Advance Journal of Food Science and Technology 16(SPL): 265-272, 2018
DOI:10.19026/ajfst.16.5966
ISSN: 2042-4868; e-ISSN: 2042-4876

Submitted: September 14, 2017 Accepted: December 26, 2017 Published: November 10, 2018

Research Article

Chromatic Techniques to Evaluate Inhibition of Enzymatic Browning in Avocado Puree

[1]Stephany Johana Salcedo Miranda, [1]Mayra Alejandra Gutiérrez Quiroz, [2]Yelitza Aguas Mendoza, [3]María José Tavera-Quiroz and [1]Rafael Olivero Verbel
[1]Universidad del Atlántico, Departamento de Ingeniería Agroindustrial, Grupo de Investigación en Bioprocesos, Km 7 Antigua vía a Puerto Colombia (Barranquilla), Colombia
[2]Universidad de Sucre, Departamento de Ingeniería Agroindustrial, Grupo de Investigación Gestión Integral de Procesos, Medio Ambiente y Calidad (GIMAC), Cra 28 # 5-267 Puerta Roja (Sincelejo), Colombia
[3]Universidad de Sucre, Departamento de Ingeniería Agroindustrial, Grupo de Investigación Desarrollo e Innovación de Procesos Alimentarios (DESINPA), Cra 28 # 5-267 Puerta Roja (Sincelejo), Colombia

Abstract: The aim of this study was to evaluate the color changes in avocado puree by Computer Vision System analysis as a useful parameter to determine inhibitory behavior of lyophilized avocado seed, fresh seed, seed coat and citric acid on enzymatic browning during storage at room temperature and cooling. Enzymatic browning can be an undesirable phenomenon in many fruits and vegetables producing color alterations. These can reduce commercial value of food products, or even make them unacceptable to consumers. Following up this reaction through low cost and easy to use technological tools is very important to avoid quality losses. In this research study, different samples of avocado puree were prepared and analyzed under cooling and room storage. Color changes were analyzed using the CIEL*a*b, h° and C* coordinates and Color Index (CI) was calculated. For both storage conditions, L* value decreased for control and sample with citric acid added and CCI calculated did not show significant differences among analyzed samples. However, a maximum CIC value was obtained for the sample treated with citric acid and a minimum for the sample with lyophilized seed, which might give indications of inhibitory action of seed, independently of storage conditions. Through use of chromatic techniques, it was possible to follow color variations in avocado puree effectively.

Keywords: Avocado, avocado seed, calculated Color Index (CI), Computer Vision System (CVS), enzymatic browning

INTRODUCTION

Enzymatic browning is a phenomenon occurring in many fruits and vegetables on the cut surface. When the tissue is submitted to any stressful conditions, it rapidly darkens because of the conversion of phenolic compounds to melanins (Mesquita and Queiroz, 2013). This problem reduces the shelf life of minimally processed products; and this deterioration of superficial tissue has great visual impacts that diminish commercial quality, organoleptic acceptance and nutritional value (Artes *et al*., 1998). Avocado is a fruit with a vital importance in agroindustry due to the multiple products that can be obtained from it. This fruit is prized for benefits to human health due to a nutrient value provided in vitamins and unsaturated fatty acids (Soliva-Fortuny *et al*., 2002). The fruit is usually consumed fresh in puree or salads. However, enzymatic browning reaction catalyzed by polyphenol oxidase rapidly produces color changes in the product. Control of this reaction during storage and processing is crucial for keeping freshness and product properties (Quevedo *et al*., 2011). Enzymatic browning can be controlled using chemical, physical or physicochemical methods. Most common methods are a reduction of temperature, addition of acids, modified atmospheres and use of films or coatings (Restrepo Suárez, 2012). Serving avocado with its seed inside for counteracting adverse effects is a widespread culinary practice in some Central American countries, (Bressani *et al*., 2009). The avocado seed represents 12-28% of the fruit weight, depending on variety. The fruit is composed of three parts, seed coat, endosperm and embryo. Seed coat and endosperm have been used in some cases as an

Corresponding Author: María José Tavera-Quiroz, Universidad de Sucre, Departamento de Ingeniería Agroindustrial, Grupo de Investigación Desarrollo e Innovación de Procesos Alimentarios (DESINPA), Cra 28 # 5-267 Puerta Roja (Sincelejo), Colombia, Tel.: +57 3012087853

antioxidant in avocado paste (Osorio-Yat, 2013; Segovia Gómez *et al*., 2014). The avocado seed contains saponins, tannins, flavonoids, alkaloids and phenols. These components could be responsible for the inhibitory action of the seed against the enzymatic browning of the pulp (Arukwe *et al*., 2012). The measure of color changes of tissue produced for the action of polyphenol oxidase allows calculating specific parameters such as Color Index (CI) and the normalized color change (ΔE). There are currently 3 types of colorimetric instruments to analyze these changes: spectrophotometers, spectroradiometers and colorimeters. However, in some cases, these devices are too expensive. For this reason, a low cost, easy to use and free access technological tool to evaluate color variations in foods is needed (Chen *et al*., 2010). Many authors have proved non-destructive techniques for evaluation of browning based on a distribution of surface color in some fruits like pears, bananas, apples (Quevedo *et al*., 2009a, 2009b, 2009c; Cho *et al*., 2016). Color can be objectively and rapidly measured by computerized image analysis techniques, also known as Computer Vision Systems (CVS) (Amodio *et al*., 2011). Image analysis techniques or computer vision system offer a methodology for measurements overall appearances in complex systems with or without uneven color surfaces (Hutchings, 1999). The system consists of a digital photo or video camera for image acquisition, a light source and a laptop with an image processing software previously calibrated (Brosnan and Sun, 2004; Amodio *et al*., 2011). The original image is converted to coordinates L^*, a^*, b^* using a digital image processing software. Also, it is possible to obtain the ratio a^*/b^* and polar coordinates C^* and h°. In CVS, image segmentation and color measurements may be performed using an algorithm (Amodio *et al*., 2011). The digital imaging system relates the spectral energy distributions of the stimulus to the digital values RGB of the image and these with the human vision system response (CIE-XYZ). This model depends not only on the image acquisition device but also requires setting the distance of the capture object, work area, lighting/observation geometry and influence of other ambient lights. This system has been successful in many applications, such as in agriculture, especially in maturing stages of crops, food processing operations and quality control of raw materials and processed foods (Brosnan and Sun, 2004). The aim of this study was to evaluate the color changes in avocado puree by Computer Vision System analysis as a useful parameter to determine the inhibitory behavior of lyophilized avocado seed, fresh seed, seed coat and citric acid on enzymatic browning during storage at room temperature and cooling.

MATERIALS AND METHODS

Sample preparation: Avocados (*Persea americana*) cv. *Lorena* were purchased at a local market and immediately processed. Fruits were selected based on uniform size and color and absence of peeling defects. These were peeled and the pulp was pieced and ground with a food multiprocessor HR 1613 (Philips Electronics, Slovenia).

The seed was processed to analyze its action in the enzymatic browning of avocado puree. The first group of avocado puree was immediately prepared with the addition of fresh seed cut in small pieces after being extracted from the fruit. A second group was treated with lyophilized seed obtained with device Freezone Brand (Labcondo, United States). Seed coat manually removed was added to the third group of samples. The last group was treated with citric acid at 3000 ppm. Avocado puree without treatment was named control. Samples obtained were divided into separate groups for the tests according to storage temperature. Samples exposed to cooling conditions (6°C) were named TR and samples exposed to ambient temperature (30°C) TA.

Measuring color by Computer Vision System (CVS): The CVS method was implemented to measure the color of samples objectively. This technique allows studying the inhibitory effects of seed in color evolution of avocado puree storage at different temperatures. A brief description of each step follows:

Image acquisition: Images were captured using a Color Digital Camera (CDC) Exilim model EXZ35 (Casio, Japan). The camera was located vertically at 21 cm from the sample. The angle between the camera lens axis and the lighting sources was 45°/0°. The white balance of the camera was set using a sheet of white photographic paper (JoJo® of 115 g/m^2). Samples of avocado puree were disposed into plastic containers on JoJo® digital paper of 115 g/m^2 to create an environment without color and reflectance interferences. Images were captured around every hour.

Illumination system: Samples were illuminated using a fluorescent lamp (General Electric, 120V-127V, 60 Hz, 15 w) with a color temperature of 6500 K (D65). The lamp was arranged as a square 20 cm above the sample to give a uniform light intensity over samples.

Processing image: Images were captured with the CDC at normal mode with settings: Flash off and focus in macro mode, at 1366×768 (HD) pixels resolution, connected to the USB port of an ACER Aspire 2.2 GHz computer. Adobe Photoshop® CS3 Software was used for directly capturing images in the computer following the Padron Pereira method of (2009).

Calculation of parameters and statistical analysis: All measures were performed in duplicates at least. CIE$L^*a^*b^*$ and C^* and h° coordinates values of images were averaged for each treatment applied in avocado puree and a Color Index was calculated (CI). To determine the effectiveness of selected extracts an

Table 1: CIE L* a* b* coordinates of samples stored at 6°C

Time	TR_1			TR_2			TR_3			TR_4			TR_5		
(h)	L*	a*	b*	L*	a*	b*	L*	a*	b*	L*	a*	b*	L*	a*	b*
1.0	76*	-7	71	76	-7	71	76	-7	71	76	-7	71	76	-7	71
1.5	73	-5	70	71	-6	69	72	-7	69	73	-8	65	70	-7	58
3.0	73	-7	67	70	-4	69	75	-7	52	67	-2	63	67	-4	54
4.0	72	-8	69	70	-8	68	67	-6	65	59	-6	58	59	-2	54
4.5	67	-4	67	73	-7	69	64	-4	62	56	-3	56	58	1	53
5.0	71	-4	67	69	-1	66	59	3	59	56	1	55	58	1	50
8.5	71	-3	67	68	-3	68	54	3	56	49	2	44	51	2	48
10.0	69	-3	66	61	2	63	58	-2	59	55	0	51	50	5	47

*: Values correspond to the average of the data obtained by duplicate for CieL*a*b* coordinates

Table 2: CIE L* a* b* coordinates of samples stored at room temperature

Time	TA_1			TA_2			TA_3			TA_4			TA_5		
(h)	L*	a*	b*	L*	a*	b*	L*	a*	b*	L*	a*	b*	L*	a*	b*
1.0	76*	-7	71	76	-7	71	76	-7	71	76	-7	71	76	-7	71
1.5	75	-7	71	75	-7	68	75	-10	71	72	-6	66	70	-5	67
3.0	75	-5	68	75	-4	71	71	-6	66	68	-5	67	72	-5	69
4.0	70	-6	65	66	-5	66	68	-5	65	68	-5	63	67	-1	57
4.5	70	-3	66	65	1	66	66	-5	64	53	5	53	56	0	55
5.0	69	-2	68	65	3	66	51	-2	52	52	3	47	54	4	52
8.5	62	2	62	62	2	63	58	1	59	49	3	41	46	12	41
10.0	62	0	61	61	1	62	51	2	56	47	3	45	46	10	42

*: Values correspond to the average of the data obtained by duplicate for CieL*a*b* coordinates

index color was calculated. CI is an index that relates CIE $L^*a^*b^*$ coordinates and can be used as a control quality variable. It is calculated according to the following equation (Vignoni *et al*., 2006):

$$CI = \left(1000\ a^*\right) / \left(L^* b^*\right) \quad (1)$$

Analysis of variance was separately conducted for each temperature of storage. For simultaneous pairwise comparisons, LSD's test was chosen. Differences in means and F-tests were considered significant with $p<0.05$. Means Confidence intervals were also calculated at $p<0.05$. All statistical procedures were computed using Statgraphics® Centurion XVI, software (Statgraphics, Inc., Evanston, USA) version 11.0.

RESULTS AND DISCUSSION

Analysis of CIE$L^*a^*b^*$ coordinates of avocado puree samples was developed: This study analyzed the inhibitory action of select avocado seed at two storage temperatures (6 and 30°C) in combination with five treatments including seed application in the surface of avocado puree to evaluate the effect of seed-applied and temperatures over browning development. Samples containing a surface application of avocado seed and exposed under cooling conditions were designated as follows: Lyophilized seed (TR_1), fresh seed (TR_2), seed coat (TR_3), control (TR_4) and a sample treated with citric acid at 3000 ppm (TR_5). Tested samples at ambient temperature were likewise named: Lyophilized seed (TA_1), fresh seed (TA_2), seed coat (TA_3), control (TA_4) and a sample with citric acid at 3000 ppm (TA_5).

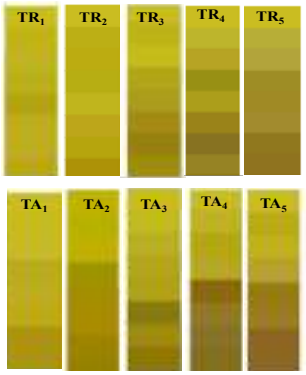

Fig. 1: RGB images obtained from samples of avocado puree stored at 6 and 30ºC

The CIE color space of coordinates L*, a* and b* is widely extended in color analysis and values are obtained from the XYZ tristimulus values (Padron Pereira, 2009). RGB values of the digital cameras are transformed into CIE-XYZ tristimulus values and later to CIE L* a* b* values (Vizhanyo and Felfoldi, 2000) using standard formulas. This procedure is done with software versions of image editor (Missimi *et al*., 2007).

Average CIEL* a* b* coordinates obtained from the images of the avocado samples for approximately 10 h of testing are shown in Table 1 and 2. Avocado puree became visually darker and less green with increasing storage time (Fig. 1).

Figure 2 and 3 showed a trend of L* value for both temperatures analyzed. This parameter showed decreasing for both storage conditions. Quevedo *et al*. (2011) obtained related results for avocado slices and

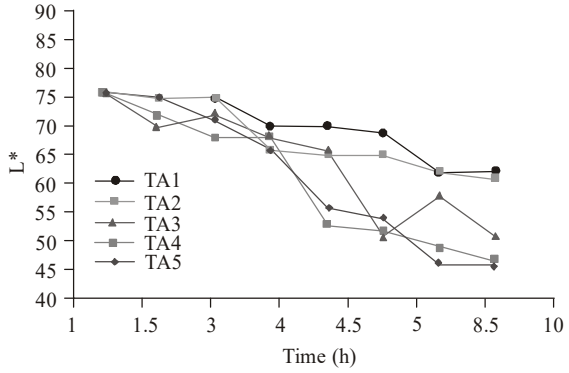

Fig. 2: Evolution of L* coordinate over time of avocado puree samples at 6°C

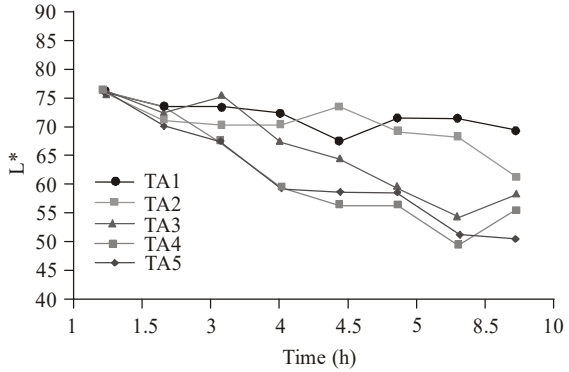

Fig. 3: Evolution of L* coordinate over time of avocado puree samples at 30°C

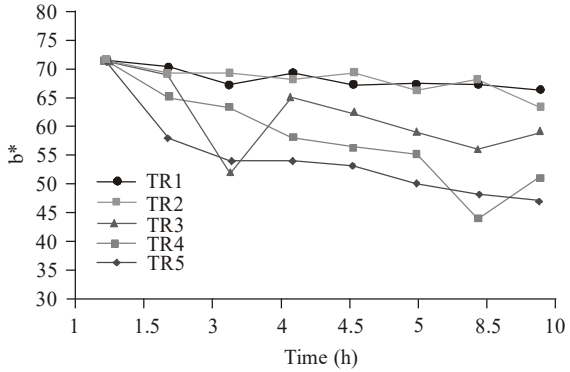

Fig. 4: Changes of b* coordinate over time of avocado puree samples at 6°C

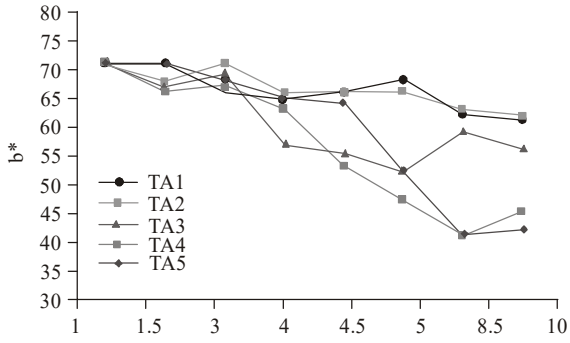

Fig. 5: Changes of b* coordinate over time of avocado puree samples at 30ºC

puree. This value considerably reduced concerning its initial value for samples TR_4 (control) and TR_5 (citric acid, T refrigeration). This behavior would indicate that there were a higher formation and development of dark pigments. Statistically significant differences were observed between the L* coordinates among the samples ($p<0.05$). In the values obtained from the L* value for samples stored at room temperature, no significant differences between their means were observed ($p>0.05$).

The primary cause of luminosity decline of samples begins from the pulping and increases with the crushing and agitation. Besides, the presence of oxygen in the process increases enzymatic activity in the avocado pulp. Degl'Innocenti *et al*. (2005) and Quevedo *et al*. (2011) state that when physical stress occurs in the avocado tissue, compartmentalization of some cells is broken and as a result, substrates of polyphenols (catechins, polyphenols) are mixed with polyphenol oxidase, phenol peroxidases or both. In general, the addition of seed to avocado puree was effective in delaying luminosity decrease during initial days of storage, compared to other treatments proved, including the addition of citric acid (Fig. 1 and 2).

Among samples analyzed under refrigeration conditions and at room temperature (30°C), a tendency to increase was observed for the coordinate a*, starting with negative values corresponding to the green color up to positive (red) values in some cases. This behavior was observed in samples TR_2 (fresh seed, T refrigeration), TR_4 and TR_5 (Table 1 and 2).

It is observed in the obtained photographs that the greenery gradually deteriorated until it was completely lost (Fig. 1).

This phenomenon is due to the chlorophylls degradation occurring during enzymatic browning of avocado pure (Watada *et al*., 1990). Since negative values correspond to a green coloration, according to visual perception, the changes agree with the increase of the coordinate a* towards the red zone ($a*>0$). For sample TR_1 (lyophilized seed, T refrigeration) this parameter did not reach positive values; a favorable result, since it would indicate that the green color remained constant concerning the other treatments applied to ambient temperature.

It was observed in the analysis of the samples kept at room temperature that for all applied treatments, a* shows positive values, tending to reddish colorations. Statistical analysis for samples in both cooling and room temperature conditions indicated that there were no significant differences between the samples ($p = 0.3323$) and ($p = 0.2801$) respectively. Lopez-Malo

Table 3: Color Index (CI) of samples stored at cooling and room temperaturas

Time (h)	TR_1	TR_2	TR_3	TR_4	TR_5	TA_1	TA_2	TA_3	TA_4	TA_5
1.0	-1.297*	-1.297	-1.297	-1.297	-1.297	-1.297	-1.297	-1.297	-1.297	-1.297
1.5	-0.978	-1.225	-1.409	-1.686	-1.724	-1.315	-1.373	-1.878	-1.263	-1.066
3.0	-1.431	-0.828	-1.795	-0.474	-1.106	-0.980	-0.751	-1.280	-1.097	-1.006
4.0	-1.610	-1.681	-1.378	-1.753	-0.628	-1.319	-1.148	-1.131	-1.167	-0.262
4.5	-0.891	-1.390	-1.008	-0.957	0.325	-0.649	0.233	-1.184	1.780	0.000
5.0	-0.841	-0.220	0.862	0.325	0.345	-0.426	0.699	-0.754	1.227	1.425
8.5	-0.631	-0.649	0.992	0.928	0.817	0.520	0.512	0.292	1.493	6.363
10.0	-0.659	0.520	0.584	0.000	2.128	0.000	0.264	0.700	1.418	5.176

*: CI obtained from CIEL*a*b* coordinates of samples stored at cooling and room temperatures

et al. (1998) have established that a* value higher than -0.5 defines the sensory acceptability limit of avocado pulp color. In this case, all samples had a good acceptability up to the first 4 h of storage for all applied treatments. TR_1 showed good acceptability throughout the storage time proved.

In samples stored at room temperature, treatments TA_1 (lyophilized seed, T ambient) and TA_2 (fresh seed, T ambient) are the ones that maintain values closer to the initial value of b*. The opposite happens for treatments TA_4 (control) and TA_5 (citric acid, T ambient). This behavior was observed in Fig. 4 and 5. Statistical analysis for the samples in both conditions, both cooling and room temperature, indicated that there were significant differences between the means of the samples with values of ($p = 0.0001$) and ($p = 0.0351$), respectively.

Padron Pereira (2009) found values for the image of avocado pulp without any treatment for L* = 95, a* = -8 and b* = 42. It is observed that the negative values of the coordinates a* indicated a slight tendency to green color and positive values of the b* coordinates showed a greater tendency to yellow color. Cajuste-Bontemps *et al*. (2002) found values for L* coordinate similar to obtained in this study research and a similar behavior for values of b* coordinate.

These results indicate that SVC technique allow obtaining images of food samples averaged in CIEL*a*b* coordinates for uniform and non-uniform samples like avocado puree.

Color Index (CI): Color changes in avocado purees during storage were followed using CI. Many authors have used diverse ways of analyzing color changes. Pedreschi *et al*. (2006) used ΔE to explain the evolution of non-enzymatic browning in potato slices. Soliva *et al*. (2000) consider that a combination of factors had to be considered to evaluate these changes, including color measurements and evaluation with ΔE during working time with avocado puree. However, these analyses were not enough to explain all phenomenon of color changes in enzymatic browning (Vignoni *et al*., 2006).

The highest CI among all samples analyzed was sample TA_5 (citric acid, T ambient) with a 5.20 value and the lowest value was TR_1 (Lyophilized seed, refrigeration T) with a 0.66 value of -0.65 (Table 3). CIs in positive values were obtained from samples

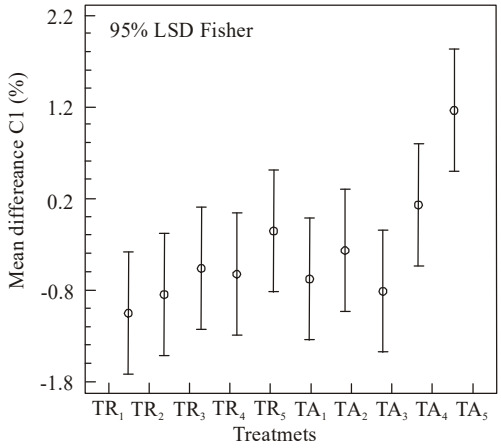

Fig. 6: Mean differences of CI of samples of avocado puree stored at cooling and room temperature

treated with citric acid at 3000 ppm (TR_5 and TA_5). The lowest CI values were presented from these authors consider that if CI is negative (-40 to -20). Its value relates the colors ranging from blue-violet to deep green; if CI is negative (-20 to -2), its value relates to colors ranging from deep green to yellowish green. CI from -2 to +2 represents greenish yellow. If CI is positive (+2 to +20), it is related to the colors ranging from pale yellow to intense orange and if it is positive (+20 to +40), it is related to colors ranging from intense orange to deep red. Samples treated with lyophilized avocado seed (TR_1 and TA_2).

Data analysis of CI did not show statistically significant differences among means ($p>0.05$) (Fig. 6).

Polar coordinates croma C* and hue angle h°, color space CIE L* C* h°: Values of hue angle (h°) from 0° to 90° indicate variations ranging from red to gradually yellow with a combination, the latter achieving its definition. From 90° to 180° the trend is from yellow to green. The chroma (C*) for a given angle indicates how pure or intense the color is on a scale of 0 to 100, where the latter value expresses the highest purity.

All samples started with a 95.63° h° located in shades ranging from yellow to green and a C* of 71.34% indicating a high percentage of purity in color. According to the results shown in Table 4, the hue angle (h°) from the avocado paste used in the study starts at 95.63°, which coincides with tones ranging from the yellow to green in the cylindrical chromatic space.

Table 4: Polar coordinates croma (C*) and hue angle (h°) obtained with Photoshop ® CS3 from the samples stored at cooling temperature

	TR_1		TR_2		TR_3		TR_4		TR_5	
Time	c*	hº	c*	hº	c*	hº	c*	hº	c*	hº
1.0	16	55	16	55	16	55	16	55	16	55
1.5	18	54	20	55	20	56	21	57	24	56
3.0	20	56	20	54	17	55	21	52	24	53
4.0	21	57	22	57	23	56	30	56	28	52
4.5	21	54	19	56	24	54	31	55	26	49
5.0	19	54	19	52	24	49	27	50	26	48
8.5	19	53	21	54	26	48	32	47	29	48
10.0	20	53	22	50	27	52	29	50	28	45

Table 5: Polar coordinates croma (C *) and hue angle (h°) obtained with Photoshop ® CS3 from samples stored at room temperature

	TA_1		TA_2		TA_3		TA_4		TA_5	
Time (h)	c*	hº	c*	hº	c*	hº	c*	hº	c*	hº
1.0	16	55	16	55	16	55	16	55	16	55
1.5	17	55	18	55	19	58	20	55	21	55
3.0	18	55	15	53	21	55	22	55	19	55
4.0	22	55	23	55	22	55	22	54	21	50
4.5	19	53	20	50	23	54	26	46	28	51
5.0	19	52	19	49	32	52	29	46	26	46
8.5	22	49	22	50	25	50	32	46	27	37
10.0	23	51	23	51	28	50	32	47	27	39

Over time all samples tend to decline in hue angle (h°), which would indicate the appearance of red tones mixed with the initial green tones; like an indicator of the darkening of the samples during the time of the study.

Among samples exposed to refrigeration temperature, the most pronounced decline in hue angle (h°) was TR_5, coinciding with high CI values. The sample that presented a more stable hue value was TR_1 (lyophilized seed, T refrigeration) makes visible the smallest change of color through the time of the avocado pulp, thus keeping tonalities ranging from yellow to green. This behavior also coincides with the lower CI value presented by this sample, showing that although there are no significant differences among values of samples studied at refrigeration temperature, the lyophilized seed generates a longer time of stability compared to the enzymatic browning of Avocado puree (*Persea americanacv*. Lorena.)

Regarding h° values presented by the samples studied at room temperature the most marked decline was presented by TA_5; this could be due to an inefficient application of a citric acid solution, as an anti-browning agent. The h° values at the end of storage at room temperature are closer to red tones in the cylindrical chromatic space, which can be interpreted, as an evolution of the enzymatic browning that was higher than that presented at the cooling temperature in the treatments. These values coincide with the report of higher CI values presented by the samples that remained at room temperature.

The values C* presented in Table 5 showed that the TR_5 sample ends the study with a purity value of less than 50% (C* = 47.27), whereas among the samples exposed at room temperature two of these present Values C<50% (TA_4 and TA_5). At the start of the study, the C* value showed a high purity value (71.34%), with the highest purity later shown by TR_1, TR_2, TA_1 and TA_2. These samples were treated with lyophilized seed and fresh seed, respectively. On the contrary, the samples that presented lower C* value were TA_5 and TR_5, which coincide with the control at room temperature and the sample cooled with citric acid.

It is observed in all analyzed cases that the refrigerated storage and the avocado seed addition allow to diminish enzymatic activity due to the polyphenol oxidase and contributes to avoiding the development of color changes due to this phenomenon. Zocca *et al*. (2010) state that natural components such as organic acids, phenols and anthocyanins may also contribute to the PPO inhibition. However, the precise mechanisms for the enzymatic anti-browning effects exhibited by avocado seed are not well understood. Bustos *et al*. (2015) demonstrated the effectiveness of Allium and Brassica extracts to inhibit the evolution of enzymatic browning of avocado pulp tissue stored at refrigeration temperature (4°C). These extracts are rich in polyphenols and some researchers have been investigated their potential as natural anti-browning agents in different matrices (Zocca *et al*., 2010; Rojas-Grau *et al*., 2008). Avocado seeds have more antioxidant activity and polyphenol content than the pulp (Soong and Barlow, 2004; Wang *et al*., 2010). Phytochemical studies on avocado seeds have identified various classes of natural compounds such as phytosterols, triterpenes, fatty acids, furanoic acids, abscisic acid, proanthocyanidins and polyphenols (Ding *et al*., 2007; Leite *et al*., 2009). Wang *et al*. (2010) have reported the presence of catechin, epicatechin and A- and B-type procyanidin dimers and trimers, tetramers, pentamers and hexamers in the seed.

Other studies on new methods to achieve inhibition of enzymatic browning in avocado (*Persea americana*) should be studied. Also, particular emphasis should be

placed on the antioxidant activity of this fruit seed in other specific uses.

CONCLUSION

This study demonstrated that image analysis is suitable to analyze browning degree of avocado puree. Use of a Computer Vision System allows measuring variations of color during storage foods, using a non-destructive technique. Values of h° and c^* obtained contributed to demonstrate the change of color through time caused by browning enzymatic activity in avocado puree. This process causes a decline in the color purity, interpreted as the appearance of dark pigments on the samples. The maximum value c^* presented by samples TA_1 and TR_1 and greater stability in the value h° presented by TR_1 show the positive effect caused by the lyophilized seed as an inhibitor of enzymatic browning.

CONFLICT OF INTEREST

The authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest, or non-financial interest in the subject matter or materials discussed in this manuscript.

REFERENCES

Amodio, M.L., A.B. Cabezas-Serrano, G. Peri and G. Colelli, 2011. Post-cutting quality changes of fresh-cut artichokes treated with different anti-browning agents as evaluated by image analysis. Postharvest Biol. Tec., 62(2): 213-220.

Artes, F., M. Castañer and M.I. Gil, 1998. Review: Enzymatic browning in minimally processed fruit and vegetables. Food Sci. Tech. Int., 4(6): 377-389.

Arukwe, U., B.A. Amado, M.K.C. Durum, E.N. Agomuo, E.A. Adindu, P.C. Odika, K.C. Lele, L. Egejuru and J. Anudike, 2012. Chemical composition of Persea Americana leaf, fruit and seed. Int. J. Recent Res. App. Stud., 11(2): 346-349.

Bressani, R., B. Rodas and A.S. Ruiz, 2009. The chemical composition, antioxidant capacity and nutritional value of the seed of avocado varieties. Tegucigalpa (Guatemala): National Science and Technology Fund-F ONACYT, University of the Valley of Guatemala-UVG, pp: 53.

Brosnan, T. and D.W. Sun, 2004. Improving quality inspection of food products by computer vision-A review. J Food Eng., 61(1): 3-16.

Bustos, M.C., M.F. Mazzobre and M.P. Buera, 2015. Stabilization of refrigerated avocado pulp: Effect of Allium and Brassica extracts on enzymatic browning. LWT-Food Sci. Technol., 61(1): 89-97.

Cajuste-Bontemps, J.F., L. López-López and J. Meza Rangel, 2002. Quality evaluation through appearance attributes of avocado fruits of the Aries and Ariete selections. In: Report 1998-2001 of the Salvador Sánchez Colín Foundation, Centro de InvestigacionesCientífica y Tecnológicasdel Aguacateen el estado de Mexico. February, Coatepec de Harinas, State of Mexico, Mexico, pp: 44-54.

Chen, K., X. Sun, C. Qin and X. Tang, 2010. Color grading of beef fat by using computer vision and support vector machine. Comput. Electron. Agr., 70(1): 27-32.

Cho, J.S., H.J. Lee, J.H. Park, J.H. Sung, J.Y. Choi and K.D. Moon, 2016. Image analysis to evaluate the browning degree of banana (Musa spp.) peel. Food Chem., 194: 1028-1033.

Degl'Innocenti, E., L. Guidi, A. Pardossi and F. Tognoni, 2005. Biochemical study of leaf browning in minimally processed leaves of lettuce (*Lactuca sativa* L. Var. acephala). J Agr. Food Chem., 53(26): 9980-9984.

Ding, H., Y.W. Chin, A.D. Kinghorn and S.M. D'Ambrosio, 2007. Chemopreventive characteristics of avocado fruit. Semin Cancer Biol., 17(5): 386-394.

Hutchings, J.B., 1999. Food Color and Appearance. Aspen Publishers Inc., Gaithersburg, Maryland, US.

Leite, J.J., E.H. Brito, R.A. Cordeiro, R.S. Brilhante, J.J. Sidrim, L.M. Bertini, S.M. Morais and M.F. Rocha, 2009. Chemical composition, toxicity and larvicidal and antifungal activities of Persea Americana (avocado) seed extracts. Rev. Soc. Bras. Med. Trop., 42(2): 110-113.

Lopez-Malo, A., E. Palou, G.V. Barbosa-Cánovas, J. Welti-Chanes and B.G. Swanson, 1998. Polyphenoloxidase activity and color changes during storage of high hydrostatic pressure treated avocado puree. Food Res. Int., 31(8): 549-556.

Mesquita, V.L.V. and C. Queiroz, 2013. Chapter 10 - Enzymatic Browning. In: Michael Eskin, N.A. and F. Shahidi (Eds.), Biochemistry of Foods. 3rd Edn., Academic Press, San Diego, pp: 387-418.

Missimi, E., J.R. Mathiassen and U. Erikson, 2007. Computer vision-based sorting of Atlantic salmon (Salmo salar) fillets according to their color level. J. Food Sci., 72(1): 30-35.

Osorio-Yat, G., 2013. Evaluation of the effect of two pH levels on the antioxidant capacity of Creole avocado seed (*Persea americana* Mill.). B.Sc. Thesis, Panamerican Agricultural School, Zamorano, Honduras.

Padron Pereira, C.A., 2009. Computerized vision system and graphic design tools for obtaining images of food samples segmented and averaged in coordinates CIEL*a*b*. Agron. Cost., 33(2): 283-301.

Pedreschi, F., J. León, D. Mery and P. Moyano, 2006. Development of a computer vision system to measure the color of potato chips. J. Food Res. Int., 39(10): 1092-1098.

Quevedo, R., O. Díaz, A. Caqueo, B. Ronceros and J.M. Aguilera, 2009a. Quantification of enzymatic browning kinetics in pear slices using non-homogenous L* color information from digital images. LWT-Food Sci. Technol., 42(8): 1367-1373.

Quevedo, R., O. Díaz, B. Ronceros, F. Pedreschi and J.M. Aguilera, 2009b. Description of the kinetic enzymatic browning in banana (*Musa cavendish*) slices using non-uniform color information from digital images. Food Res. Int., 42(9): 1309-1314.

Quevedo, R., M. Jaramillo, O. Díaz, F. Pedreschi and J.M. Aguilera, 2009c. Quantification of enzymatic browning in apple slices applying the fractal texture Fourier image. J. Food Eng., 95(2): 285-290.

Quevedo, R., B. Ronceros, K. Garcia, P. Lopez and F. Pedreschi, 2011. Enzymatic browning in sliced and puréed avocado: A fractal kinetic study. J. Food Eng., 105(2): 210-215

Restrepo Suárez, A.M., 2012. Alternatives for the conservation of avocado (*Persea americana* Mill, c.v Hass) on inhibition of enzymatic browning. M.Sc. Thesis, Engineering School, Universitaria Lasallista Corporation.

Rojas-Graü, M.A., R. Soliva-Fortuny and O. Niartín-Belloso, 2008. Effect of natural antibrowning agents on color and related enzymes in fresh-cut fuji apples as an alternative to the use of ascorbic acid. J. Food Sci., 73(6): 267-272.

Segovia Gómez, F., S. Peiró Sánchez, M.G.G. Iradi, N.A. Mohd Azman and M.P. Almajano, 2014. Avocado seeds: Extraction optimization and possible use as antioxidant in food. Antioxidants, 3(2): 439-454.

Soliva, R.C., P. Elez, M. Sebastian and O. Martin, 2000. Evaluation of browning effect on avocado puree preserved by combined methods. Innov. Food Sci. Emerg., 1(4): 261-268.

Soliva-Fortuny, R.C., P. Elez-Martinez, M. Sebastian-Caldero and O. Martin-Belloso, 2002. Kinetics of polyphenol oxidase activity inhibition and browning of avocado puree preserved by combined methods. J. Food Eng., 55(2): 131-137.

Soong, Y.Y. and P.J. Barlow, 2004. Antioxidant activity and phenolic content of selected fruit seeds. Food Chem., 88(3): 411-417.

Vignoni, L.A., R.M. Cesari, M. Forte and M.L. Mirabile, 2006. Determination of color index in minced garlic. Inf. Tecnol., 17(6): 63-67.

Vizhanyo, T. and J. Felfoldi, 2000. Enhancing colour differences in images of diseased mushrooms. Comput. Electron. Agr., 26(2): 187-198.

Wang, W., T.R. Bostic and L. Gu, 2010. Antioxidant capacities, procyanidins and pigments in avocados of different strains and cultivars. Food Chem., 122(4): 1193-1198.

Watada, A.E., K. Abe and N. Yamaguchi, 1990. Physiological activities of partially processed fruits and vegetables. Food Tech., 44(5): 116-122.

Zocca, F., G. Lomolino and A. Lante, 2010. Antibrowning potential of Brassicacaea processing water. Bioresource Technol., 101(10): 3791-3795.