause harm to health, nor alter the sensory characteristics; this is beneficial for the consumer because the obtained product complies with all the quality standards for its commercialization (Campos *et al.,* 2011).

MATERIALS AND METHODS

Plant Material

The selected strawberry, during this work, was of the variety "Oso Grande", coming from the canton Chambo of the province of Chimborazo-Ecuador, whose location has a latitude of 1°44'00'' and a longitude of 78°35'00'. The selection was made according to Barquero (2007), considering the degree of maturation, size, uniformity and health of the fruit, without containing any dirt or foreign matter, in addition to having a minimum of 75% red coloration.

Preparation of the Coatings

The brands of the different substances used were: Gel'hada gelatin, Home Chef pectin and Apicare beeswax, the clove essential oil brand Isabrú Botanik with a 100% purity; distilled water with 98% of Purity Mark Prodont; Glycerin with a 99% purity Mark Ofmagnet and the CMC brand of magnets with a 99.5% purity. The formulation of edible coatings is shown in Table 1.

Table 1. Formulation of edible coatings.

Coatings	Comp.	Glic.	CMC	Pectin	AECO	A.D.
			(%)			
T0R (control)	0	0	0	0	0	0
T1R (gelatin)	3	0.75	0.75	0	1	94.50
T2R (pectin)	3	0.75	0.75	0	1	94.50
T3R (beeswax)	0.5	0.75	0	1.8	1	95.95
T0C (control)	0	0	0	0	0	0
T1C (gelatin)	3	0.75	0.75	0	1	94.50
T2C (pectin)	3	0.75	0.75	0	1	94.50
T3C (beeswax)	0.5	0.75	0	1.8	1	95.95

Room temperature R; Cooling temperature C; T0, T1, T2 y T3 Coatings used; Glic: Glycerin; CMC: Carboxymethylcellulose; AECO: Clove essential oil; A.D.: Distilled water.

The edible coatings were prepared by heating the distilled water at 65 - 75 °C, with constant stirring. The ingredients were added in the following order: The main component (gelatin, pectin or beeswax), glycerin, carboxymethylcellulose until a homogeneous mixture was obtained; finally, the temperature was reduced to 20 °C, and the clove essential oil was added. In the case of beeswax, it was first diluted at 62 - 65 °C, which was subsequently incorporated into the mixture with the other components.

The fruit was washed and disinfected by immersion in ozonated drinking water for 15 min. Then, left to dry; after that, the coating was applied by dipping the fruit and leaving it to drain for 1.5 min. Finally, it dried at temperature of 14 - 24 °C until its compaction. The storage was carried out on plastic trays, at an ambient temperature of 13 °C, with a relative humidity of 66.30%, and at refrigerated temperature of 4 °C, with a relative humidity of 95% (FRN – ESPOCH, 2016).

Physical and chemical properties assessment

Weight loss (%): performed by the gravimetric method, using a pioneer precision analytical balance. (Restrepo and Aristizabal, 2010).

Texture: the measurement of this property was done according to the INEN 1909 (2015); using a penetrometer mark QA. supplies, fruit pressure tester, FT 327 model and 3.5 mm diameter plunger.

Soluble solids (%): A refractometer: ATAGO brand, Model PAL1, was used as described in INEN 380 (1985).

pH: in this property measurement a potentiometer Testr 30 waterproof, Mark Oakton was used as described in the INEN 389 (1986). Titratable acidity (%) was performed according to the INEN 381 (1986), using an acid titrator: burette Dornic Marca BRIXCO (Camacho *et al*., 2009).

Lifetime Valuation

This was carried out by establishing Alvarado´s method, through the count of molds and yeasts (Alvarado, 1996).

Economic valuation

Production costs were determined based on projection for one year, according to the established FAO (2016a) method.

Experimental design

The experimental design was based on the evaluation of physical-chemical properties (VD: effects): weight loss (1); texture (2); soluble solids (%) (3); pH (4) and titratable acidity (% citric acid) (5) of the “Oso Grande” strawberry variety, in the post-harvest conservation through the addition of edible coatings, in front of a control. The process was carried out using a completely randomized design, with factorial arrangement, involving the following independent variables (VI): three types of edible coatings based on gelatin, pectin and beeswax; temperature: ambient and cooling; time: 11 days, with three replicates each. This same procedure was repeated, but with 12 levels for VI

Time. The results were subjected to analysis of variance and the means separation according to Tukey test.

The experimental treatments number for each VD measurement: physical and chemical properties: weight loss (1), texture (2), soluble solids (%) (3), pH (4) and titratable acidity (5) were calculated through the product independent variables levels (VI), according to the following mathematical model:

$$N_T = nT \,.\, nt \,.\, nTR \qquad (1)$$

Where:
N_T: Treatments number
nT: Levels number of the independent variable (VI): Time
nt: Levels number VI temperature: ambient (A) and refrigerated (R)
nTR: Levels number the VI type coating: gelatin, pectin and beeswax

Then, the total experimental runs number (NCET) was obtained by multiplying the number of treatments by the number of repetitions (coefficient k) (Equation 2).

$$N_{CET} = k \,.\, N_T \qquad (2)$$

By explicitly replacing expressions 1 and 2, the total treatments number and the experimental runs were obtained, respectively.

The total treatments number, according the modified Equation 1, in the measurement the physicochemical properties studied, is given according to the following mathematical models 3, 4 and 5.

$$N_{T\ VD\,1} = (nT.\ nt \,.\, nTR\,) \,.\, (TEx\,) = [(11) \,.\, (2) \,.\, (3) \,.\, (1)] = 66 \qquad (3)$$

$$N_{T\ VD\,2,3,4\text{ and }5} = (nT.\ nt \,.\, nTR\,) \,.\, (TEx\,) = [(12) \,.\, (2) \,.\, (3) \,.\, (4)] = [(72) \,.\, (4)] = 288 \qquad (4)$$

$$N_{TT\ VD\,1,2,3,4\text{ and }5} = N_{T\ in\ VD\,1} + N_{T\ VD\,2,3,4\text{ and }5} = 288 + 66 = 354 \qquad (5)$$

The experimental runs were performed with three replicates (coefficient k) for each VD. The total experimental runs value was given by the sum of the experiments, considering absence of control (Equation 6) and adding the total sum of control used; the value obtained is given after Equations 7 and 8.

$$N_{CT\text{ without }T\ VD\,1,2,3,4\text{ and }5} = (3) \,.\, (354) = 1062 \qquad (6)$$

$$N_{TM\ VD\,1,2,3,4\text{ and }5} = N_{CT\text{ without }T\ VD\,1,2,3,4\text{ and }5} + \mathrm{N}_{T\ VD\,1,2,3,4\text{ and }5} \qquad (7)$$

$$N_{T\ samples\ VD:\,1,2,3,4\text{ and }5} = 1062 + 354^* = 1416 \qquad (8)$$

Where,
$N_{T\ VD1}$: Treatments measurement number the VD_1
$N_{T\ VD2,3,4\ and\ 5}$: Treatments measurement number the $VD_{2,3,4\text{ and }5}$
TEx: Type of Experiment, according to VD type
$N_{TT\ VD1,2,3,4\ and\ 5}$: Total Treatments number $VD_{1,2,3\text{ and }5}$
$N_{CTwithoutVD1,2,3,4\ and\ 5}$: Total runs number the $VD_{1,2,3,4\text{ and }5}$ measurement; no control treatment
$N_{Tsamples\ VD1,2,3,4\ and\ 5}$: Total Samples number used in all trials

RESULTS AND DISCUSSION

Assessment of physico - chemical characteristics

Weight loss (%). In the analysis of the weight loss variable, referential studies, such as those performed by Robinson *et al.* (1975) report that the maximum percentage of weight loss, for the marketing of the strawberry is 6%. In this research, these values are within the established parameter up to the third and fourth day (which correspond to the treatments in beeswax and gelatin refrigeration respectively). Other treatments are outside the set parameter (from the third day). Weight loss values (from day 2 to day 12) are shown in Figure 1. The results were re-obtained from the second day, since the initial measurements (first day) constitute the starting point for this research.

The treatment with gelatin was the one that presented the best characteristics in this parameter, since its weight loss percentage only reached a value of 5.26. This is because gelatin is a hydrocolloid substance (gelling agent), which gives the coating thickening properties that do not allow the fruit to lose the water it has in its composition because it forms a good barrier to the transfer of gases and water vapor (Trejo *et al*., 2007).

Figure 1 shows a considerable weight loss of the treatments at room temperature in relation to those of refrigeration. This is because, after fruits are harvested, physiological changes occur, such as perspiration (Fernández *et al.,* 2015); and because the fruit is constituted mainly of water (72 - 95%). There is a great dehydration or wilting, which controlled by refrigeration avoids the loss of water that is produced by evaporation (Pelayo and Castillo, 2002).

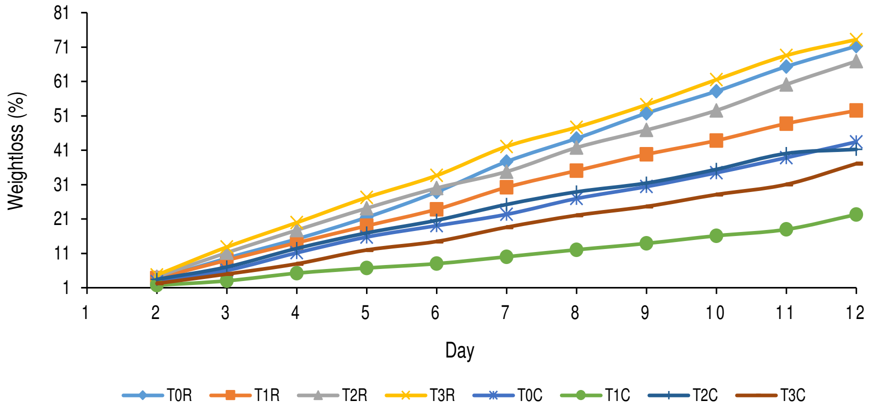

Figure 1. Weight loss depending on the experimentation days at room temperature and refrigeration.

Texture. The loss of firmness constitutes one of the most significant physiochemical changes; it is associated with the loss of water, generated through perspiration and respiration of the fruit. As a result, wilting and loss of consistency occur. It is one of the main factors used to determine fruit quality and post-harvest shelf life (Acuña, 2009).

With regard to the variable texture, there are investigations, such as Alcántara (2009), where they indicate that, for its commercialization, the strawberry must have a firmness oscillating between 9.8 – 11.5 N. In the present investigation, at refrigeration temperature, it is within the parameter until the fifth day in the treatments coated with beeswax, pectin and control and until the sixth day with the treatment of gelatin.

Gelatin coatings are those that delayed the softening of the fruit longer, presenting a value (per day six) of 9.92 N. This was because the gelatin develops excellent mechanical properties that are very favorable to cover food (Acosta, 2014); in this order, treatments with pectin and beeswax were followed which (until day five) presented a value of 10.02 N; because polysaccharides, such as pectin, are capable of constituting a structural matrix, allowing to obtain edible coatings with moderate mechanical properties (Eum *et al*., 2009). In the case of beeswax, these results were due to the addition of polysaccharide (CMC) in the formulation of the treatment, which provided good mechanical properties since lipids, on their own, present drawbacks in this aspect (Campos *et al*., 2011; Pavón and Valencia, 2016).

Analyzing temperature factor, it can be observed that the effect of refrigeration presented better results with respect to the ambient temperature treatments, obtaining values similar to those reported by Trejo *et al*. (2007) in his research. For this reason, the application of 1% of gelatin for edible coatings in strawberries influenced the softening of tissues; since the uncoated fruits showed a 62% loss of firmness; meanwhile, the coated strawberries showed 5% values from the third day of storage. In Figure 2, it can be seen that the texture decreases with storage time, until finally softening is achieved.

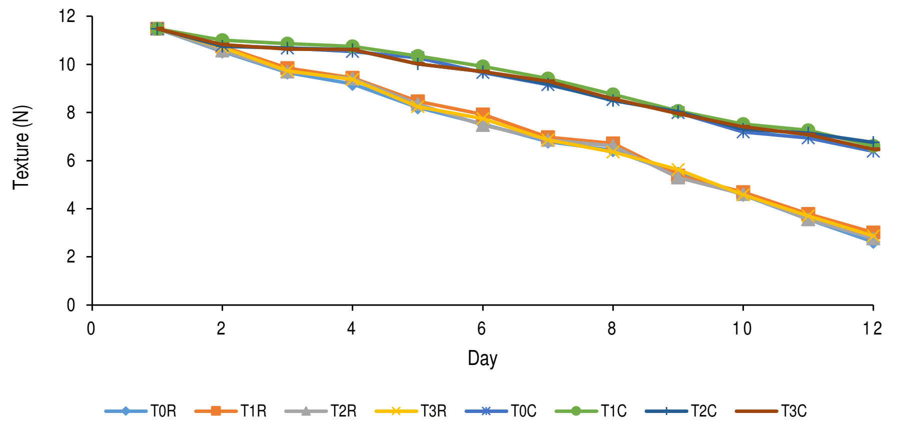

Figure 2. Texture Behavior (N) as a function of elapsed time at room temperature and refrigeration.

Soluble solids (%). For the soluble solids variable, researches such as that of Chicaiza (2015), assert that for the "Oso Grande" variety, this parameter must have a minimum value of 6.91 ° Bx; while Reyes and Zschau (2012) confer a maximum value of 8.2 °Bx, so that the fruit is acceptable. In this research, these values are within the established data until the twelfth day (in the treatments in gelatin refrigeration, beeswax and without coating), and the pectin until the eleventh day. The percentages of soluble solids obtained in the research are shown in Figure 3.

The treatments with gelatin kept stable the amount of soluble solids present in the strawberry, reporting a percentage of 7.49 because the gelatin, when presenting excellent barriers to oxygen, slows down the process of degradation of sucrose that cause fungi, thus avoiding an increase in soluble solids. Refrigeration (considering the temperature factor) maintains the activity of the microorganisms in the latent state, which allows a lesser variation of soluble solids present in the fruit (Ruiz, 2015). The soluble solids variation can be seen in Figure 3.

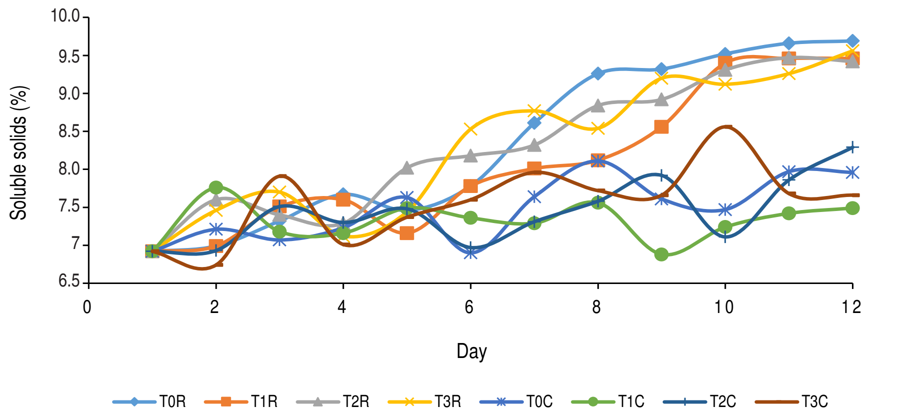

Figure 3. Soluble solids (%) depending on the experimentation days at room temperature and refrigeration.

pH and titrable acidity. In regard to the pH variable, reference studies such as those of Nunes (2007) report values between 3.4 – 3.75. In this research these values remained until the eighth day, which correspond to the treatments that are at room temperature, but until day 12 for those that are in refrigerated conditions (this was because bacteria and fungi use, as a source of energy and nutrients, the components present in food, such as sugars, amino acids, and phenolic compounds). In this case, organic acids or glucose may be produced. The production of these compounds causes an increase in the concentration of OH-ions, which results in an increase in pH. This type of process is what causes food to deteriorate (Fennema, 1996).

The gelatin-based coatings maintain the pH of the strawberry stable, reporting a value of 3.69, since the gelatin forms a protective layer, avoiding the entry of oxygen and stopping the activity of the fungi and bacteria, which keeps the pH in the fruit stable. In Figure 4 it is possible to observe the increase of the pH of the treatments at room temperature with respect to those of refrigeration.

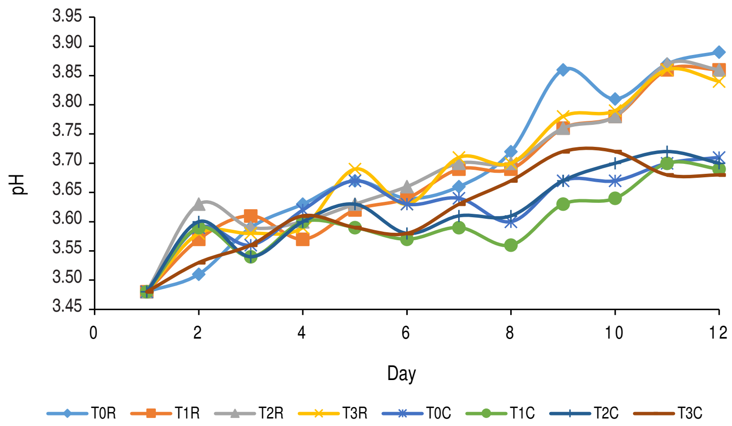

Figure 4. pH behavior as a function of elapsed time at room temperature and refrigeration.

As for the titratable acidity variable, researches such as that of Chicaiza (2015), indicate that the strawberry should have a minimum percentage of 0.69 g and a maximum of 0.89 g of citric acid per 100 g of product. In this research these values are within the established data until the ninth day; which corresponds to the treatments in gelatin refrigeration, pectin, and beeswax with percentages of 0.73, 0.71 and 0.69, respectively. This was due to the conservation effect provided by the low temperatures; the coatings create a protective layer on the fruit that retains volatile compounds and slows its senescence process, stabilizing the organic acids longer (ELIKA, 2010; Villegas and Albarracín, 2016).

The acidity reduction coincided with the pH increase. The cause was the use of organic acids as an energy source to support the process of senescence of the fruit (Chicaiza, 2015). In addition, it must be considered that the organic acids present in the food influence the taste, color and stability of the same. Acidity values can be very variable, as in fruit. Citric acid can constitute up to 60% of the total soluble solids in the edible portion (Figure 5).

Molds and yeasts. In regard to the parameter molds and yeasts, reference studies such as those carried out by Frazier and Westhoff (2003); report that in order for a fresh fruit to be consumed, without causing any health risk, it must possess a range acceptable to oscillate between 3 log CFU mL^{-1} and 4 log CFU mL^{-1}. In this research, these values remain until the ninth day in treatments with refrigerated coatings; other treatments are outside the parameter set from the third day.

The incorporation of lipids, such as essential oils in an edible coating, is an effective method to solve some of these problems, as well as in the control of fungal diseases of the fruit (Pontigo-Suárez *et al.,* 2015) by reducing the diffusion processes and the maintenance of high concentrations of active molecules on the surface of the fruit (Shao *et al.*, 2015). Clove essential oil has been shown to have antimicrobial, antifungal, and antiviral activity due to its main chemical component, which is eugenol (Hall and Fernandez, 2004; Anjum and Akhtar, 2012; Vesaltalab *et al*, 2012; Chaieb *et al*., 2007; Shao *et al*., 2015).

The gelatin coatings presented the lowest microbial load, with a value of 45 CFU mL^{-1} because when combined with a protein, a polysaccharide and a lipid, this helps to minimize the disadvantages of the individual components,

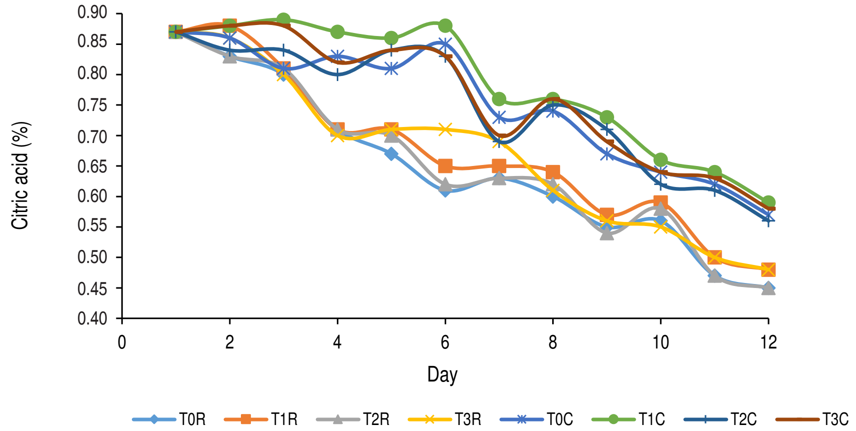

Figure 5. Citric acid (%) as a function of elapsed time at room temperature and refrigeration.

making synergy of their functional and physical properties (Pascall and Lin, 2013).

Beeswax, as a coating, presented good characteristics within this parameter, with a value of 51 CFU mL^{-1} because, when using lipids such as beeswax and essential oils, combined with polysaccharides such as CMC, coatings are obtained with excellent barriers against oxygen, carbon dioxide and moisture (Parzanese, 2009).

Treatments with pectin followed, in numerical value, to beeswax with a value of 52 CFU mL^{-1}; since, when using polysaccharides in combination with essential oils, a good combination is produced, obtaining edible coatings with good barriers against humidity and moderate mechanical properties (Parzanese, 2009; Ruiz *et al.,* 2016).

The conservation in low temperatures is essential to avoid the development of molds and yeasts, especially the development of the mold *Botrytis cinerea*, since according to Shao *et al.* (2015); it is this mold that most affects the strawberry (grows at temperatures of 15 - 20 ºC and in conditions of high relative humidity with values between 85 – 90%). The temperature directly affects the conservation of the food, it already keeps the microorganisms in latent life (inactivity), thus increasing the useful life of the product (ISETA, sf.). This is demonstrated in the results of this research, since refrigeration achieved up to 50% fungal growth, compared with treatments at room temperature (Figure 6).

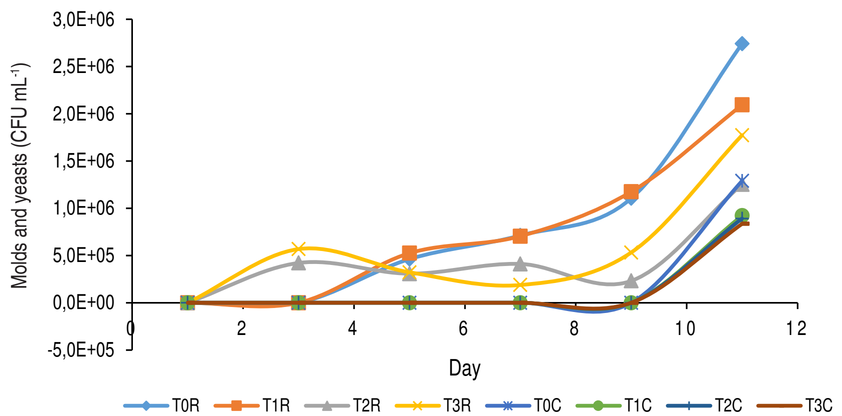

Figure 6. Growth of molds and yeasts as a function of elapsed time at room temperature and refrigeration.

Value of shelf life

Edible coatings at room temperature reported values between 2 to 3 days of shelf life. These data are consistent with those of the FAO (2016b); which states that the strawberry is very perishable and deteriorates within 2 or 3 days of harvesting in natural environmental conditions.

In the treatment of refrigerate fruit, values of 4 to 5 days were obtained. These values exceed that indicated by Acuña and Llerena (2001); which shows that the strawberry lasts up to four days in refrigeration; this verifies the effectiveness of the use of coatings in the post-harvest handling of this valuable fruit (Villegas and Albarracín, 2016)..

The useful life of the strawberry can improve by performing a good post-harvest management, avoiding in this way the activation of metabolic processes that cause the deterioration of the fruit. Temperature is a very important factor for storage conservation. At high temperatures, senescence processes develop at high speed, and at low temperatures, metabolic activity and moisture loss is reduced, slowing microbial proliferation. For this reason, the preparation of the fruit at refrigerated temperatures after collection is recommended (Ariel, 2004). The values used for the calculation of useful life can be seen in Table 2.

Economic valuation

All production costs were projected for one year, with a production capacity of 300 kg of strawberry daily, using 75% capacity. In Table 3, production costs can be seen for obtaining the three types of coatings.

Table 2. Values used for the calculation of useful life of the strawberry.

	Molds and yeasts							
	Room temperature				Cooling temperature			
Time (days)	T0R	T1R	T2R	T3R	T0C	T1C	T2C	T3C
1	3.19	3.19	3.19	3.19	3.19	3.19	3.19	3.19
3	3.50	3.22	12.70	12.60	3.09	3.04	3.18	3.30
5	12.96	13.25	13.28	12.76	3.66	3.76	3.53	3.04
7	13.16	13.78	14.27	14.28	3.74	3.47	3.22	3.30
9	14.33	13.30	13.78	13.33	12.02	3.81	3.95	3.93
11	15.12	14.79	14.60	14.85	14.36	14.07	13.93	14.08
Shelf life (days)	3	3	2	2	4	5	5	5

Table 3. Production costs for one year (USD).

	Covering		
Concept	Gelatin	Pectin	Beeswax
Direct materials	174,144.43	174,171.32	174,163.41
Direct labor	12,413.26	124,13.26	12,413.26
Indirect costs of production	29,280.46	29,280.46	29,280.46
TOTAL $USD	**215,838.15**	**215,865.04**	**215,857.13**

CONCLUSIONS

In this research the physicochemical parameters of weight loss, texture, soluble solids, pH and acidity proved the efficacy of edible coatings in the post-harvest management of the strawberry variety “Oso Grande”. The use of edible membranes, with bioactive agents such as cloves and low temperatures, allowed extending up to a maximum of five days the physicochemical and sanitary characteristics of the fruit under study.

Based on the results obtained in the physicochemical and microbiological analyses, the following results were determined: the gelatin coating presents the best characteristics with a lower percentage of weight loss (5.26), a delay in the softening of the texture (9.92 N), slowing of senescence maintaining the stability of soluble solids (7.49%), pH (3.69), acidity (0.73%) and better inhibition of the proliferation of molds and yeasts into the strawberry.

ACKNOWLEDGEMENTS

The authors thank the Escuela Superior Politécnica de Chimborazo and, the School of Livestock Sciences and especially the engineering degree in Livestock Industries for all the support granted.

REFERENCES

Acosta S. 2014. Propiedades de films de almidón de yuca y gelatina. Incorporación de aceites esenciales con efecto antifúngico. Tesis Doctoral. Universidad Politécnica de Valencia, Valencia, España. 279 p.

Acuña J. 2009. Preservación de pepinos mediante el empleo de coberturas de quitosano. Tesis para título en Licenciatura en Ciencias Alimentarias. Universidad de La Habana, La Habana. Cuba.

Acuña O. and Llerena T. 2001. Manual post cosecha de frutilla. Universidad Politécnica Nacional. Gráficas Gumar, Quito. 50 p.

Alcántara M. 2009. Estimación de los daños físicos y evaluación de la calidad de la fresa durante el manejo post cosecha y el transporte simulado. Tesis Doctoral. Universidad Politécnica de Valencia, Valencia, España. 279 p.

Alvarado J. 1996. Principios de ingeniería aplicados a alimentos. Segunda edición. Facultad de Ciencia e Ingeniería en Alimentos. Universidad Técnica de Ambato, Ecuador. pp. 156-157.

Anjum T, Akhtar N. 2012. Antifungal activity of essential oils extracted from clove, cumin and cinnamon against blue mold disease on citrus fruit. pp. 321–326. In: International Conference on Applied Life Sciences (ICALS). Turkey.

Ariel V. 2004. Efecto de tratamientos térmicos de alta temperatura sobre calidad y fisiología postcosecha de frutillas (*Fragaria* x *ananassa* Duch.). Tesis Doctoral. Facultad de Ciencias Exactas. Departamento de Química. Universidad Nacional de la Plata, Argentina. 235 p.

Barquero J. 2007. Agrocadena de Fresa. pp. 4, 8, 10, 14, 15, 16. En: Botanical-online la Cera de Abeja http://www.botanical-online.com/ceradeabeja.htm. Primera edición. Editorial Prisa, San José, Costa Rica.

Bestfleisch M, Luderer PM, Hofer M, Schulted E, Wunsche JN, Hankea MV and Flachowsky H. 2014. Evaluation of strawberry (*Fragaria* L.) genetic resources for resistance to *Botrytis cinerea.* Plant Pathology 64(2): 396–405. doi: 10.1111/ppa.12278

Camacho A, Giles M, Ortegón A, Palao M, Serrano B and Velázquez O. 2009. Técnicas para el análisis microbiológico de alimentos. Segunda edición. Facultad de Química. UNAM. México. En: http://depa.fquim.unam.mx/amyd/archivero/TecnicBasic-Dilucio nes_6526.pdf

Campos C, Gerschenson L and Flores S. 2011. Development of edible films and coatings with antimicrobial activity. Food and Bioprocess Technology 4(6): 849-875. doi: 10.1007/s11947-010-0434-1

Chaieb K, Hajlaoui H, Zmantar T, Kahla-Nakbi AB, Rouabhia M, Mahdouani K, Bakhrouf A. 2007. The chemical composition and biological activity of clove essential oil, *Eugenia caryophyllata* (*Syzygium aromaticum* L. Myrtaceae). Phytotherapy Research 21(6): 501-506. doi: 10.1002/ptr.2124

Chicaiza J. 2015. Determinación de los parámetros físico-químicos y microbiológicos de la fresa (*Fragaria vesca*) Variedad Oso Grande como base para el establecimiento de la Norma de Requisitos. Tesis grado de Bioquímico Farmacéutico. Facultad de Ciencias Médicas. Universidad Regional Autónoma de los Andes. Ambato, Ecuador. 85 p.

ELIKA. 2010. Agentes de recubrimientos comestibles. En: http://www.elika.net/datos/artículos/Archivo652/berezia_agentes%20de%20recubrimiento.pdf

FRN – ESPOCH. 2016. Estación Meteorológica de la Facultad de Recursos Naturales. Riobamba, Ecuador.

Eum H, Hwang D, Linke M, Lee S and Zude M. 2009. Influence of edible coating on quality of plum (*Prunus salicina* Lindl. cv. 'Sapphire'). European Food Research and Technology 229(3): 427-434. doi: 10.1007/s00217-009-1054-8

FAO. 2009. Las pérdidas post-cosecha agravan el hambre. Roma, Italia. En: http://www.fao.org/news/story/es/item/36864/icode/

FAO. 2016a. Costos de producción. Roma, Italia. En: http://www.fao.org/docrep/003/v8490s/v8490s06.htm

FAO. 2016b. Conservación de fresas. Roma, Italia. En: http://www.fao.org/docrep/008/y5771s/y5771s03.htm

Fennema O (ed.). 1996. Food chemistry. Third edition. University of Wisconsin, Madison, Wisconsin. Marcel Dekker, Inc., N.Y. USA. 1071 p.

Fernández D, Bautista S, Ocampo A, García A and Falcón A. 2015. Películas y recubrimientos comestibles: Una alternativa favorable en la conservación poscosecha de frutas y hortalizas. Revista Ciencias Técnicas Agropecuarias 24(3): 52- 56.

Frazier W and Westhoff D. 2003. Microbiología de los alimentos. Cuarta edición. Ed. Acribia, Zaragoza, España. 681 p.

Hall DJ and Fernández YJ. 2004. In vitro evaluation of selected essential oils as fungi-cides against *Penicillium digitatum* SACC. Proceedings of the Florida State Horticultural Society 117: 377–379.

INEN 380. 1985. Conservas vegetales. Determinación de sólidos solubles. En: http://apps.normalizacion.gob.ec/descarga/

INEN 381. 1986. Conservas vegetales - Determinación de acidez titulable. Método potenciométrico de referencia. En: http://apps.normalizacion.gob.ec/descarga/

INEN 389. 1986. Conservas vegetales - Determinación de la concentración de ión hidrógeno (pH). En: http://apps.normalizacion.gob.ec/descarga/

INEN 1909. 2015. Frutas frescas. Tomate de árbol. Requisitos. En: http://apps.normalizacion.gob.ec/descarga/

ISETA (sf.). Importancia de la refrigeración de los alimentos. Argentina. Recuperado de: http://www.iseta.edu.ar/ARTICULOS%20DE%20INTERES/Refrige.pdf

Nunes M. 2007. Caracterización y procesado de kiwi y fresa cultivados por diferentes sistemas. Tesis Doctoral. Departamento de Química Analítica, Nutrición y Bromatología. Universidad de Santiago de Compostela, Galicia, España. 242 p.

Parzanese M. 2009. Películas y recubrimientos comestibles. Ficha No. 7. Argentina. En: http://www.alimentosargentinos.gob.ar/contenido/sectores/tecnologia/Ficha_07_PeliculaComestible.pdf

Pascall M and Lin S. 2013. The application of edible polymeric films and coatings in the food industry. Food, Processing and Technology 4(2): 1-2. En: http://web.udlap.mx/tsia/files/2015/05/TSIA-82-Velazquez-Moreira-et-al-2014.pdf

Pavón D and Valencia S. 2016. Efecto de recubrimientos comestibles compuestos a base de goma tara en la calidad poscosecha de frutilla (*Fragaria ananassa*). Revista Iberoamericana de Tecnología Postcosecha 17(1): 65-70.

Pelayo C and Castillo D. 2002. Técnicas de manejo pos cosecha a pequeña escala. Manual para los productos hortofrutícolas. 4a. Ed. Series de Horticultura Postcosecha No. 8. Universidad de California, Davis. Centro de Investigación e Información en Tecnologías Postcosecha. 269 p.

Pontigo SAG, Trejo Márquez MA and Lira VAA. 2015. Desarrollo de un recubrimiento con efecto antifúngico y antibacterial a base de aceite esencial de orégano para conservación de papaya 'Maradol'. Revista Iberoamericana de Tecnología Postcosecha 16(1): 58-63.

Pérez G, Río M and Rojas A. (sf.). Recubrimientos Comestibles en Frutas y Hortalizas. En: http://www.horticom.com/pd/imagenes /69/831/69831.pdf.

Restrepo J and Aristizabal I. 2010. Conservación de fresa (*Fragaria x ananassa* Duch cv. *Camarosa*) mediante la aplicación de recubirmientos comestibles de gel mucilaganoso de penca sábila (*Aloe barbadensis* Miller) y cera de carnaúba. Revista Iberoamericana de Tecnología Postcosecha 17(3): 252-263.

Reyes M and Zschau B. 2012. Frutilla, consideraciones productivas y manejo, InnovaChile 1(252): 31.

Robinson JE, Browne KM, and Burton WG. 1975. Storage characteristics of some vegetables and soft fruits. Annals of Applied Biology 81: 399.

Ruiz MM, Ávila J and Ruales J. 2016. Diseño de un recubrimiento comestible bioactivo para aplicarlo en la frutilla (*Fragaria vesca*) como proceso de postcosecha. Revista Iberoamericana de Tecnología Postcosecha 17(2): 276-287.

Ruiz M. 2015. Diseño de un recubrimiento comestible bioactivo para aplicarlo en la frutilla (*Fragaria vesca*) como proceso de postcosecha. Tesis Ingeniero Químico. Facultad de Ingeniería Química y Agroindustria. Escuela Politécnica Nacional, Quito. 165 p.

Shao X, Cao B, Xu F, Xie S, Yu D and Wang H. 2015. Effect of postharvest application of chitosan combined with clove oil against citrus green mold. Postharvest Biology and Technology 99: 37-43. doi: 10.1016/j.postharvbio.2014.07.014

Trejo M, Ramos K and Pérez C. 2007. Efecto de la aplicación de un recubrimiento comestible a base de gelatina sobre la calidad de fresa (*Fragaria vesca* L.) almacenada en refrigeración. En: V Congreso Iberoamericano de Tecnología Postcosecha y Agroexportaciones. Murcia, España: Asociación Iberoamericana de Tecnología Postcosecha (AITEP).

Vesaltalab Z, Gholami M and Zafari D. 2012. Clove buds (*Eugenia caryophyllata*) and rosemary (*Rosmarinus officinalis*) essential oils effects on control of grapes graymold *in vitro*. Annals of Biological Research 3(5): 2447-2453.

Villegas C and Albarracín W. 2016. Aplicación y efecto de un recubrimiento comestible sobre la vida útil de la mora de castilla (*Rubus glaucus* Benth). Vitae, Revista de la Facultad de Ciencias Farmacéuticas y Alimentarias 23(3): 202-209. doi: 10.17533/udea.vitae.v23n3a06

Wang S and Gao H. 2013. Effect of chitosan-based edible coating on antioxidants, antioxidant enzyme system, and postharvest fruit quality of strawberries (*Fragaria* x *Aranassa* Duch.). LWT - Food Science and Technology 52(2): 71-79. doi: 10.1016/j.lwt.2012.05.003