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ORIGINAL ARTICLE

# Optimization of the blanching time and temperature in the manufacture of Hass avocado pulp using low quality discarded fruits

*Otimização do tempo e da temperatura de branqueamento na elaboração de polpa de abacate Hass utilizando frutas de descarte por baixo calibre*

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## Abstract

In Peru, approximately 20% of the production of avocado var. *Hass* is discarded due to its low quality, and sold at low prices in local markets. The aim of this study was to optimize the blanching time and temperature to produce avocado pulp, using low quality discarded fruits as the raw material. The process was optimized using Response Surface Methodology with a $2^2$ central composite rotational design ($R^2 \geq 0.75$; $p < 0.05$). The independent variables studied were the blanching time (0, 1.5, 5, 8.5, 10 min) and temperature (65, 68, 75, 82, 85 °C), where the avocados were blanched by immersion (with peel), and the pulp extracted, processed, vacuum sealed (0.035 MPa) and stored under refrigeration at 5 °C for 49 days. The low quality discarded avocados were shown to be ideal for pulping, since 98% of the fruits had an oil content below 15% with an average pulp yield of 79.23%. The results indicated that longer blanching times and higher temperatures of above 5 min and 75 °C, respectively, retained the green colour and increased the brightness of the pulp, avoiding enzymatic browning. In addition, the increase in both contributed to the stability of the product acidity and pH level, extending its shelf life. However, in the sensory analysis, the pulp submitted to temperatures above 82 °C obtained the lowest scores for taste, odour and general acceptance due to the presence of a bitter taste and unpleasant odours in the pulp. The central point trials (5 min; 75 °C) presented the best scores for the independent variables such as colour, taste, odour and sensory texture, also showing good physicochemical stability with a shelf life of 37 days.

**Keywords:** Waste management; Value added; Shelf life extension; Enzymatic browning; Avocado oil; Sustainability.

## Resumo

No Peru, aproximadamente 20% da produção de abacate var. *Hass* é descartada pelo baixo calibre, sendo vendida a preços baixos nos mercados locais. O propósito do trabalho foi otimizar o tempo e a temperatura de branqueamento para a produção de polpa de abacate, utilizando como matéria-prima frutos de descarte por baixo calibre. A otimização foi realizada utilizando a Metodologia de Superfície de Resposta com delineamento rotacional composto central $2^2$ ($R^2 \geq 0,75$; $p < 0,05$). As variáveis independentes estudadas foram o tempo (0; 1,5; 5; 8,5; 10 min) e a temperatura (65, 68, 75, 82, 85 °C) de branqueamento, em que os abacates foram branqueados por imersão (com casca), a polpa foi extraída, processada, selada a vácuo (0,035 MPa) e armazenada em refrigeração a 5 °C durante 49 dias. Os abacates de baixo calibre mostram-se ideais para a produção de polpa, pois 98% dos frutos apresentaram um teor de óleo inferior a 15%, com um rendimento médio em polpa de 79,23%. Os resultados indicaram que tempos longos e temperaturas altas de branqueamento acima de 5 min e 75 °C, respectivamente, retêm a cor verde e aumentam o brilho na polpa, evitando o escurecimento enzimático; além disso, o aumento de ambos contribui na estabilidade da acidez e do nível de pH do produto, estendendo sua vida útil. No entanto, na análise sensorial, a polpa submetida a temperaturas acima de 82 °C obteve as menores pontuações em sabor, odor e aceitação geral, devido à presença de sabores amargos e odores desagradáveis na polpa. Os testes do ponto central (5 min; 75 °C) apresentaram as melhores pontuações para as variáveis independentes, como cor, sabor, odor e textura sensorial, além de apresentar boa estabilidade físico-química com uma vida útil de 37 dias.


**Palavras-chave:** Utilização de resíduos; Valor agregado; Extensão da vida útil; Escurecimento enzimático; Óleo de abacate; Sustentabilidade.

## 1 Introduction

In 2017, the production of avocados in Peru exceeded 470 thousand tons, of which 53% was destined for export, placing it as the second avocado supplier (in volume) worldwide (Asociación Peruana de Productores de Palta del Perú, 2018). The remaining 47% goes to the national market, whose commercial standards are less demanding, however, between 5% to 20% of this volume is discarded due to its low weight or size (caliber) (AGRODATA, 2018), being sold in local markets at relatively low prices, which decreases profitability and profits of producers (Perú, 2008).

The demand for perfect products is a problem that has been increasing in recent years, especially in developed countries such as the United States, causing producers to lose up to 30% of their crops (Goldenberg, 2016). According to Grewal et al. (2019), this cult of perfection in food causes the sacrifice of many nutritious and high-value foods. This is the case of Low-Caliber Discard (LCD) Hass avocado that, despite the difference in size, has the same components as a normal size avocado, since this fruits just can differ quantitatively based on climate, place, and type of crop (Salazar-García et al., 2011).

The use of discarded raw materials in the elaboration of processed foods is an alternative that contributes to giving them an added value and greater economic yield, the destination of use will depend on specific fruit characteristics. In avocados, oil content is considered one of the main selection parameters to determine its destination of production (Ortiz et al., 2003), fruits with a high oil content (greater than 15%) are commonly used to the extraction of oil for cosmetic use, while those with a lower oil content are destined to the production of pulp (Jiménez et al., 2004).

Since they are harvested ahead of time, LCD Hass avocados present a low percentage of oil in its composition (less than 15%), so the authors recommend the search for added value, through the pulping (Olaeta, 2003; Ortiz et al., 2003).

Avocado pulp is highly perishable due to the presence of enzymes that produce rapid darkening when encountering oxygen from the air. Scalding is a treatment that mixes the use of times and temperatures to denature these enzymes that cause browning (Ortiz et al., 2003). Several authors have determined the ideal scalding parameters to the production of Hass avocado pulp using high-caliber raw material (export size > 125 g) (Palou et al., 2000; Woolf et al., 2013), however, these estimates are of little use for LCD Hass avocados, since they have a smaller size and diameter, therefore, their heating is faster.

In this sense, the objective of this study was to optimize the time and temperature of scalding to produce Hass avocado pulp, using LCD Hass avocados as raw material, via Response Surface Methodology (RSM).

## 2 Material and methods

There were used 50 kg of LCD Hass avocado (weight ≤ 125 g), coming from *Casma* valley (9° 28'27" S 78° 18'38" W), *Ancash* region in Peru.

### 2.1 Determination of moisture and oil content in LCD Hass avocados

Samples of avocado were selected from a lot by their stage of maturity (green, mature and over-ripe). The moisture (%H) of pulp was determined according to the methodology described by Association of Official Analytical Chemists (1970), where a sample of 20 g of laminated pulp was placed in an oven at 70 °C for 72 h until reaching a constant weight. To determine the oil content (% OC) was used 5 g of the powdered sample (from the dehydrated pulp where moisture was previously determined). The extraction method used was Soxhlet, using petroleum ether (90 °C) as a solvent during 2 h of heating with reflux. Both analyses were performed in duplicate for each sample, so later the relationship moisture-oil content in LCD *Hass* avocados was determined by linear regression.

### 2.2 Elaboration of avocado pulp

#### 2.2.1 Experimental design

Variation effects in scalding time and temperature were analyzed using the Response Surface Methodology (RSM), with a $2^2$ central composite rotational design (Rodrigues & Lemma, 2005). The independent variables studied were: scalding time ($X_1$: 0, 1.5, 5, 8.5 and 10 min) and scalding temperature ($X_2$: 65, 68, 75, 82 and 85 °C). A total of 11 experiments were performed (4 factorial points, 4 axial points and 3 repetitions of the central point), Table 1 presents coded and real values of the RSM $2^2$.

**Table 1.** Coded values and real values of the RCCD $2^2$.

| Experiment | Coded values | | Real values | |
|---|---|---|---|---|
| | $X_1$ | $X_2$ | Time (min) | Temperature (°C) |
| E1 | -1 | -1 | 1.5 | 68 |
| E2 | +1 | -1 | 8.5 | 68 |
| E3 | -1 | +1 | 1.5 | 82 |
| E4 | +1 | +1 | 8.5 | 82 |
| E5 | - 1.4142 | 0 | 10 | 75 |
| E6 | 1.4142 | 0 | 0 | 75 |
| E7 | 0 | - 1.4142 | 5 | 65 |
| E8 | 0 | 1.4142 | 5 | 85 |
| E9 | 0 | 0 | 5 | 75 |
| E10 | 0 | 0 | 5 | 75 |
| E11 | 0 | 0 | 5 | 75 |

#### 2.2.2 Elaboration process

Mature avocado samples (stage 3) were selected and processed according to the march proposed by Vildósola (2008) that can be observed in Figure 1. The scalding process was carried out by applying heat by direct immersion of the whole fruit with peel in hot water. As for the scalding time, a thermometer was placed in the center of one fruit and time was counted from when the central point reached the experiment temperature.

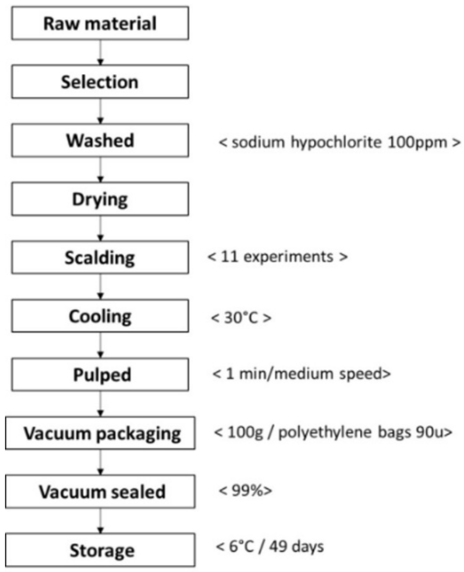


**Figure 1.** Diagram of elaboration process of avocado pulp.

### 2.3 Evaluation of the pulp quality

PH, titratable acidity and instrumental color of experiments were analyzed (in triplicate) on day 0, and every 7 days during the 49 days of their storage in refrigeration at 5 °C.

The color parameters (L*, a*, b*) were measured in the CIELab system using digital colorimeter CR-400 (Konica Minolta, Japan), with the obtained data the chromaticity (C*) and the hue angle (h*) were calculated using Equations 1 and 2, respectively.

$$C^* = \sqrt{\left(a^*\right)^2 + \left(b^*\right)^2} \tag{1}$$

$$h^* = tan^{-1}\left(\frac{b^*}{a^*}\right) \tag{2}$$

The pH was determined directly, as described by Vildósola (2008), on a homogeneous solution of 10 g of pulp with 50 mL of distilled water. The titratable acidity was determined by a potentiometric method using the suspension of the pH determination (1:5), which was titrated with a 0.1 N of NaOH solution until reaching a pH of 8.2, results were expressed as a percentage of oleic acid per 100 mL of sample (Association of Official Analytical Chemists, 1990).

### 2.4 Sensory analysis of avocado pulp

A preference analysis and a purchase intention test were done using a hedonic scale, with the participation of 40 consumers, between 19 to 28 years old. Each one was offered four samples (three chosen with the best results in the physicochemical analysis, and a control sample without treatment) spread on a sliced of white bread.

In the preference analysis, consumers evaluated four sensory attributes as smell, taste, color, and texture, using a hedonic scale of 9 points; while in the second part, the purchase intention was evaluated using a hedonic scale of 5 points (Meiselman & Schutz, 2003).

### 2.5 Statistical analysis

Linear regression of the relationship between moisture and oil content in LCD Hass avocados was determined using Statgraphic Centurion XV [*version 15.2.06*] program (StatPoint, Inc., Herndon, USA). While, the data obtained from the experimental design was analyzed using Statistica [*version 12.0*] program (StatSoft, Inc., Tulsa, USA) to determine the effects of the independent variables, to calculate regression coefficients ($R^2$), carry out analysis of variance (ANOVA) and build the response surface, at a 5% significance level. Finally, from the regression equation obtained, the three-dimensional response surface graph and contour curves ($R^2 \geq 0.75$; $p < 0.05$) for each analysis were generated. For sensory analysis data, results were evaluated by analysis of variance (ANOVA) at a significance level of 5%, and the difference between treatments was determined by Tukey test of multiple comparisons ($p < 0.05$) using the statistical program Statgraphic Centurion XV [*version 15.2.06*] program (StatPoint, Inc., Herndon, USA).

## 3 Results and discussion

### 3.1 Relationship moisture-oil contend in LCD Hass avocados

The linear regression of the obtained data is shown in Figure 2, where it is observed that there is an inversely proportional relationship between moisture and oil content in LCD Hass avocados, being that fruits with higher %H have lower %OC. Likewise, it was observed that 98% of fruits presented %OC between 7 to 15%.

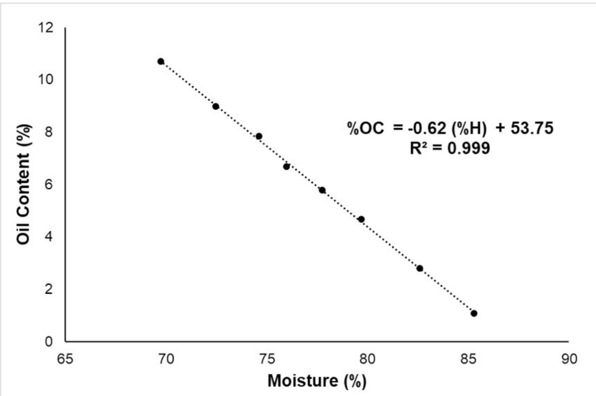


**Figure 2.** Linear regression of relationship between Moisture (%H) and Oil Content (%OC) in LCD avocados.

Our results are similar to those obtained by Loayza et al. (2015) who established the relationship between moisture and oil content for commercial avocados, grown in the *Casma* valleys, in the equation %OC = 59.89 - 0.598%H with $R^2 = 0.41$; but differ from those obtained for fruits from *Huaura* valley, where the equation was %OC = 64.62 - 0.65%H with $R^2 = 0.65$. In Chile, Esteban (1993) also obtained a similar result with a relationship of %OC = 53.48 - 0.58%H with $R^2 = 0.98$ for standard quality avocados. The similarities observed in between the obtained equations in our study and the others, confirms that LCD Hass avocados present a development and maturation process equal to that of a higher caliber, so, the size is not a factor that affects the oil content.

Oil content in avocados varies due to external factors such as climate, number of fruits per plant, among others. In case of LCD Hass avocados, since they have not completed their growth and maturation cycle in the plant, most of them present less than 15% of oil content, so they would not be suitable for oil extraction but it would be appropriate for pulp production.

### 3.2 Production of avocado pulp

The average pulp yield of LCD Hass avocados was 79.23%, remains such as peels and seeds constituted 16% and 4.76% respectively.

A study on avocado industrialization carried out by the Corporation of Production and Development of Chile, cited by Romero (2006), compared the avocado pulp yield from different cultivars, finding the highest yields in *Fuerte* and Hass varieties with 69.8%, because they have a smaller and lighter seed compared to other cultivars. Another study conducted by Kruger et al. (1995) showed 71.37% of pulp yield in Hass avocado using medium-high caliber samples (150 to 300 g). On the other hand, Delgado et al. (2014) in its project of design an avocado pulp processing plant in Piura region, had a 50% of pulp yield, due to the losses generated by work machinery.

Comparing results, in our study there was achieved a pulp yield 10% higher, because LCD Hass avocados have a smaller and lighter seed than higher-weight avocados, since the losses by seed were 4.76%, while in avocados of greater size this percentage commonly exceeds 12%.

### 3.3 Quality characteristics of avocado pulp

During storage, variations in the quality characteristics of experiments were observed. Unlike the *in natura* fruit, avocado when going through the pulping process this one accelerates enzymatic reactions, for this reason, it is combinate with treatments to prolong their shelf-life. In our study, vacuum sealing and subsequent storage in refrigeration were fixed complements to scalding process, to prolong the pulp's shelf-life, by slowing down the enzymatic browning. The effect of the different scaling parameters on the pulp quality was appreciated as the days went by (see Supplementary Material). This is how on day 0 the differences were minimal, while on day 49 these were pronounced. In this way, the results obtained at the beginning and end of the evaluation of the pulp were analyzed, compared and discussed below.

#### 3.3.1 Instrumental color

Luminosity (L*) is the main parameter-indicator associated with enzymatic browning (Gómez-López, 2002), its value indicates the clarity and brightness of sample, high values (>80) reveal a clear pulp, while lower values (close to 0) indicate a dark color, or in this case a brownish and oxidized pulp (Esteller et al., 2005).

The results obtained, on day 0 and day 49, allowed to establish predictive models of this parameter. In the ANOVA, scalding time ($X_1$) and scalding temperature ($X_2$) presented a $p < 0.05$, therefore, they have a significant effect on L* of avocado pulp. Also, given that the coefficient of determination ($R^2$) was 0.92, it was possible to establish a coded response model of this variable in avocado pulp within the parameters studied. The equations obtained were (Equation 3) and (Equation 4), for days 0 and 49 respectively.

$$L^*_{Day\,0} = 58.82 + 2.45(X_1) + 2.73(X_2) + 2.14(X_2)^2 \quad (3)$$

$$L^*_{Day\,49} = 55.13 + 12.22(X_1) + 9.80(X_2) \quad (4)$$

This is how the response surface graphs and contour curves could be constructed (Figure 3). On day 0, it was observed that tests subjected to longer scalding time and scalding temperature (E8 and E5) had a higher response in L* and therefore presented a lighter color in comparison with those of shorter time and temperature of scalding. Vildósola (2008), observed similar results using the same scalding method by immersion of the avocado pulp. According to this author, since heat contact is indirect due to the thick husk of Hass avocado variety, it protects the pulp and keeps it shiny for a longer time.

Compared to day 0, where L* value range of the experiments was between 59 to 60, on day 49 it was between 40 to 66, so there were experiments that maintained their luminosity, as well as those that significantly decreased, which finally generated a significant difference between treatments for the last day of storage. On the other hand, when comparing the equations obtained in both cases, the regression coefficients of time and temperature for day 49 were two to three times greater than day 0 model, which indicates that the effects of scaling variables were greater throughout the storage time.

Comparing our results using scalding with other conserved methods, we obtained similar data to Bustos et al. (2015) who used citric acid as a browning inhibitor (69.5 to 57.5); and better effects in compared to the light pulsations method (49.68) used by Aguiló-Aguayo et al. (2014).

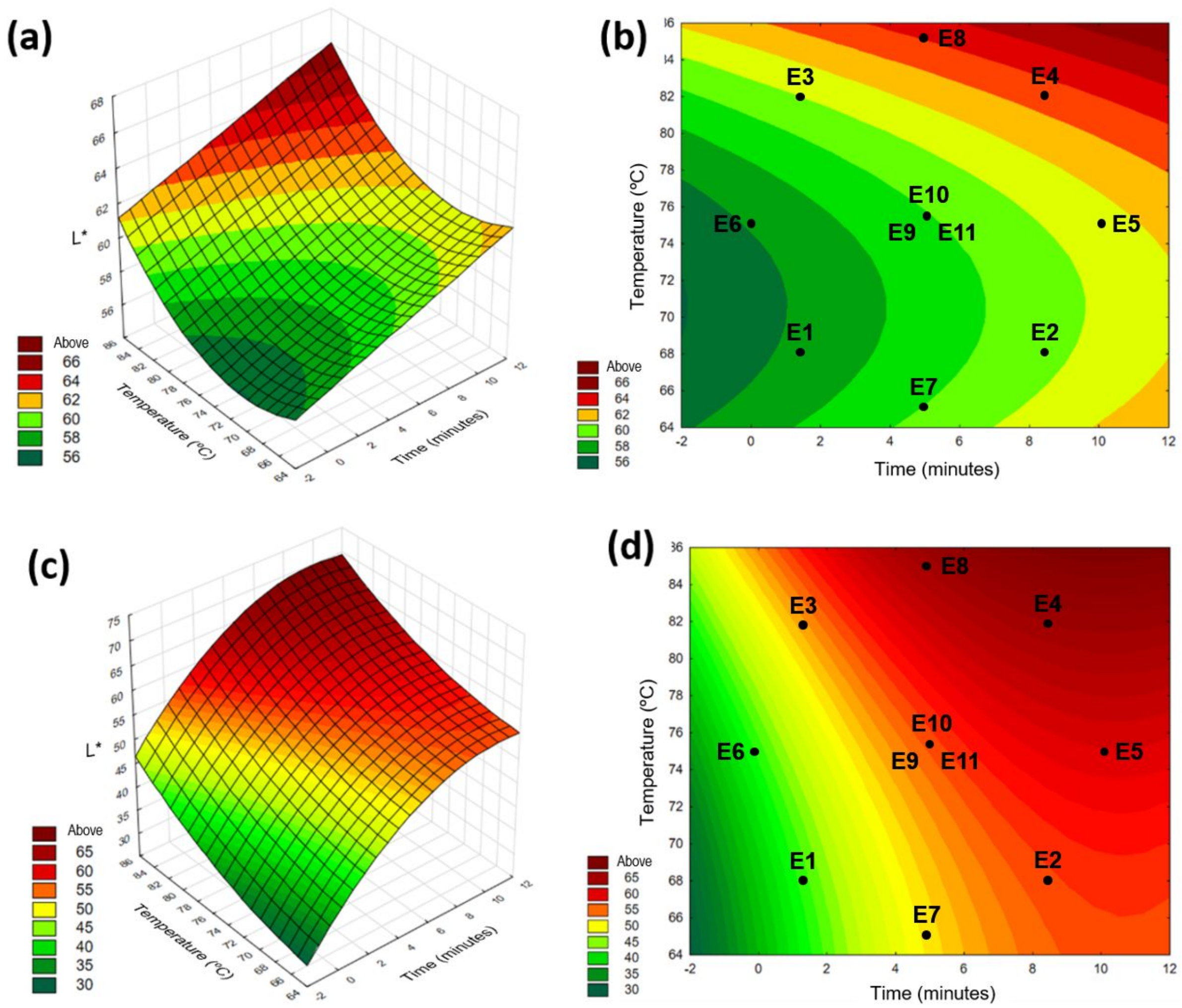


**Figure 3.** Response surface and contour curves for the parameter L* of the color of the Hass avocado pulp as a function of the time and temperature of scalding on day 0 (a) and (b), and day 49 (c) and (d).

Chromaticity or color intensity is an important parameter since it influences the customer's purchasing decision (Restrepo et al., 2012). Vivid and intense colors are preferable to opaque and lifeless; many people associate an intense color with freshness and a high-quality product (Dias et al., 2012).

Although it was not possible to determine a response model of C* for day 0, due to the low correlation coefficient, after several days it was observed that the color intensity between the formulations varied considerably. Experiments subjected to high temperatures and times of scalding (E4, E5, and E8) maintained their C* values; the central points (E9, E10, and E11) presented a slight decrease in this parameter; while tests subjected to low temperatures and times of scalding (E1, E2, E3, and E6) considerably reduced this value. With the data obtained on day 49, a predictive response model to C* was obtained for the avocado pulp ($R^2 = 0.83$), and it is showed in the Equation 5.

$$C^*_{Day\,49} = 30.19 + 8.50(X_1) - 0.39(X_1)^2 + 8.28(X_2) + 0.54(X_2)^2 + 1.94(X_1)(X_2) \tag{5}$$

The response surface model and the contour curves obtained from the analysis can be seen in Figure 4. Chroma is defined as the purity of color by McQuire (1992). On day 0, C* values were between 37 to 40, while on day 49 this range was extended to 20 to 40, due to the differences of time and temperature of scalding between experiments. Studies show that high scalding temperatures help to improve color in food (Zhou et al., 2002; Aguilar-Machado et al., 2017) acting on pigments such as chlorophyll, increasing its stability. This means that during storage, experiments subjected to temperatures above 80 °C lost less color compared to the rest, and as chlorophyll is more stable it degrades slowly (Bustos et al., 2015).

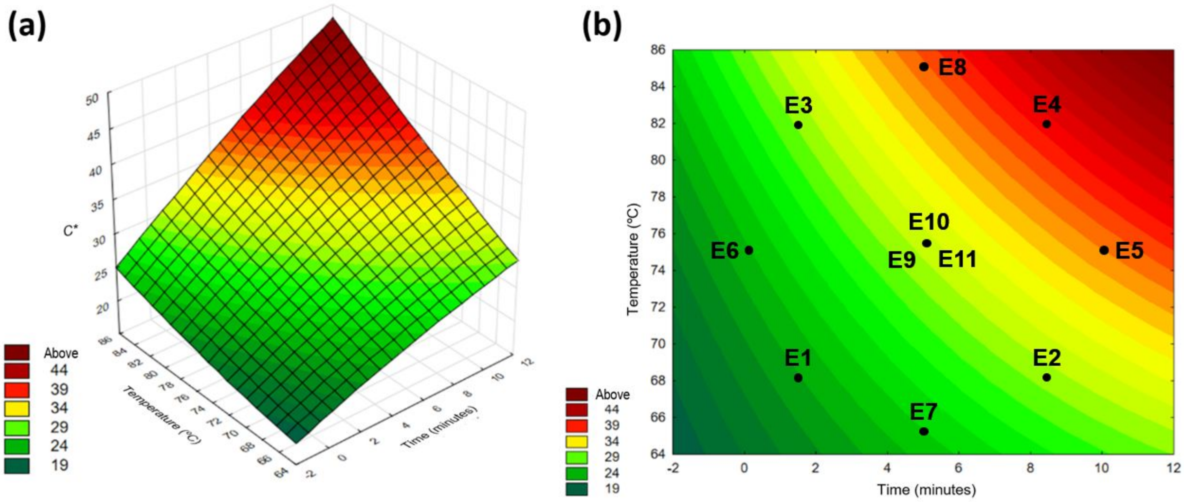


**Figure 4.** Response surface (a) and contour curves (b) for the parameter C* of the color of *Hass* avocado pulp as a function of the time and temperature of scalding (Day 49).

The hue angle h* indicates in degrees the sample tone color, values close to 90° (+b*) indicate a yellow tone, while those close to 180° (-a*) a tendency to green tones, an intermediate value of 135° can be considered a green-yellow or lemon-green colors.

With the data obtained on day 0 and day 49, predictive response models were determined, with $R^2$ of 0.82 and 0.85 respectively, obtaining Equations 6 and 7:

$$h^*_{Day\,0} = 109.17 - 0.44(X_1) + 1.07(X_1)^2 - 1.96(X_2) + 2.80(X_2)^2 + 0.12(X_1)(X_2) \tag{6}$$

$$h^*_{Day\,49} = 79.10 + 10.48(X_1) + 5.94(X_1)^2 + 5.25(X_2) + 17.53(X_2)^2 + 6.26(X_1)(X_2) \tag{7}$$

Figure 5 shows the response surfaces and contour curves for the established models. On day 0, it can be seen that the increase of scalding temperature decreases h* in pulp towards a yellow-green color (E9, E10 and E11), however, from 75 °C (central point) the pulp increases again h* changing to an intense green color, this behavior differs with Jiménez et al. (2004) who affirm that the increase of scalding temperature in avocado intensifies the green color and therefore increases its h*. However, Calvo (2008), who obtained similar results to those of this study, explains that this decrease of h* in the avocado is an effect of heat since the loss of the magnesium atom in chlorophyll, which produces the formation of pheophytin that affected the pulp color, making it a yellow-green tone at the beginning and olive-green if the scalding conditions are increased.

As was already mentioned, variations in the colors of the avocado pulp were observed during storage. Comparing results from day 0 to day 49, it was observed that samples decreased their h*. Experiments that were subjected to temperatures higher than 80 °C decreased between 5° to 7° of h* (preserved their green color), while those subjected to lower temperatures and times of scalding lost up to 30° of h*, inclining to yellow-brown tones. This behavior is due to during storage avocado pulp is affected by enzymatic browning reactions (Jiménez et al., 2004; Fernández, 2015), where polyphenol-oxidase (PPO) induces the dark colors, characteristic of this reaction (Rodríguez-Carpena et al., 2011). Like most enzymes, PPO is sensitive to heat; studies show that it can be inhibited by scalding processes from 73 °C/ 10 min to 85 °C/ 4.6 min (Ortiz et al., 2003).

That is why the treatments E5 and E8 maintained their shades, given that in these treatments the temperatures and time used to guarantee the inhibition of the PPO and therefore considerably decreases the reaction rate of browning.

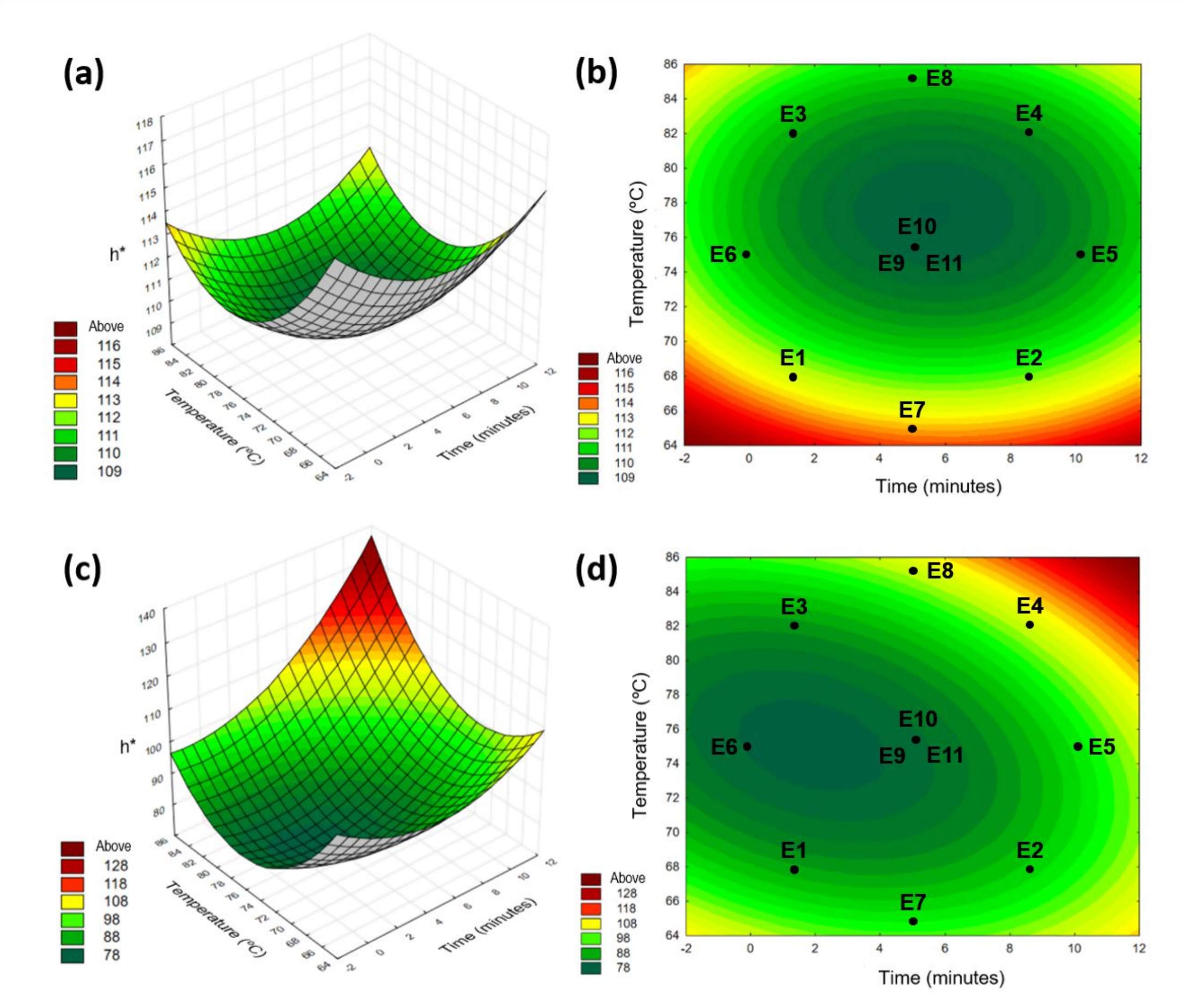


**Figure 5.** Response surface and contour curves for the parameter h* of the color of the *Hass* avocado pulp as a function of the time and temperature of scalding on day 0 (a) and (b), and day 49 (c) and (d).

### 3.3.2 pH

Analyzing the pH results of day 0, it was observed that experiments subjected to high temperatures and short scalding times (E8 and E5) presented higher pH-values than those subjected to low temperatures and short scalding times. The regression coefficients obtained revealed that within the studied parameters, the time and the interaction Time x Temperature of scalding have a significant effect ($p < 0.05$) on pH levels of samples. While the time had a positive effect, the interaction Time × Temperature had a negative, the model obtained ($R^2 = 0.81$) that describes this behavior is expressed in Equation 8.

$$pH_{Day\,0} = 6.46 + 0.11(X_1) + 0.01(X_1)^2 + 0.06(X_2) + 0.01(X_2)^2 - 0.17(X_1)(X_2) \quad (8)$$

Figures 6a and 6b present the response surface and contour curves that represent the obtained model. In this, treatments subjected to high temperatures and short times of scalding had the lowest pH values in day 0. This result coincides with Ortiz et al. in 2003, where pureed avocado treatments subjected to high temperatures (80 to 85 °C) and short times (1 to 3 min) of scalding raised their pH level, while those subjected to temperatures below 70 °C decreased considerably its value.

Regarding the decrease of pH in treatments with high temperature and scalding time, Chavez (2010) who carried out a study about heat treatment in avocado using microwaves, obtained similar results. According to this author, the drop in pH is due to the dissociation of H+ and OH- ions from water (contained in pulp) and which occurs at temperatures close to boiling.

During storage was observed a decrease in pH levels in all the experiments, with E6 showing the greatest variation with a low pH of 5.76, and E8 exhibiting stability with a pH of 6.35. The regression coefficients on day 49, indicated that the Time and the interaction Time x Temperature have a significant effect on the pH response for avocado pulp ($p < 0.05$), the model ($R^2 = 0.89$) that describes this response is expressed in Equation 9.

$$pH_{Day\,49} = 6.11 + 0.27(X_1) - 0.16(X_1)^2 + 0.13(X_2) + 0.13(X_2)^2 - 0.23(X_1)(X_2) \quad (9)$$

Figures 6c and 6d represent the response surface and contour curves of the obtained model. Clearly, it is observed that the experiments subjected to temperatures below 70 °C and times less than 5 min (E1, E6, E7) presented a pH level below 6.0; while the rest kept this value above 6.17.

According to Nickerson & Karel (1964a), this difference is due to the lipolytic oxidation of pulp (rancidity of glycerides) that occurs during the storage, in which some fatty acids are released which cause the acidification of medium and therefore a decrease in pH. This reaction is inhibited at high temperatures, which keeps the pH for those treatments.

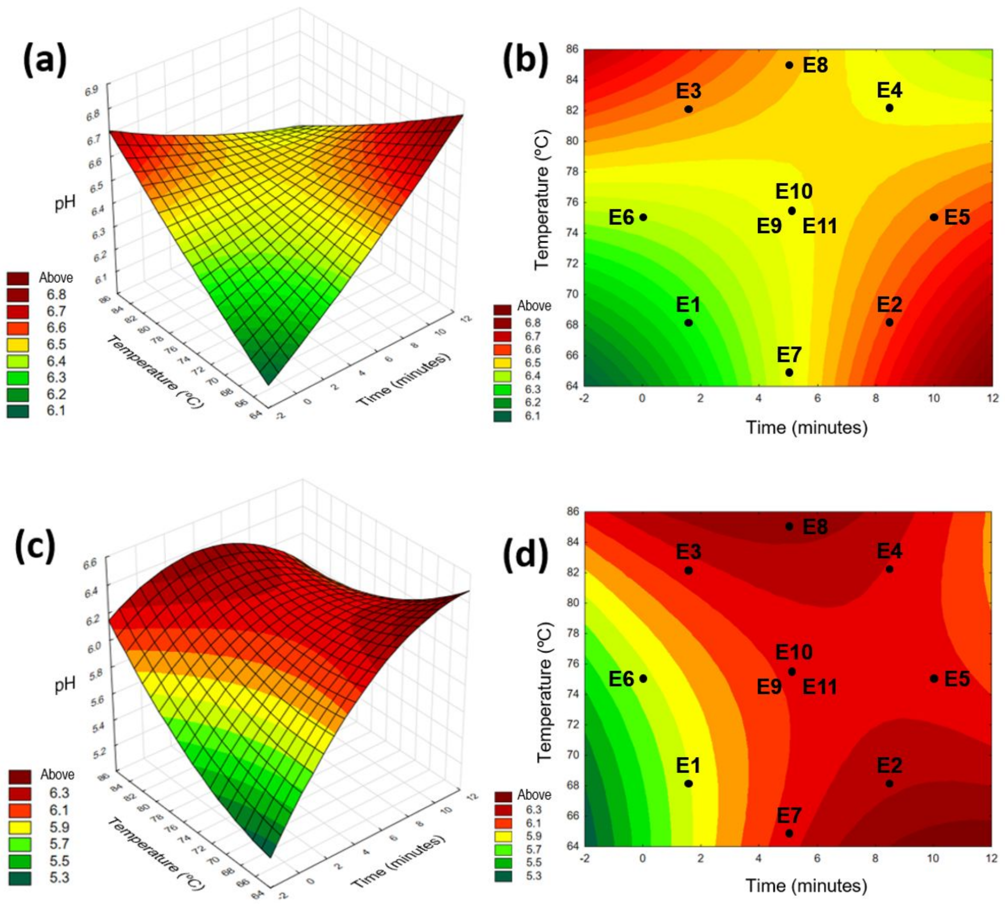


**Figure 6.** Response surfaces and contour curves for the pH of the *Hass* avocado pulp as a function of the time and temperature of scalding on day 0 (a) and (b), and day 49 (c) and (d).

### 3.3.3 Titratable acidity

The acidity of avocado pulp is an important parameter since it measures the oxidation degree or rancidity of a sample (Zhou et al., 2002).

On day 0 the acidity of samples was in a range between 0.46% to 0.51% of oleic acid. The experiments subjected to low temperatures for long periods of time ($X_2$ > 5 min) presented the lowest acidity values compared to those subjected to high temperatures and scalding time.

When determining the predictive model, it was observed, according to the obtained regression coefficients, that the Time and the interaction Temperature x Time of scalding had a significant effect on the acidity response of experiments. The adjusted model ($R^2$ = 0.90) is expressed in the Equation 10.

$$Acidity\ \%_{Day\,0} = 0.49 - 0.02(X_1) + 0.03(X_1)(X_2) \quad (10)$$

Figures 7a and 7b show the response surface and contour curves obtained for the model, samples subjected to prolonged scaling times (above 5 min) obtained a lower percentage of acidity compared to the rest of the treatments.

It is normal to expect that samples subjected to low scalding parameters have a higher acidity, due to the lipolytic oxidation that occurs in avocado pulp (Nickerson & Karel, 1964a; Chavez, 2010). However, this reaction, catalyzed by enzymes, is inhibited at high temperatures so treatments carried out at temperatures above 78 °C are not affected. To explain the high acidity in the pulp subjected to high temperatures, Calvo

(2008) mentions that this phenomenon is due to the release of acids present in the vacuoles, because of the dissociation of H+ and OH- from the avocado´s water when it is submitted at temperatures above 78 °C, which generates an increase in the acidity.

During storage, an increase in the acidity of pulp was observed in all experiments, in different proportions. On day 49, the time and the temperature of scalding showed a statistically significant effect on pulp acidity ($p < 0.05$). According to their regression coefficients, this influence was negative for both on the measurement of acidity, obtaining a model ($R^2 = 0.83$) that is presented in Equation 11.

$$Acidity_{Day\,49} = 0.85 - 0.41(X_1) + 0.37(X_1)^2 - 0.52(X_2) + 0.06(X_2)^2 + 0.15(X_1)(X_2) \quad (11)$$

Figures 7c and 7d show the response surface and contour curves of the model. As mentioned before, the increase in acidity is remarkable in those treatments subjected to low temperatures and scalding times (E1 and E6) compared to those subjected to high ranges of these variables (E8), which maintained their acidity values stable in time. This difference in behavior is due to the inhibition, caused by the increase of temperature of the enzymes involved in lipid oxidation of fatty acids (mainly oleic acid, linolenic acid) presented in the avocado oil (Nickerson & Karel, 1964b).

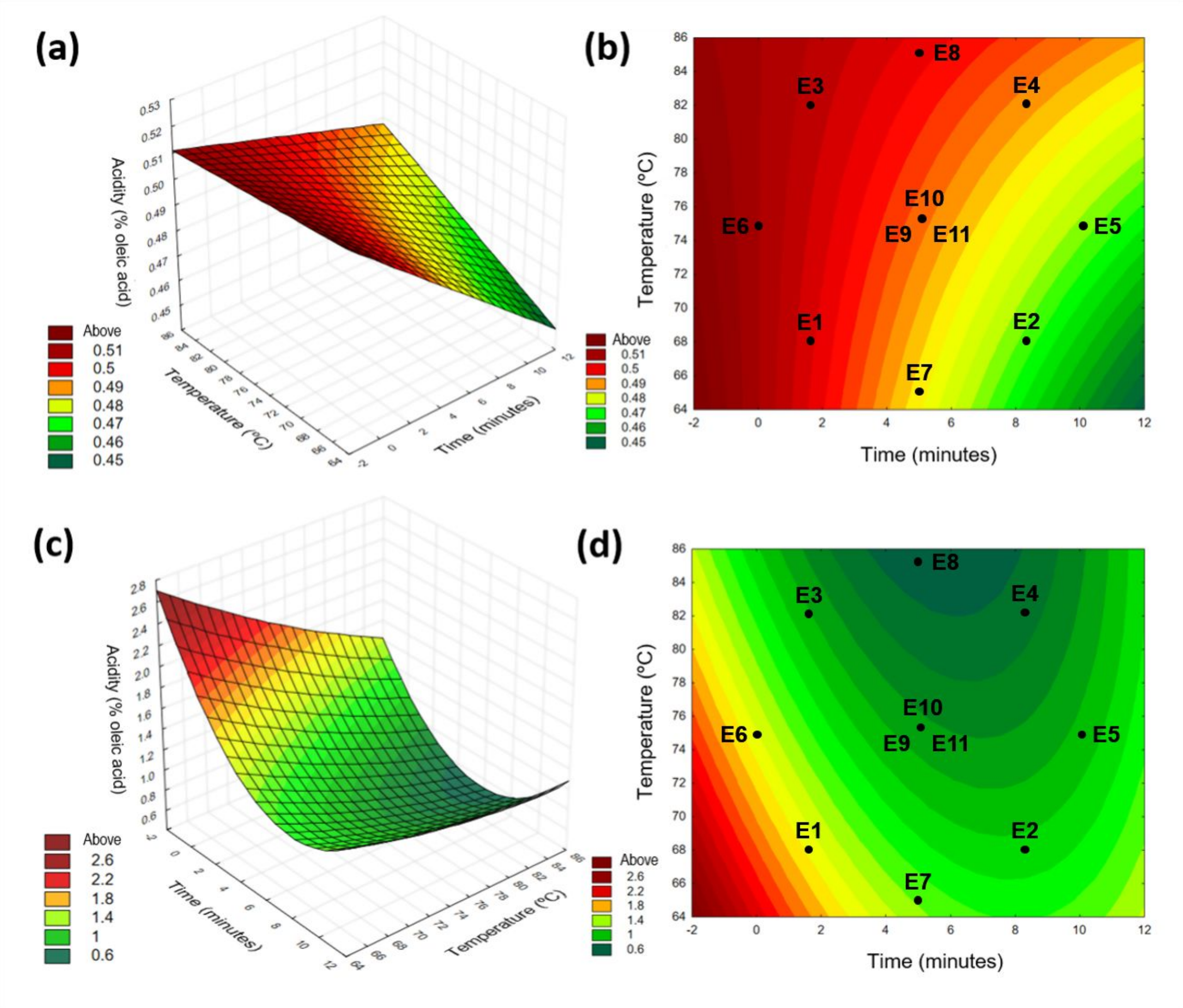


**Figure 7.** Response surfaces and contour curves for the titratable acidity of the Hass avocado pulp as a function of the time and temperature of scalding on day 0 (a) and (b), and day 49 (c) and (d).

### 3.4 Sensory characteristics of avocado pulp

According to the results obtained in the quality evaluation of Hass avocado pulp, there were selected the experiments: E5, E8 and the central point E9 (Figure 8), which showed greater stability in color, pH and acidity during storage. E4 (82 °C/ 8.5 min) was not selected due to the high results of color intensity, pH and initial acidity. These selected samples were analyzed together with a control sample without heat treatment.

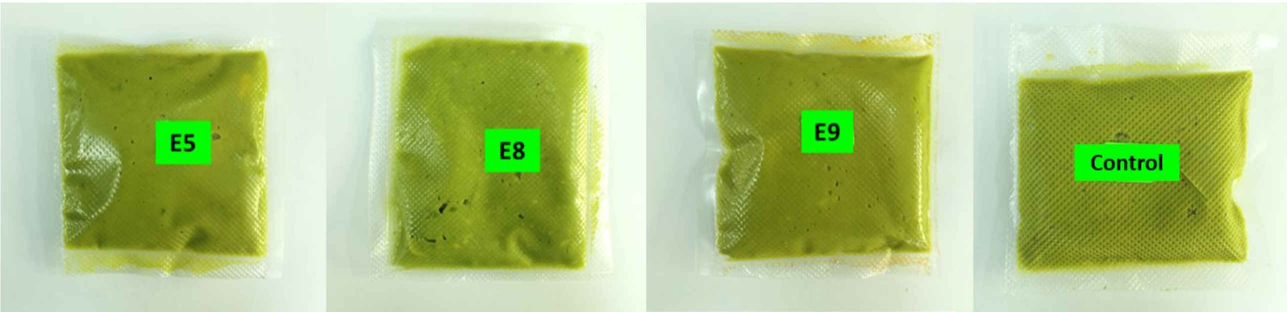


**Figure 8.** Samples of avocado pulp selected for sensory evaluation.

Table 2. Shows the average scores assigned to each experiment by consumers in the sensory analysis of attributes as color, smell, texture, and taste.

**Table 2.** Scores obtained by the samples evaluated in the sensory analysis of preference.

| Experiment | Score[1] | | | |
|---|---|---|---|---|
| | Color | Smell | Texture | Taste |
| E5 | 8.59 ± 0.33[b] | 8.54 ± 0.63[ns] | 6.46 ± 0.79[b] | 6.97 ± 0.67[b] |
| E8 | 8.83 ± 0.57[a] | 8.33 ± 0.76[ns] | 5.89 ± 0.65[c] | 3.74 ± 1.08[c] |
| E9 | 8.31 ± 0.81[b] | 8.85 ± 0.95[ns] | 8.71 ± 0.86[a] | 8.10 ± 0.76[a] |
| Control | 8.13 ± 0.69[c] | 8.76 ± 0.87[ns] | 8.68 ± 0.98[a] | 8.52 ± 0.58[a] |

[1]Results are presented as mean ± standard derivation. Means followed by different letters on the same column differ significantly from each other for the Tukey test of multiple comparison ($p < 0.05$); [ns] = not significant.

The results of the sensory analysis regarding the color of the samples determined that there were differences in the preferences of consumers for the experiments, likewise, it was observed that this increases proportionally to the scalding conditions, as E8 (85 °C/ 5 min) who obtained the highest score. This indicates that consumers prefer an avocado pulp with an intense color since this is an effect of high temperatures in avocado pulp (intensify chlorophyll pigments).

For Valenzuela (1996) this is since people commonly associate an intense and luminous green with a fresh and natural product, while the green-yellow color relates it to a rancid or oxidized product.

Regarding the scores obtained by the samples respect to their smell, it was not observed differences of preferences (α = 0.05) between the experiments studied. Among the comments made by consumers on the evaluation sheet, many stressed that the smell of samples was strong but pleasant. This fact is due to the type of scalding carried out, which, when is made with peel, intensifies the smell of pulp (Chavez, 2010).

No differences of preferences in texture, between experiment E9 and the control, were observed. For Vildósola (2008), this is because that temperature has no an effect on the avocado texture since high temperatures modify it by converting a naturally soft and spreadable pulp into a lumpy and slightly watery paste.

Finally, regarding the taste E9 and the control pulp obtained the highest scores from the rest. E5 and E8 obtained the lowest scores, which indicates that they were not preferred by consumers who dislike their taste in different ways. According to Vildósola (2008), high scalding temperatures generate a bitter taste in the avocado pulp so it is not advisable to subject it to temperatures above 78 °C and times longer than 5 min.

Purchase intention results indicate that consumers preferred E9 and the control samples, in contrast, a large percentage of them indicated that they would not buy E5 and E8 avocado pulp.

Within the three experiments evaluated, E9 (75 °C/5 min) was the one that obtained a higher percentage of "Yes it would buy" (79%) compared to E5 and E8 whose percentages were 3% and 5% respectively. Also, this experiment presented better results compared to the control sample, which although achieved 80% of "If I would buy it", also had a 15% of "I would probably buy it" and 5% of "maybe I would buy it".

The results indicate that consumers are inclined towards a product with bright color and a light taste (the closest thing to natural food), and discard those with intense flavors.

## 4 Conclusion

The results obtained in the present study allowed us to conclude that LCD Hass avocados are viable for the elaboration of pulp since their oil content is between 7% and 15% and have a high pulp yield of 79.23%. The experimental design to determine the influence of independent variables (time and temperature) of scalding on the pulp quality parameters showed that:

- Longer scalding times and higher temperatures, above 5 min and 75 °C, respectively, retained the green color and increased the brightness in pulp avoiding the enzymatic browning; likewise, both contributed to the stability of the acidity and pH level of product extending its shelf-life;
- Temperatures above 82 °C caused the presence of bitter tastes and unpleasant odors in the pulp, generating lower scores by consumers.

So, the optimal time and temperature of scalding for the elaboration of LCD Hass avocado pulp was 75 °C for 5 min, since these parameters decelerate the enzymatic browning conserving its organoleptic characteristics (taste, smell and color).

This study showed that technologically it is possible to take advantage of a raw material, which is usually discarded or sold at low prices, for the elaboration of products with added value, generating higher incomes for producers and companies.

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## Supplementary Material

Supplementary material accompanies this paper.

TABLE A1: Quality parameters of avocado pulp experiments according to the experimental design RSM (Day 0).

TABLE A2: Quality parameters of avocado pulp experiments according to the experimental design RSM (Day 7).

TABLE A3: Quality parameters of avocado pulp experiments according to the experimental design RSM (Day 14).

TABLE A4: Quality parameters of avocado pulp experiments according to the experimental design RSM (Day 21).

TABLE A5: Quality parameters of avocado pulp experiments according to the experimental design RSM (Day 28).

TABLE A6: Quality parameters of avocado pulp experiments according to the experimental design RSM (Day 35).

TABLE A7: Quality parameters of avocado pulp experiments according to the experimental design RSM (Day 49).

Figure A1: Avocado pulp samples (Day 0).

Figure A2: Avocado pulp samples (Day 7).

Figure A3: Avocado pulp samples (Day 14).

Figure A4: Avocado pulp samples (Day 21).

Figure A5: Avocado pulp samples (Day 28).

Figure A6: Avocado pulp samples (Day 35).

Figure A7: Avocado pulp samples (Day 49).

Figure A8: pH level evolution of experiments of avocado Pulp during 49 days of storage at 6°C.

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