Coverage of chitosan and essential cinnamon oil for strawberry conservation (*Fragaria ananassa*) var. Aroma, minimally processed

Magaly Zavaleta, B.Sc.[1], Carlos Echeverría, B.Sc.[1], Jackeline León-Vargas, B.Sc.[2], Leslie Lescano, M.Sc.[3], Jesús Sánchez-González, M.Sc.[3], Guillermo Linares, Dr.[3], and Meliza Lindsay Rojas, Dr.[4]*
[1]Escuela de Ingeniería Agroindustrial, Universidad Nacional de Trujillo, Perú, mzavaleta.garcia@gmail.com, charly_10_cancer@hotmail.com,
[2]Ingeniería Agroindustrial, Universidad Privada del Norte, Perú, jackeline.leon@upn.edu.pe
[3]Departamento de Ciencias Agroindustriales, Universidad Nacional de Trujillo, Perú, llescano@unitru.edu.pe, jsanchezg@unitru.edu.pe, glinares@unitru.edu.pe
[4]Dirección de Investigación y Desarrollo, Universidad Privada del Norte, Perú, meliza.rojas@upn.edu.pe
*Corresponding autor: meliza.rojas@upn.edu.pe; Av. Del Ejército 920, Trujillo, Perú.

Abstract*– The use of edible coverage represents one of the important methods used to preserve the quality of minimally processed products. The aim of this research was to determine the effect of chitosan and essential cinnamon oil coverage in the phenolic content, antioxidant capacity, mould and yeast count, and general acceptability in minimally processed strawberry along 16 days of refrigerated storage at 10 °C, in order to improve the conservation and characteristics of minimally processed strawberry var. aroma. In this experiment a response surface methodology using a Central Composite Rotational Design (CCRD) was carried out; the variable ranges used were 0.7 – 2% (Chitosan) and 0.02 – 0.1% (cinnamon essential oil). As results, it was found that the significant variable ($p<0.05$) was cinnamon essential oil for both phenols content and antioxidant capacity. For these characteristics, a concentration of 0.1% cinnamon essential oil was the most effective. The antioxidant capacity and phenolic contents showed an increase during the first 7 days of storage, decreasing after that for all treatments. It was also found that both independent variables significantly influence ($p<0.05$) in the decrease of microbial load being the optimal range of chitosan (1.33-1.71%) and cinnamon essential oil (0.056-0.087%). In addition, the use of coverage of chitosan and cinnamon essential oil does not negatively affect the sensory acceptability and helps to maintain the shelf life of minimally processed strawberry.

***Keywords*-- Strawberry; edible coverage; antioxidant capacity; chitosan; Cinnamon essential oil.**

I. Introduction

The strawberry is a non-climacteric fruit, highly appreciated by consumers because of its organoleptic properties. They are rich in antioxidants such as phenolic acids, flavonoids and anthocyanins [1]. Recent studies have shown that consumption of red fruits reduces the risk of developing degenerative diseases [2]. However, the rapid perishability strawberry has stimulated the search for new natural conservation systems, based edible coverage [3]. The use of edible coverage represents one of the important methods used to preserve the quality of minimally processed products. The consumption of fresh, sliced or minimally processed foods is a trend that has been widely accepted in the world food trade [4].

The application of chitosan as a film serves as a primary packing and as a coverage (by immersion) for the direct protection of food [5], but one of the most important drawbacks is its poor property of water vapour barrier [6], however, the biocompatibility of chitosan with various compounds, is used to incorporate hydrophobic compounds [7].

Essential oils are natural antioxidant and antimicrobial substances and majority consist of a mixture of terpenes, terpenoids and other aromatic and aliphatic compounds [8], but their composition can vary considerably depending on the origin; the cinnamon essential oil leaves has shown not only to possess antifungal and antibacterial properties against a broad spectrum of microorganisms causing food spoilage, but also antioxidant activity lost [9].

In minimally processed fruits, due to their characteristics of process and conservation, they require systems that are able of acting as barriers against water vapour, gases and oxidative processes during storage [6]. In studies carried out by Dos Santos et al. [10] determinate the chitosan and essential oil of oregano can control the growth of grape pathogens during post-harvest storage. The effect of the combination of bergamot essential oil, chitosan and carboxymethylcellulose was also evaluated to increase grape storage life, finding that the combination of oil and chitosan decreased the respiratory rate of the grape and increased mechanical resistance to damage. An increase in antimicrobial activity was also found compared to the other treatments [11]. The objective of this work was to determine the effect of coverage with chitosan and cinnamon essential oil in the conservation of minimally processed strawberry (*Fragaria ananassa*) var. aroma.

II. Materials and Methods

A. Raw material

Fresh strawberries of the Aroma variety were obtained from Laredo, La Libertad, Peru. Strawberries were selected according to their shape uniformity, size, absence of

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mechanical damages, weight of 11.0 ± 2.0 g, and colour level of 5 - related to the state of maturity [12]. Fresh strawberries were transported to the site of analysis at 10° C, later they were washed and immersed in 5% sodium hypochlorite solution.

B. Experimental design

The experimental scheme of the present work was presented in Fig. 1.

By applying the Central Composite Rotational Design (CCRD) using the software STATISTICA 7.0, it was evaluated the strawberry coverage with different chitosan and cinnamon essential oil concentrations. The chitosan (Omnichen SAC, Peru) limits of 0.7 - 2% (w/v) and cinnamon essential oil (Aromas del Peru, Peru) 0.02-0, 1% (w/v) were evaluated.

In each treatment, the chitosan was dissolved in acetic acid (> 99,8%, Sigma Aldrich, Germany) 0.5% v/v at 40 °C for 2 h and then cinnamon essential oil was added, after 30 min, the glycerol plasticizer (Consorcio Químico Barrera Pacheco SAC, Peru) 0.3 (g/g chitosan) and 0.1% (v/v) of Tween 80 surfactant (Consorcio Químico Barrera Pacheco SAC, Peru) were finally added [13]. Whole procedure was performed under continuous homogenization using a paddle stirrer.

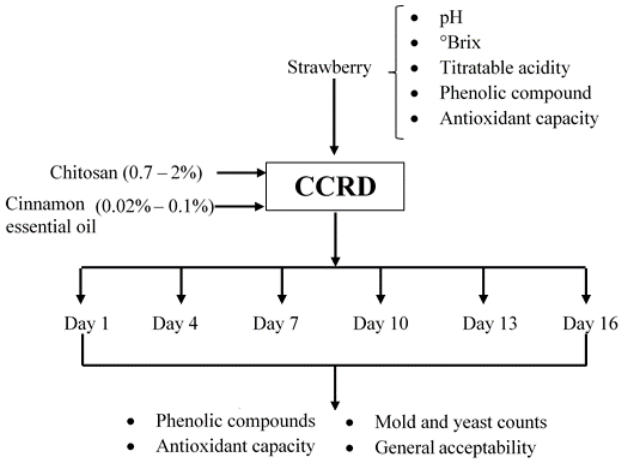

Fig. 1 Experimental design.

C. Application of coverage

Strawberries were immersed in each treatment solution for 30 s, then dried at room temperature for 3 h, to sequentially be stored in polypropylene containers previously codified. The treatments were stored at 10 °C and evaluated each 1, 4, 7, 10, 13 and 16 days. The performed analyses are as follows.

D. Physicochemical characterization

The pH [14], soluble solids [15], and acidity [16] were determined for strawberries as initial raw material.

E. Determination of phenols

The total phenols were determined according to Viuda-Martos, et al. [17], Holtung, et al. [18], Waterhouse [19]. Analyses were performed by visible spectrophotometry (Spectronic 20, Germany) at 760 nm after reaction with Folin-Ciocalteu reagent (Merck KGaA, Germany). Ethanol (80 °GL) was added to each strawberry sample (2 g) up to 10 mL, this mixture was stirred and centrifuged at 4200 rpm for 15 min, finally filtered. Then, 40 µL of the sample was placed in test tubes, with 1560 µL of distilled water, shaken and 100 µL of Folin-Ciocalteu reagent (2N) was added. The mixture was stirred and allowed to stand for 15 min at room temperature, finally 300 µl, of 20% sodium carbonate (Na_2CO_3) (Merck KGaA, Germany) was added, mixed, and incubated for 2 h at room temperature. The absorbance was measured at 760 nm and the results were calculated using a calibration curve obtained from a standard gallic acid and expressed as milligrams of gallic acid per 100 g sample.

F. Determination of antioxidant capacity

The antioxidant activity was determined by the method of DPPH radical (1,1-diphenyl-2-picrilhdracilo) (Merck KGaA, Germany).

G. Microbiological evaluations

Microbiological evaluations of the minimally processed samples with coverage and storage for 1, 4, 7, 10, 13 and 16 days were performed. Procedures of International Commission on Microbiological Specifications for Foods (ICMSF)[20] were used with Oxytetracycline Glucose Agar (OGA) agar culture medium. Approximately 11 g of strawberry was taken and placed in a flask with 23 mL of peptone water which was stirred and then 0.1 mL was taken and inoculated on plates of each treatment. It was then incubated at room temperature for 5-7 days. The counting was performed and reported as colony forming units per gram of sample (cfu/g).

H. General acceptability

For selecting the strawberry, minimally processed with coverage, which had greater general acceptance was applied a hedonic scale of 9 points. The test was applied to a group of 40 not trained consumers with age range of 21 to 28 years [21].

I. Statistical analysis

TABLE I
FACTORIAL PLANNING (2K + 2 K + CP)

Treatments	Chitosan (g/100 mL)	Cinnamon essential oil (g/100 mL)
1	0.89	0.03
2	1.81	0.03
3	0.89	0.09
4	1.81	0.09
5	0.70	0.06
6	2.00	0.06
7	1.35	0.02
8	1.35	0.10
9	1.35	0.06
10	1.35	0.06
11	1.35	0.06

A Central Composite Rotational Design (CCRD) of second order Response Surface Methodology was applied, totalling 11 treatments (Table I) and being able to evaluate the response variables (Y): phenolic compounds, antioxidant capacity, mould and yeast counts, and general acceptability.

An ANOVA was performed for the models generated, as well as their degree of adjustment, from which the best model ($p < 0.05$ and $R^2aj > 0.85$) was chosen, and finally the response surfaces were generated, where regions of interest were sought to maximize or minimize the effect [22].

The microorganisms growth kinetics was analysed using the mathematical model of Gompertz (1) proposed by Nakashima et al. [23].

$$\log\left(\frac{N}{N_0}\right) = a \times \exp(-\exp(b - c \times t)) \quad (1)$$

Where N is the microorganism concentration (N_0 is the initial condition); t: is the time [h]; and the constants of the curve are: a, b, and c.

The parameters of the model are, μ_{max}: Specific speed of growth (2), λ: Duration of the lag phase (3), G: Generation time (4).

$$\mu_{max} = a \times c \quad (2)$$

$$\lambda = \frac{(b-1)}{c} \quad (3)$$

$$G = \frac{\ln(2)}{\mu_{max}} \quad (4)$$

On the other hand, the general acceptability was evaluated as a randomized complete block design (RCBD), where each consumer constitutes a block and each of the 11 treatments, if ANOVA determines differences between treatments, the Duncan multiple range test is performed ($\alpha = 0.05$) and the possibility of taking the average values for the surface response analysis (CCRD) is evaluated [24].

III. Results and Discussion

A. *Physicochemical characteristics*

The physicochemical characteristics were showed in Table II, as observed the values were similar to the reported by previous authors.

TABLE II
PHYSICOCHEMICAL CHARACTERISTICS OF STRAWBERRY

Characteristic	This Study	Other authors
°Brix	6.6	6.2 [25], 6.62 [26], 6.0 – 9.8 [27]
Acidity (% of citric acid)	0.86	0.88 [25], 0.8 [26], 0.99 [28]
pH	3.42	3.99 [26], 3.4 – 3.75 [29]
Phenolics compounds (mg GA/100 g)	109.02	126.32 [30]
Antioxidant activity (% inhibition)	28	25 [31]

B. *Phenolic compounds*

Fig. 2 shows the phenolic compounds during storage time of the minimally processed strawberries. It was observed that during storage at 10 °C there was an increase for all treatments until reaching values of 115-162 mgGA/100g of product until day 7. The phenolic compounds obtained amounts are similar to those reported by other studies with coverage in mangoes [32] and strawberries [33] reaching in the latter 160 mgAG/100g in the day 15 of storage, this accumulation of phenols content in treated strawberries could be promoted because of the enzyme phenylalanine ammonia activity (PAL) [34]. In addition, it has been related to the increase of phenolic compounds with the high content of eugenol and cinnamaldehyde in the cinnamon essential oil [35], this can be observed in Fig. 2, where T8, has a higher content of phenolic compounds at the day 15 of storage.

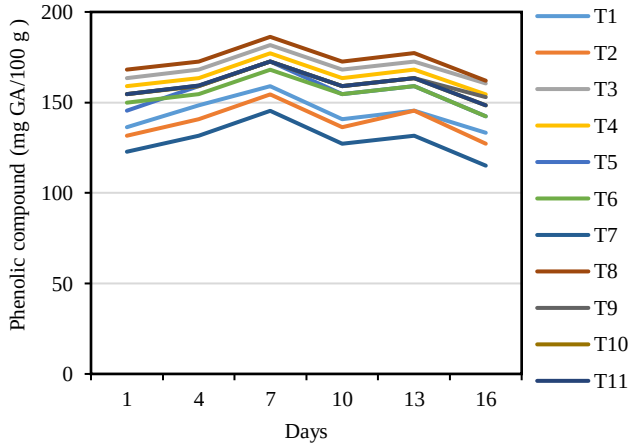

Fig. 2 Phenolic compounds along storage time.

The analysis of regression coefficients showed that cinnamon essential oil (linear and quadratic) had a significant effect ($p < 0.05$) on phenols content during the storage; these results agree with Silva et al. [31] who mentioned that there are significant differences ($p < 0.05$) between the different concentrations of cinnamon essential oil used and the total phenols content of strawberry fruits.

The model of total phenols, for the different treatment days have $R^2 > 0.96$. The mathematical model that explains the highest phenolic content along the storage, was during day 7 (5), where; PC: Phenolic compound; C: Chitosan; O: Cinnamon essential oil

$$PC = 125.8 + 10.3C - 5.3C^2 + 967.3O - 4258.7O^2 - 5.0 * 10^{-12}CO \quad (5)$$

Fig. 3 shows that the best values of phenolics compounds (day 7) are given at higher content of cinnamon essential oil during storage at a temperature of 10 °C.

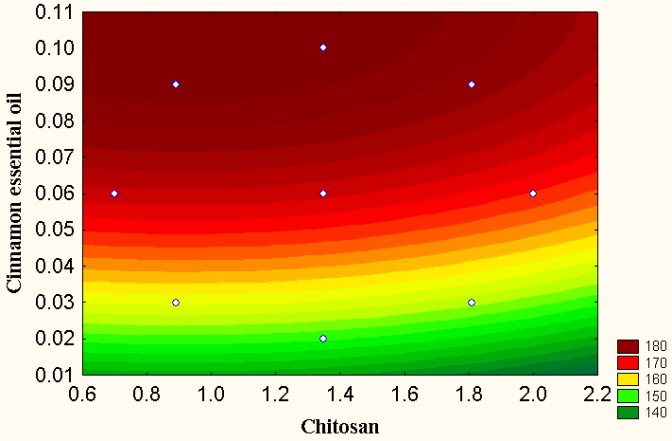

Fig. 3 Contour plot for phenolics compounds (day 7).

C. *Antioxidant capacity*

The results obtained indicated that fruits treated with higher concentrations of cinnamon essential oil had a higher percentage of inhibition; in this sense, the percentage of radical inhibition (DPPH) of the treated strawberries was between 31% and 63%. Fig. 4 shows the increase of the antioxidant capacity of treated strawberries until day 7.

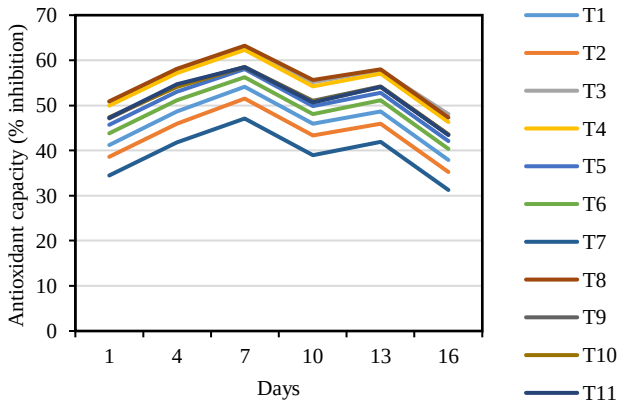

Fig. 4 Antioxidant capacity during storage time.

The cinnamon essential oil showed significant effect in the inhibition percentage. Perdones, et al. [36] mentioned that films containing cinnamon essential oil show antioxidant and antifungal properties, according to Fig. 4 the percentage of inhibition of the DPPH in strawberries was between 31% and 63%, it was slightly lower than those reported by López et al. [33], whose intervals in treated strawberries were between 50% and 85%.

The models of antioxidant capacity (AC), during each day of treatment have a $R^2 > 0.97$. The following mathematical model (6) explains the higher antioxidant capacity during day 7 of treatment ($R^2 = 97.56\%$).

$$AC = 44.67 - 0.37C - 1.47C^2 + 316.16O - 1636.34O^2 + 48.49CO \quad (6)$$

Fig. 5 shows that at day 7, the coverage with a higher concentration of cinnamon essential oil has greater antioxidant power, it can be justified by the addition of the essential oil [31]; where the antioxidant activity increases as the cinnamon concentration increases [33]. It has been reported that eugenol is the main component responsible for the radical uptake capacity of cinnamon bark essential oil, demonstrating a much higher DPPH radicals uptake capacity than cinnamaldehyde [37]. Finally, antioxidant capacity and phenolic compounds concentration behaviour could be corelated (Fig. 2 and 4).

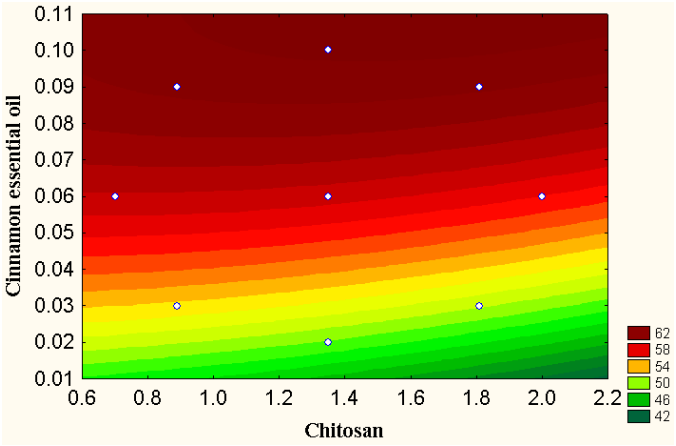

Fig. 5 Contour plot for antioxidant capacity (day 7).

D. *Microbiological analysis*

Table III shows that in the first days of analysis, the treatment 8 (1.35% chitosan and 0.1% cinnamon essential oil g/100 ml) has a great antimicrobial effect, however in the last days, it was detected that the treatments 9, 10 and 11 (1.35% of chitosan and 0.06% of essential oil of cinnamon g / 100 ml) had lower counts of colonies.

TABLE III
YEAST AND MOLD COUNT (CFU/G) IN STRAWBERRIES FOR 16 DAYS STORAGE.

Treatments	Day 1	Day 4	Day 7	Day 10	Day 13	Day 16
1	14.5	26.4	102.7	149.1	246.4	560.9
2	16.4	20	93.6	107.3	197.3	465.5
3	11.8	13.6	61.8	118.2	214.5	500.9
4	4.5	11.8	37.3	55.5	158.2	408.2
5	15.5	22.7	90	171.8	261.8	589.1
6	12.7	14.5	78.2	94.5	187.3	450.9
7	17.3	24.5	98.2	126.4	222.7	509.1
8	0.9	0.9	1.8	42.7	172.7	419.1
9	1.8	1.8	15.5	68.2	153.6	375.5
10	0.9	0	13.6	61.8	158.2	390.9
11	0.9	1.8	16.4	70	153.6	384.5
Control	31.8	50.9	142.7	259.1	529.1	881.8

In Fig. 6, the microbial growth curve is presented described by the Gompertz model [38], Gimeno y Cosano [38] mentioned that empirical models, such as the Gompertz function, are of

interest in practical situations and is capable to effectively describe the growth data under experimental conditions. In Fig. 6 the curve of microbial growth for the treatment 8 (T8) is presented, which has a long latency period (λ = 155 h) and a lower generation time (G = 13.03 h) despite having a specific growth rate (μmax = 0.053 h^{-1}) high.

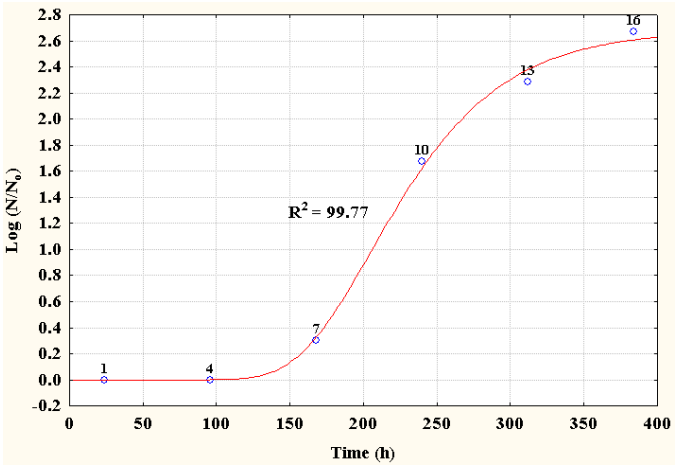

Fig. 6 Growth curve (T8) of moulds and yeasts by the Gompertz Model.

Perdones et al. [36] mentioned that the microbiological damage decreased when the chitosan coverage was incorporated cinnamon essential oil in a ratio greater than 1: 0.25%. The antimicrobial activity of these essential oils is due to the presence of aromatic compounds and phenolic groups such as eugenol [39]. The values in all treatments (Table IV) analysed over time were underneath the maximum allowable limit of $1x10^6$ cfu/g, recommended by the sanitary standard of microbiological criteria for fresh fruits and vegetables [40].

TABLE IV
VALUES OF KINETIC PARAMETERS OF MOULD AND YEAST GROWTH ADJUSTED TO THE GOMPERTZ MODEL

Treatments	λ	μ_{max} (h^{-1})	G (h)	R^2
T1	45.267	0.015	44.350	97.10
T2	62.033	0.014	49.439	94.52
T3	79.905	0.018	38.505	97.70
T4	39.837	0.016	42.636	97.82
T5	63.836	0.017	40.334	98.02
T6	68.826	0.015	44.511	94.80
T7	55.215	0.014	49.471	96.11
T8	155.00	0.053	13.030	99.77
T9	100.11	0.033	20.945	98.97
T10	97.664	0.039	17.361	98.75
T11	71.327	0.032	21.047	99.45
Control	60.555	0.015	46.940	99.40

Mathematical models for effect of strawberry coverage on the growth of moulds and yeasts (M.Y) during each treatment day have an R^2> 0.93. Mathematical model for the last day of storage is detailed (6), R^2 = 99.84% and $R^2_{adj.}$ = 98.9%.

$$M.Y = 1335.96 - 952.77C + 313.07C^2 - 6878.85O + 47727.30^2 - 52.45CO \quad (6)$$

For the case of moulds and yeasts concentration response, this model has an $R^2_{adj.}$ > 0.98 which indicates that the model represents an adequate fit for the process; similar results showed Sánchez [41] in grapes with edible coverage, who reports that there is lower count of moulds and yeasts during 35 days of storage compared to Control.

ANOVA for moulds and yeasts revealed that they are significant (p <0.05), and at the same time have high determination coefficient (R^2> 0.85), so the models predict these variables consistently. Fig. 7 shows that response surface confirms that optimum antimicrobial zone is between 1.33 to 1.71% of chitosan and 0.056 to 0.087% of essential cinnamon oil. The edible coverage incorporation of compounds with specific activity: antioxidant or antimicrobial, improves food preservation and extend its shelf life through the controlled release of compounds [11, 42]. Edible coverage act as barriers, which restrict water transfer and protect the skin from fruit from mechanical damage, seal the small wounds of the product after cutting and therefore delay dehydration [43, 44]; it has been noted that the chitosan in combination with essential oils increases its antimicrobial activity [45]. The edible coverage are more efficient when they contain antimicrobial additives in their composition, allowing some compounds to migrate gradually and selectively to the food surface [46].

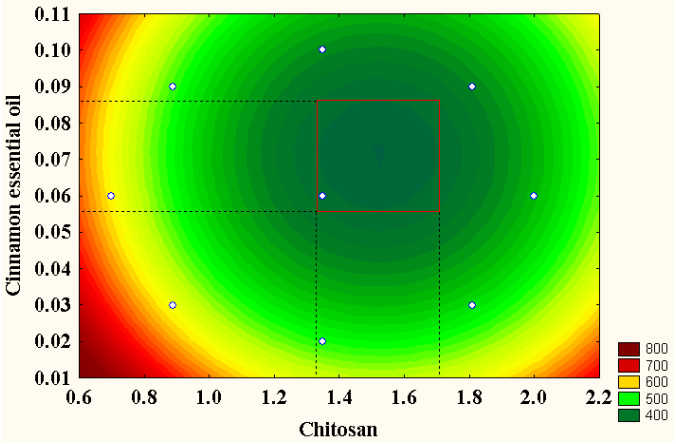

Fig. 7 Contour plot for moulds and yeasts (day 16).

Finally, Table IV shows high values of determination coefficient and the best treatments against fungal action have treatment 8 (T8), together with the central points (T9, T10 and T11), because they have a long latency period and a lower generation time (G) despite having a high specific speed growth rate (μ_{max}). Therefore, probably the coverage in these treatments delayed the response of the microbial population to a change. In the study by Goy et al [47] reported that the activity of chitosan against fungi has a fungistatic character rather than fungicide being very effective in inhibiting spore germination.

D. General acceptability

The values in Table V show the general acceptability of the strawberry variety Aroma minimally processed with the different treatments. Statistical analysis showed that there was

statistically significant variation ($p < 0.05$) in the acceptability between treatments over the 16 days of storage at 10° C.

TABLE V
GENERAL ACCEPTABILITY OF STRAWBERRY EVALUATED.

Treatments	Day 1	Day 6	Day 11	Day 16
1	6.825 ± 0.78b	6.75 ± 0.81b	6.9 ± 0.78a	6.55 ± 0.93a
2	4.525 ± 1.09c	4.45 ± 0.78c	4.825 ± 0.78b	4.325 ± 0.83a
3	7.05 ± 0.96b	6.975 ± 0.97b	7.15 ± 0.92a	6.825 ± 0.96b
4	7.15 ± 1.10b	7.075 ± 1.00b	7.25 ± 0.95a	6.925 ± 1.14a
5	7.075 ± 1.05b	6.975 ± 1.14b	7.225 ± 1.05a	6.8 ± 1.24a
6	4.55 ± 0.99c	4475 ± 0.88c	4.975 ± 0.92b	4.375 ± 0.95b
7	7.1 ± 1.17b	7.025 ± 1.10b	7.15 ± 1.08a	6.875 ± 1.04a
8	7.7 ± 0.99a	7.675 ± 1.00a	7.85 ± 0.92a	7.4 ± 1.37a
9	7.65 ± 0.98a	7.575 ± 0.98a	7.6 ± 1.01a	7.35 ± 1.14a
10	7.675 ± 0.69a	7.6 ± 0.84a	7.65 ± 0.74a	7.375 ± 0.87a
11	7.6 ± 0.71a	7.525 ± 0.75a	7.575 ± 0.71a	7.275 ± 0.88a

Average with different letters in the same column are significantly different ($p < 0.05$).

According to Rico [48] sensory acceptance is an important limitation for the use of chitosan and essential oils. In present investigation using the Duncan test, one of the most accepted samples was treatment 8 (chitosan 1.35% and cinnamon essential oil 0.1%) at the end of storage. These results agree with López et al. [33] who in their research reported that application of chitosan coverage 1.0% and 0.1% of cinnamon essential oil maintained the highest acceptability throughout the 15 days of storage. Similarly Hernández-Muñoz et al. [49] reported that the application of edible coverage of chitosan 1.5% and 1% of calcium gluconate maintained the highest acceptability. On the contrary, Perdones et al. [50] reported that coverage of chitosan and lemon essential oil had a negative sensorial impact; similarly to the reported by Rico [48] in his research about coverage of chitosan and orange essential oil.

Mathematical models for general acceptability (A) on days 1, 6, 11 and 16 have an $R^2 > 0{,}85$, explaining that there is an influence of chitosan and cinnamon essential oil. Mathematical model (7) for the day 16 of treatment show $R^2 = 93.1\%$.

$$A = 3.38 + 7.62C - 4.37C^2 - 21.95O - 186.84O^2 + 44.71CO \quad (7)$$

Table VI shows the average of the central point results for phenolic content, antioxidant capacity, moulds and yeasts growth and acceptability throughout storage. A variation statistically significant ($p < 0.05$) between the different days analysed was observed. Significant difference in phenolic content during storage days may be due to temperature, mechanical and biologic stress, exposure to light and oxygen availability [51]. However, the decrease of phenolics compounds on day 10, and subsequently suffer a slight increase at day 13 was observed, the latter can be attributed to the response of tissue to fungal attack, as there is evidence that this type of attacks stimulates the phenolics compounds production. González-Aguilar, et al. [3], Ayala-Zavala, et al. [52] found that the use of treatments with natural compounds could cause an increase in the antioxidant capacity of fruits due to the induction of metabolite synthesis with antioxidant capacity.

Regarding the growth of moulds and yeasts, the chitosan addition also contributed to decrease their growth, which coincides with Ghaouth et al. [53], who mentioned that chitosan significantly reduces the radial growth of *Botrytis cirenea* and *Rhizopus stonolifer* with a large effect at high concentrations. Table V also shows that the application of coverage is not a limiting factor in sensory acceptance.

TABLE VI
COMPARISON OF PHENOLICS COMPOUNDS, ANTIOXIDANT CAPACITY, YEASTS AND MOULDS COUNTS, AND GENERAL ACCEPTABILITY DURING STORAGE DAYS (1.35% CHITOSAN AND 0.06% ESSENTIAL CINNAMON OIL G/100 ML).

Day	Phenolics compounds	Antioxidant capacity	Moulds and Yeasts	Day	General acceptability
1	154.45 ± 0.0b	47.27 ± 0.19b	1.2 ± 0.5b	1	7.64 ± 0.04b
4	159.30 ± 0.26a	54.43 ± 0.52a	1.2 ± 1.1c	6	7.57 ± 0.04a
7	172.62 ± 0.0c	58.49 ± 0.03c	15.1 ± 1.4a		
10	158.99 ± 0.0a	50.82 ± 0.39d	66.63 ± 4.3d	11	7.61 ± 0.04a
13	163.54 ± 0.0d	54.14 ± 0.21a	155.1 ± 2.6a		
16	149.91 ± 2.62e	43.52 ± 0.17e	383.6 ± 7.7e	16	7.33 ± 0.05a

Average with different letters in the same column are significantly different ($p < 0.05$).

Therefore, the edible coating prepared with cinnamon essential oil and chitosan enhanced the conservation of strawberries. Compared to reported by Gil-Giraldo, et al. [54] who stored strawberries at 5 ºC for 12 days, using chitosan films, even having used a higher temperature (10 ° C) in the present study, a permissible levels of moulds and yeasts were achieved up to 16 days of storage with good general acceptability levels.

IV. CONCLUSIONS

In conclusion, chitosan coverage and cinnamon essential oil had a significant effect on the conservation of strawberry (*Fragaria ananassa*) var. aroma minimally processed. At day 7, the highest total phenol content (186.25 mg GA / 100 g) and antioxidant capacity (63.23% inhibition) were observed, where the essential oil of cinnamon in the cover had significant effect. In the response surface analysis, the optimal range of chitosan (1.33-1.71) and essential oil of cinnamon (0.056-0.087) g/100 mL showed an inhibitory interaction of moulds and yeast growth, increasing the period of latency. On the other hand, with the concentrations of chitosan and cinnamon essential oil in the coverage, good acceptability of strawberries is achieved up to 16 days of storage.

REFERENCES

[1] C. Guo, J. Yang, J. Wei, Y. Li, J. Xu, and Y. Jiang, "Antioxidant activities of peel, pulp and seed fractions of common fruits as determined by FRAP assay," *Nutrition research*, vol. 23, pp. 1719-1726, 2003.

[2] A. M. RESTREPO, M. CORTÉS, and B. A. ROJANO, "Potenciación de la capacidad antioxidante de fresa (Fragaria ananassa Duch.) por incorporación de vitamina E utilizando la técnica de impregnación a vacío," *Vitae*, vol. 17, pp. 135-140, 2010.

[3] G. A. González-Aguilar, E. Valenzuela-Soto, J. Lizardi-Mendoza, F. Goycoolea, M. A. Martínez-Téllez, M. A. Villegas-Ochoa, *et al.*, "Effect of chitosan coating in preventing deterioration and preserving the quality of fresh-cut papaya 'Maradol'," *Journal of the Science of Food and Agriculture*, vol. 89, pp. 15-23, 2009.

[4] G. Oms-Oliu, M. A. Rojas-Graü, L. A. González, P. Varela, R. Soliva-Fortuny, M. I. H. Hernando, *et al.*, "Recent approaches using chemical treatments to preserve quality of fresh-cut fruit: A review," *Postharvest Biology and Technology*, vol. 57, pp. 139-148, 2010.

[5] L. E. Abugoch, C. Tapia, M. C. Villamán, M. Yazdani-Pedram, and M. Díaz-Dosque, "Characterization of quinoa protein–chitosan blend edible films," *Food Hydrocolloids*, vol. 25, pp. 879-886, 2011.

[6] M. Vargas, L. Sánchez-González, M. Cháfer, A. Chiralt, and C. González-Martínez, "Edible chitosan coatings for fresh and minimally processed foods," in *Emerging Food Packaging Technologies*, ed: Elsevier, 2012, pp. 66-95.

[7] D. Lin and Y. Zhao, "Innovations in the development and application of edible coatings for fresh and minimally processed fruits and vegetables," *Comprehensive Reviews in Food Science and Food Safety*, vol. 6, pp. 60-75, 2007.

[8] F. Bakkali, S. Averbeck, D. Averbeck, and M. Idaomar, "Biological effects of essential oils–a review," *Food and chemical toxicology*, vol. 46, pp. 446-475, 2008.

[9] G. Singh, S. Maurya, M. DeLampasona, and C. A. Catalan, "A comparison of chemical, antioxidant and antimicrobial studies of cinnamon leaf and bark volatile oils, oleoresins and their constituents," *Food and chemical toxicology*, vol. 45, pp. 1650-1661, 2007.

[10] N. S. T. dos Santos, A. J. A. A. Aguiar, C. E. V. de Oliveira, C. V. de Sales, S. d. M. e Silva, R. S. da Silva, *et al.*, "Efficacy of the application of a coating composed of chitosan and Origanum vulgare L. essential oil to control Rhizopus stolonifer and Aspergillus niger in grapes (Vitis labrusca L.)," *Food microbiology*, vol. 32, pp. 345-353, 2012.

[11] L. Sánchez-González, M. Cháfer, C. González-Martínez, A. Chiralt, and S. Desobry, "Study of the release of limonene present in chitosan films enriched with bergamot oil in food simulants," *Journal of Food Engineering*, vol. 105, pp. 138-143, 2011.

[12] J. I. Restrepo and I. D. Aristizábal, "Conservación de fresa (fragaria x ananassa duch cv. camarosa) mediante la aplicación de recubrimientos comestibles de gel mucilaginoso de penca sábila (aloe barbadensis miller) y cera de carnaúba," *Vitae*, vol. 17, pp. 252-263, 2010.

[13] I. Leceta, P. Guerrero, I. Ibarburu, M. Dueñas, and K. De la Caba, "Characterization and antimicrobial analysis of chitosan-based films," *Journal of Food Engineering*, vol. 116, pp. 889-899, 2013.

[14] A. o. O. A. Chemists, *Official methods of analysis of AOAC International*, 1995.

[15] M. Coronado and R. Hilario, "Organización y Gestión/En: Procesamiento de alimentos para pe-queñas y microempresas agroindustriales/Unión Europea, CIED."

[16] AOAC, "AOAC official methods of analysis," ed: AOAC International Arlington, 2002.

[17] M. Viuda-Martos, Y. Ruiz Navajas, E. Sánchez Zapata, J. Fernández-López, and J. A. Pérez-Álvarez, "Antioxidant activity of essential oils of five spice plants widely used in a Mediterranean diet," *Flavour and Fragrance Journal*, vol. 25, pp. 13-19, 2010.

[18] L. Holtung, S. Grimmer, and K. Aaby, "Effect of processing of black currant press-residue on polyphenol composition and cell proliferation," *Journal of agricultural and food chemistry*, vol. 59, pp. 3632-3640, 2011.

[19] A. L. Waterhouse, "Determination of total phenolics," *Current protocols in food analytical chemistry*, vol. 6, pp. I1. 1.1-I1. 1.8, 2002.

[20] ICMSF, *Microorganismos de los Alimentos 1: Su significado y Métodos de Enumeración*, 2 ed. Zaragoza, 2002.

[21] C. Rodeiro, V. Gonzales, C. Sanmartín, and S. Vila, "Introducción al análisis sensorial: Estudio hedónico del pan en el IES Murgados," *Sociedad Galega para la promoción de la estadística y la investigación de operaciones*, 2014.

[22] I. IQ Mendoza Brito, "Caracterización de Soluciones Formadoras de películas elaboradas con harina y almidón de cebada," 2011.

[23] S. M. Nakashima, C. D. S. d. André, and B. D. G. d. M. Franco, "Revisão: aspectos básicos da Microbiologia," *Brazilian Journal of Food Technology*, vol. 3, pp. 41-51, 2000.

[24] J. Pérez, "Efecto del agente antimicrobiano del aceite esencial de canela y aceite esencial de limón en la cobertura comestible y el tiempo de almacenamiento sobre las características fisicoquímicas, recuento de mohos y levaduras y aceptabilidad general en rodajas de banano (musa paradisíaca)," Tesis para optar el Título Profesional de Ingeniería de Industrias …, 2016.

[25] A. C. R. KROLOW, J. E. SCHWENGBER, and N. L. FERRI, "Avaliações físicas e químicas de morango cv. Aromas produzidos em sistema orgânico e convencional," *Revista Brasileira de Agroecologia*, vol. 2, 2007.

[26] G. Martínez-Soto, J. Mercado-Flores, M. López-Orozco, and B. Prieto-Velásquez, "Propiedades fisicoquímicas de seis variedades de fresa (Fragaria ananassa) que se cultivan en Guanajuato," *Revista Salud Pública y Nutrición*, vol. 8, pp. 1-11, 2008.

[27] J. Wang and G. Mazza, "Inhibitory effects of anthocyanins and other phenolic compounds on nitric oxide production in LPS/IFN-γ-activated RAW 264.7 macrophages," *Journal of Agricultural and Food Chemistry*, vol. 50, pp. 850-857, 2002.

[28] E. Almenar, P. Hernández-Muñoz, J. M. Lagarón, R. Catalá, and R. Gavara, "Controlled atmosphere storage of wild strawberry fruit (Fragaria vesca L.)," *Journal of agricultural and food chemistry*, vol. 54, pp. 86-91, 2006.

[29] M. E. Olsson, J. Ekvall, K.-E. Gustavsson, J. Nilsson, D. Pillai, I. Sjöholm, *et al.*, "Antioxidants, low molecular weight carbohydrates, and total antioxidant capacity in strawberries (Fragaria× ananassa): effects of cultivar, ripening, and storage," *Journal of Agricultural and Food Chemistry*, vol. 52, pp. 2490-2498, 2004.

[30] M. da Silva Pinto, F. M. Lajolo, and M. I. Genovese, "Bioactive compounds and quantification of total ellagic acid in strawberries (Fragaria x ananassa Duch.)," *Food Chemistry*, vol. 107, pp. 1629-1635, 2008.

[31] B. A. Silva-Espinoza, L. A. Ortega-Ramírez, G. A. González-Aguilar, I. Olivas, and J. F. Ayala-Zavala, "Protección antifúngica y enriquecimiento antioxidante de fresa con aceite esencial de hoja de canela," *Revista fitotecnia mexicana*, vol. 36, pp. 217-224, 2013.

[32] C. Di Vaio, G. Graziani, A. Gaspari, G. Scaglione, S. Nocerino, and A. Ritieni, "Essential oils content and antioxidant properties of peel ethanol extract in 18 lemon cultivars," *Scientia Horticulturae*, vol. 126, pp. 50-55, 2010.

[33] M. A. López-Mata, S. Ruiz-Cruz, C. Navarro-Preciado, J. de Jesús Ornelas-Paz, M. I. Estrada-Alvarado, L. E. Gassos-Ortega, *et al.*, "Efecto de recubrimientos comestibles de quitosano en la reducción microbiana y conservación de la calidad de fresas," *Biotecnia*, vol. 14, pp. 33-43, 2012.

[34] G. Oms-Oliu, R. Soliva-Fortuny, and O. Martín-Belloso, "Using polysaccharide-based edible coatings to enhance quality and antioxidant properties of fresh-cut melon," *LWT-Food science and technology*, vol. 41, pp. 1862-1870, 2008.

[35] G. R. Mallavarapu, S. Ramesh, R. Chandrasekhara, B. Rajeswara Rao, P. Kaul, and A. Bhattacharya, "Investigation of the essential

oil of cinnamon leaf grown at Bangalore and Hyderabad," *Flavour and fragrance journal*, vol. 10, pp. 239-242, 1995.

[36] Á. Perdones, M. Vargas, L. Atarés, and A. Chiralt, "Physical, antioxidant and antimicrobial properties of chitosan–cinnamon leaf oil films as affected by oleic acid," *Food Hydrocolloids*, vol. 36, pp. 256-264, 2014.

[37] C.-W. Lin, C.-W. Yu, S.-C. Wu, and K.-H. Yih, "DPPH Free-Radical Scavenging Activity, Total Phenolic Contents and Chemical Composition Analysis of," *Journal of food and drug analysis*, vol. 17, 2009.

[38] R. M. García Gimeno and G. Zurera Cosano, "Modelización predictiva del desarrollo bacteriano en los alimentos," 2004.

[39] E. A. García-Camarillo, M. Y. Quezada-Viay, J. Moreno-Lara, G. Sánchez-Hernández, E. Moreno-Martínez, and M. C. J. Pérez-Reyes, "Actividad antifúngica de aceites esenciales de canela (Cinnamomum zeylanicum Blume) y orégano (Origanum vulgare L.) y su efecto sobre la producción de aflatoxinas en nuez pecanera [Carya illinoensis (FA Wangenh) K. Koch]," *Revista Mexicana de Fitopatología*, vol. 24, pp. 8-12, 2006.

[40] R. M. No, "No 591-2008/MINSA," *Norma Sanitaria que establece criterios microbiológicos de calidad sanitaria e Inocuidad para alimentos y bebidas de consumo humano. Ministerio de Salud. Diario Oficial El Peruano*, vol. 29, 2008.

[41] M. Sánchez, "Efecto de la cobertura comestible con aceite esencial de canela (Cinnamomum zeylanicum) y clavo de olor (Syzygium aromaticum), tipo de envase y tiempo de almacenamiento sobre las características fisicoquímicas, microbiológicas y sensoriales en uva (Vitis vinifera L.), variedad Red Globe," Tesis para optar el título profesional de Ingeniera en Industrias …, 2012.

[42] A. Perdones, L. Sánchez-González, A. Chiralt, and M. Vargas, "Effect of chitosan–lemon essential oil coatings on storage-keeping quality of strawberry," *Postharvest biology and technology*, vol. 70, pp. 32-41, 2012.

[43] M. Chiumarelli, L. M. Pereira, C. C. Ferrari, C. I. Sarantópoulos, and M. D. Hubinger, "Cassava starch coating and citric acid to preserve quality parameters of fresh - cut "Tommy Atkins" mango," *Journal of food science*, vol. 75, pp. E297-E304, 2010.

[44] V. S. Bierhals, M. Chiumarelli, and M. D. Hubinger, "Effect of cassava starch coating on quality and shelf life of fresh - cut pineapple (Ananas comosus L. Merril cv "Pérola")," *Journal of Food Science*, vol. 76, pp. E62-E72, 2011.

[45] L. Sánchez-González, C. González-Martínez, A. Chiralt, and M. Cháfer, "Physical and antimicrobial properties of chitosan–tea tree essential oil composite films," *Journal of Food Engineering*, vol. 98, pp. 443-452, 2010.

[46] V. Falguera, J. P. Quintero, A. Jiménez, J. A. Muñoz, and A. Ibarz, "Edible films and coatings: structures, active functions and trends in their use," *Trends in Food Science & Technology*, vol. 22, pp. 292-303, 2011.

[47] R. C. Goy, D. d. Britto, and O. B. Assis, "A review of the antimicrobial activity of chitosan," *Polímeros*, vol. 19, pp. 241-247, 2009.

[48] F. Rico Rodríguez, "estudio de la aplicación de recubrimientos comestibles de quitosano y su combinación con aceites esenciales sobre la vida útil del mango (Mangifera indica L.) mínimamente procesado," *Facultad de Ciencias*, 2013.

[49] P. Hernández-Muñoz, E. Almenar, M. J. Ocio, and R. Gavara, "Effect of calcium dips and chitosan coatings on postharvest life of strawberries (Fragaria x ananassa)," *Postharvest Biology and Technology*, vol. 39, pp. 247-253, 2006.

[50] Á. Perdones, I. Escriche, A. Chiralt, and M. Vargas, "Effect of chitosan–lemon essential oil coatings on volatile profile of strawberries during storage," *Food chemistry*, vol. 197, pp. 979-986, 2016.

[51] M. Naczk and F. Shahidi, "Extraction and analysis of phenolics in food," *Journal of chromatography A*, vol. 1054, pp. 95-111, 2004.

[52] J. F. Ayala-Zavala, S. Y. Wang, C. Y. Wang, and G. A. González-Aguilar, "Effect of storage temperatures on antioxidant capacity and aroma compounds in strawberry fruit," *LWT-Food Science and Technology*, vol. 37, pp. 687-695, 2004.

[53] A. El Ghaouth, J. Arul, C. Wilson, and N. Benhamou, "Ultrastructural and cytochemical aspects of the effect of chitosan on decay of bell pepper fruit," *Physiological and Molecular Plant Pathology*, vol. 44, pp. 417-432, 1994.

[54] E. Y. Gil-Giraldo, A. L. Duque-Cifuentes, and V. D. Quintero-Castaño, "Obtaining minimally processed strawberry (Fragaria x ananassa) products and their physicochemical, microbiological, and sensory characterization by using edible coatings," *Dyna*, vol. 85, pp. 183-191, 2018.