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Improvement of Organoleptic Properties of Red Grapefruit Juice (*Citrus Paradise*) Processed By Non-Conventional Technologies

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ABSTRACT

The aim of this study was to analyze the effect of ohmic heating and ultrasound on quality parameters of red grapefruit juice (*Citrus paradisi*). The juice was processed by ohmic heating (120 V, 70 and 80 °C, 30 and 180 s) and ultrasound (amplitude of 40 and 50 µm, and 2 and 10 minutes). The treatments did not significantly affect the cloud value, pH, non-enzymatic browning and colorimetric parameters. The taste was the determining parameter in the choice of juice by consumers. Juices processed with ohmic heating showed sensory characteristics more like the natural juice. The best juice was obtenied by processing with OH at 70 °C for 30 s. According to the present study it could be suggested that red grapefruit juice processed by ohmic heating could improve sensory characteristics without changes in quality parameter.

Keywords: juice, grapefruit, ohmic, sensory, ultrasound.

I. INTRODUCTION

Citrus juices are considered to be the most popular beverages among all the fruit juices [1]. Citrus fruits are very famous due to its high content of vitamin C, which plays an important role in reducing the risk of many diseases originating from oxidative stress. In addition to vitamin C, citrus fruits are also rich in phenolic compounds that are very beneficial to human health due to their antioxidant potential as they scavenge free radicals [2], [3]. In fact, all the edible varieties of citrus fruits contain citric acid, vitamin C, carotenoids, bioactive compounds, flavonoids, trace elements and dietary fibre [2], [3]. Among them, red grapefruit is a very common variety that can significantly contribute to a healthy human diet. The consumption of red grapefruit juice, speed up the human metabolism, and is also an important source of phytochemicals and nutrients, which play a role in the prevention of cancer and chronic diseases [1], [2], [4]. In recent years, consumption of processed fruit juice has been increased in the developed countries instead of eating citrus fruits themselves [2]. Due to advancement in scientific knowledge consumers are now more conscious about health and diet. They want food not only with extended shelf life but also with improved quality and natural fresh like characteristics [2]. Conventional food processing techniques such as thermal pasteurization, cooling and drying can ensure the safety of food and improve the shelf life but they also cause losses in nutrients and organoleptic properties [2], [5]. In order to meet the demands of consumer, researchers are now looking for non-conventional food processing technologies that can not only retain the original properties of food but also improve its nutritional and sensory profile.

Among the technologies that have shown be effective in maintaining the quality and organoleptic properties of food is the ohmic heating [6]. The ohmic heating is a thermal process in which heat is generated by passing alternative electric current through food, which behaves as an electrical resistance [7], [8], [9], [10], [11], [12], [13], [14]. The heating rate is directly proportional to the square of the electric field strength, electrical conductivity and the type of processed food [9], [10], [12], [13], [15]. The principal advantage of ohmic heating technology is the homogeneous distribution of heat, compared with traditional methods of pasteurization, avoiding food to be burn, and requiring a short time to be processed [8], [9], [12], [16]. This leads to a minimal mechanical damage of foods and better retention of sensory and nutritional quality [8], [12], [17]. Ohmic heating has been employed in pasteurising and sterilising of liquid and mixture of solid-liquid foods, especially of ready-to-serve meals, fruits, vegetables, meat, poultry or fish, and is an alternative to sterilisation of foods by means of conventional heat exchangers or autoclaves [8], [10]. Ohmic processing of liquids is industrially applied, ohmic heating of solid foods has not yet led to commercial applications although few works indicate that this technology shows great promise [8], [15], [18].

Other of the emerging technologies with potential applications in retention of the quality characteristics of food is the ultrasound. It is reported that ultrasound technology has minimal effect on the quality of grapefruit juice [2], orange juice [19], [20], guava [21], strawberry juice [22], carrot juice [23], and apple juice [24], [25], among others. Food processing using ultrasound involves the transmission of energy at frequencies higher than 20 kHz [25]. Ultrasound has been effective in reducing microbial load, because ultrasound waves propagates in the liquid medium creating micro bubbles that violently collapse together, reaching temperatures of 5000 °K pressures above 50000 MPa, causing lysis of the cell membrane of bacteria and yeasts. This phenomenon is known as cavitation [24], [26], [27], [28]. This technology can reduce microorganisms to 5 log10, as required by the standard of the Food and Drug Administration of USA [20], [22].

Non conventional technologies have shown to be effective in maintaining the quality and organoleptic properties of foods [24]. Among these the cloud value, is one of the critical parameters in the fruit juice, is related to the particles composed of cellulose, hemicelluloses, protein, lipids, pectin and some other minor components in the juice and improves the flavor, color and taste [2], [20]. Browning is an important parameter on which the quality of stored and processed food is based. In citrus fruit juices mostly, the degradation of ascorbic acid may cause non-enzymatic browning [2]. Colour is a visual indicator to judge the quality of fruit juices and plays an important role in consumer satisfaction [2]. The color is directly related to the nutrient content of fruit juice primarily anthocyanins and flavonoids [20]. Physical-chemical analyses have fundamental importance in food quality [29], but provides an incomplete profile. On the other hand, the responses given by consumers in sensory analysis are derived from the behavior (psychological characteristics) and stimuli (physical and chemical characteristics) that the product offers to them, which determine the sensations and interpretation of product properties [29], [30]. In spite of all these research works about alternative technologies to process fruit juices, there are not studies on regarding the impact of ohmic heating and ultrasound processes on sensory quality in of grapefruit juice. Juices processed with ohmic heating and ultrasound technologies; therefore, the aim of this study was to analyze the impact of ohmic heating and ultrasound technologies on the sensory quality and physicochemcial profile of red apply these technologies to grepefruit juice evaluate the physicochemical and sensory properties of pasteurized red grapefruit juice.

II. MATERIAL AND METHODS

2.1 Obtaining of grapefruit juice

Red grapefruits (*Citrus paradisi*) were obtained in a local market in Saltillo (Coahuila, México) in May and November 2011. The juice was extracted using a home extractor (Moulinex, México) and subsequently processed by ohmic heating or ultrasound technologies. Comercial red grapefruit juices were obtained for a local market of Saltillo City. The initial pH of the red grapefruit juice was 3.24±0.5. Grapefruit juice un-processed was used as control sample.

2.2 Ohmic heating

Samples of 500 mL of redgrape juice were processed at two different temperatures (70 and 80 °C) and at different periods of time (30 and 180 secs). The initial voltage applied was 120 V for all processed samples. After OH treatment, proceeded samples were stored for 3 h at 5 °C and subsequently submitted for sensory analysis. There were also used two commercial red grapefruit juices for comparison. Un-processed and commercial samples were stored for 3 h at 5 °C and subsequently the sensory analysis was developed.

2.3 Ultrasound

Samples of 500 mL of red grapefruit juice were processed at two amplitudes (40 and 60 µm) and two different periods of time (2 and 10 minutes). After ultrasound treatment, proceeded samples were stored for 3 h at 5 °C and subsequently submitted for sensory analysis. There were also used a commercial juice sample and the sample treated with ohmic heating to more severe conditions (temperature of 80 ° C for 180 s). All samples were stored for 3 h at 5 °C and subsequently conducted sensory analysis.

2.4 Sensory evaluation

Sensory analysis of OH and US processed red grapefruit juice was performed by un-trained panel composed of 40 panlists. The distribution in age was in range between 19-21 years old, and the distribution in female and male was 60 and 40% respectively. The evaluation was conducted in the sensory analysis laboratory of the Department of Food Research, of the Universidad Autónoma de Coahuila, México. The conditions of the sensory room were 22 °C of temperature and white light illumination. A hedonic scale (1-7) for color, turbidity, odor, taste sour, bitter flavor, grapefruit flavor, taste and general taste in general (7 like very much, 1 dislike very much, and 3 was the rejection point).

2.5 Physicochemical analysis

Cloud value was determined using the methodology reported by Versteeg et al. (1980) [31]. Non-enzymatic browning (NEB) was determined using the method reported by Meydav et al. (1977) [32]. Red grapefruit juice color was measured using a colorimeter Macbeth Color Eye Greetag team XTS (Marca, País). The determinations were made by triplicate and fresh red grapefruit juice was used as control, also commercial juices were analyzed for comparisons.

2.6 Experimental Design

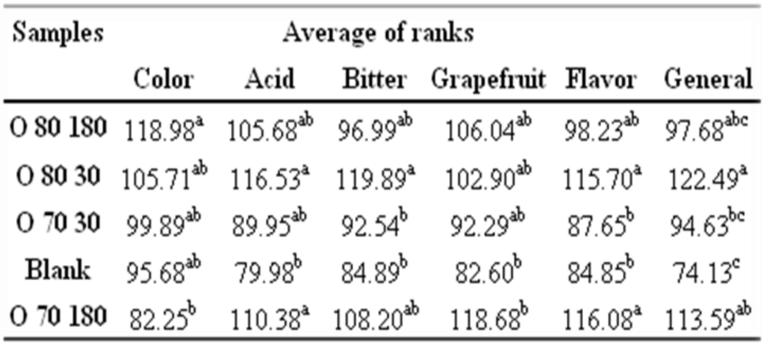
A completely randomized experimental design 2x2 for the ohmic heating and ultrasound processing was used. Sensory analysis data were analyzed using a Kruskhal-Wallis test. Duncan test was apply to compare sums of ranks and principal component analysis (p=0.05). Data analysis was carried out using Statgraphics Centurion XV software version 16.1.15 Statpoint Technologies, Inc. Warrenton, Virginia

III. RESULTS AND DISCUSSION

3.1 Sensory evaluation

Data from sensory analysis of red grapefruit juice processed by ohmic heating compared with fresh juice are shown in Table 1. Samples treated at O-70-30 (Ohmic-70°C-30s) and O-80-180 showed no significant difference in any attribute. However samples processed by O-80-30 showed less acceptance for acidity, bitter, overall flavor and overall liking, and sample O-70-180 for grapefruit flavor, overall flavor and overall liking. The similarity between O-70-30 and natural juice may be explained because of the mildest processing factors of this sample, but between O-80-180 (highest temperature and processing time) and natural juice, the reason of the high level of acceptance may be a caramelization reaction which is well known develop a sweeter taste [33]. The samples which differ significantly from the blank, in the attributes of acidity, flavor and taste were generally O-80-30 and O-70-180; addition, the sample O-70-180 differ significantly in color and work to grapefruit and the sample at O-80-30 bitter taste. The samples processed by ohmic heating technology showed a small difference between them, these data are in agreement with those reported by Onwuka (2011) [34] regarding the sensory analysis of palm wine processed by ohmic heating.

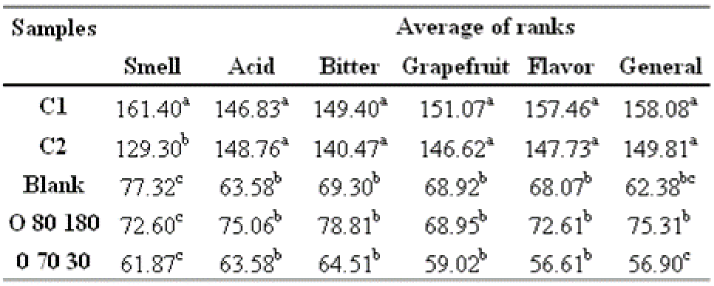
Table 1. Duncan's test multiple range for sensory analysis of grapefruit juice processed with ohmic heating compared with natural juice p = 0.05.



Samples	Average of ranks					
	Color	Acid	Bitter	Grapefruit	Flavor	General
O 80 180	118.98^{a}	105.68^{ab}	96.99^{ab}	106.04^{ab}	98.23^{ab}	97.68^{abc}
O 80 30	105.71^{ab}	116.53^{a}	119.89^{a}	102.90^{ab}	115.70^{a}	122.49^{a}
O 70 30	99.89^{ab}	89.95^{ab}	92.54^{b}	92.29^{ab}	87.65^{b}	94.63^{bc}
Blank	95.68^{ab}	79.98^{b}	84.89^{b}	82.60^{b}	84.85^{b}	74.13^{c}
O 70 180	82.25^{b}	110.38^{a}	108.20^{ab}	118.68^{b}	116.08^{a}	113.59^{ab}

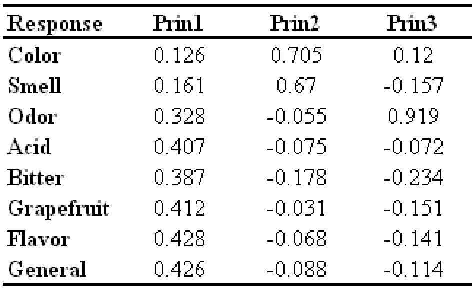
Data from the sensory analysis of two selected samples processed by ohmic heating, natural juice without treatment and two comercial brand juices are shown in Table 2 and Figure 1 It clearly shows that the samples processed using ohmic heating showed the best acceptance of all sensory attributes evaluated (p=0.05). This coincides with the particulate foods studies which reported that the ohmic heating does not alter the sensory characteristics of food [17], [35]. The principal component (PC) analysis for the samples processed by ohmic heating (Table 3) shows that 75 % of the variation is explained by PC 1, 2 and 3; PC1 was influenced by taste attributes and overall flavor, PC2 by color and turbidity and CP3 by odor and sour taste.

Table 2. Duncan's test multiple range for sensory analysis of processed grapefruit juice compared with ohmic heating commercial juice samples p = 0.05.



Samples	Average of ranks					
	Smell	Acid	Bitter	Grapefruit	Flavor	General
C1	161.40^{a}	146.83^{a}	149.40^{a}	151.07^{a}	157.46^{a}	158.08^{a}
C2	129.30^{b}	148.76^{a}	140.47^{a}	146.62^{a}	147.73^{a}	149.81^{a}
Blank	77.32^{c}	63.58^{b}	69.30^{b}	68.92^{b}	68.07^{b}	62.38^{bc}
O 80 180	72.60^{c}	75.06^{b}	78.81^{b}	68.95^{b}	72.61^{b}	75.31^{b}
0 70 30	61.87^{c}	63.58^{b}	64.51^{b}	59.02^{b}	56.61^{b}	56.90^{c}

Table 3. First three principal components of the sensory analysis of grapefruit juice processed by ohmic treatment compared with commercial samples.



Response	Prin1	Prin2	Prin3
Color	0.126	0.705	0.12
Smell	0.161	0.67	-0.157
Odor	0.328	-0.055	0.919
Acid	0.407	-0.075	-0.072
Bitter	0.387	-0.178	-0.234
Grapefruit	0.412	-0.031	-0.151
Flavor	0.428	-0.068	-0.141
General	0.426	-0.088	-0.114

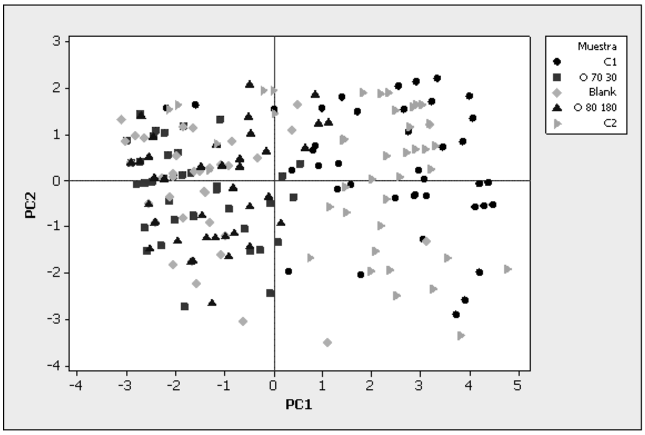
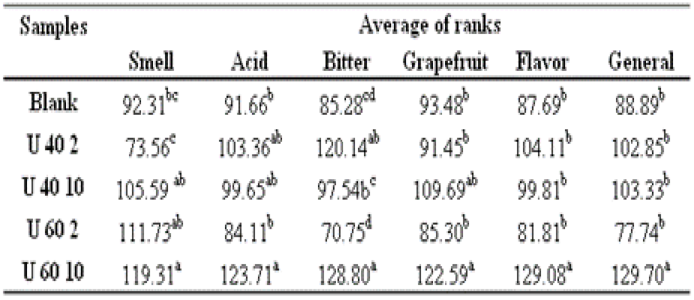


Figure 1. Comparison of the first principal component against the second component in sensory analysis of grapefruit juice samples processed by ohmic heating compared with commercial samples.

Results from sensory analysis of samples of grapefruit juice processed by ultrasound are presented in Table 4. Significant differences were not observed between juices processed at a low amplitude at different times in comparison with control samples (p=0.05). However as ultrasound amplitude was increased, unpleasant effects were observed in all sensory characteristics evaluated, this was also observed by Valero et al. (2007), which reported that ultrasound did not affect the quality of orange juice processed at low amplitudes [19].

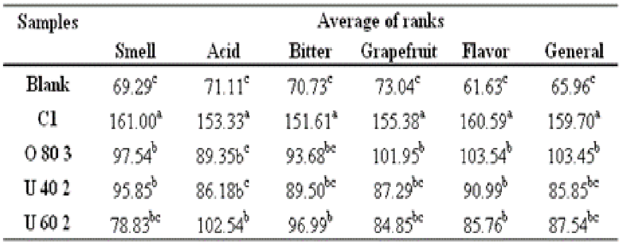
Table 4 Duncan's test multiple range for sensory analysis of grapefruit juice processed with ultrasound compared with natural juice p = 0.05.



Samples	Average of ranks					
	Smell	Acid	Bitter	Grapefruit	Flavor	General
Blank	92.31^{bc}	91.66^{b}	85.28^{cd}	93.48^{b}	87.69^{b}	88.89^{b}
U 40 2	73.56^{c}	103.36^{ab}	120.14^{ab}	91.45^{b}	104.11^{b}	102.85^{b}
U 40 10	105.59^{ab}	99.65^{ab}	$97.54b^{c}$	109.69^{ab}	99.81^{b}	103.33^{b}
U 60 2	111.73^{ab}	84.11^{b}	70.75^{d}	85.30^{b}	81.81^{b}	77.74^{b}
U 60 10	119.31^{a}	123.71^{a}	128.80^{a}	122.59^{a}	129.08^{a}	129.70^{a}

A comparison of the sensory quality of raw, processed (OH and US) and commercial juices was carried out, observing that juices processed by OH and US presented better scores (p=0.05) than commercial juices (Table 5). A principal component analysis used to determine the factors that significantly influenced the taste of judges. This indicates that 84 % of the variation is explained by the three first PC; in the first component influence the attributes of taste and general taste in the second color and turbidity and odor, however, by plotting both components there is not a clear separation of the samples.

Table 5 Duncan's test multiple range for sensory analysis of grapefruit juice processed with ultrasound compared with samples of juice, and processed commercial ohmic heating p = 0.05.



Samples	Average of ranks					
	Smell	Acid	Bitter	Grapefruit	Flavor	General
Blank	69.29^{c}	71.11^{c}	70.73^{c}	73.04^{c}	61.63^{c}	65.96^{c}
C1	161.00^{a}	153.33^{a}	151.61^{a}	155.38^{a}	160.59^{a}	159.70^{a}
O 80 3	97.54^{b}	89.35b^{c}	93.68^{bc}	101.95^{b}	103.54^{b}	103.45^{b}
U 40 2	95.85^{b}	86.18b^{c}	89.50^{bc}	87.29^{bc}	90.99^{b}	85.85^{bc}
U 60 2	78.83^{bc}	102.54^{b}	96.99^{b}	84.85^{bc}	85.76^{b}	87.54^{bc}

The second PCA, which included commercial juices, samples processed by OH and US indicated that 82 % of the variation is explained by the two first PC; as in the above analysis, the first component is influenced by the attributes of flavor and the second component by color and turbidity. Figure 2 shows a clear separation of commercial juices at the right side (area of least satisfaction for flavor attributes; on the other hand PC2 (turbidity and color) did not cause a grouping influence. So, it is considered that the acceptance degree of the judges for the juices processed by ohmic heating and un-treated juice (left side) was due to the flavor attributes.

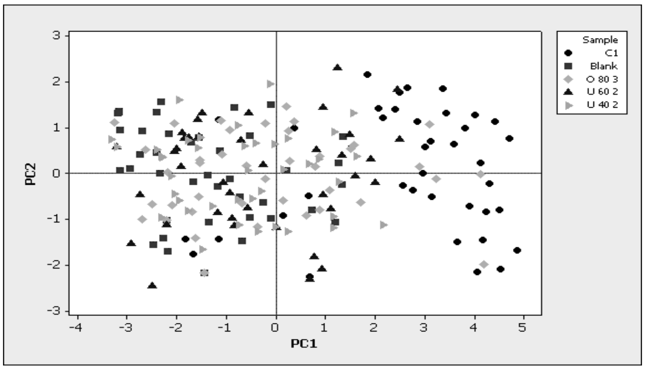


Figure 2. Comparison of the first principal component against the second component in sensory analysis of samples processed grapefruit juice by ultrasound compared with different samples of grapefruit juices.

The taste of grapefruit, bitter taste and overall flavor were decisive in the election. US processed juices showed a pleasant taste; this was because the sound vibrations significantly increase the extraction of compounds responsible for aroma. The turbidity was not a factor in the choice of juice by the judges, this coincides with that reported for apple juice [36].

3.2 Physicochemical characterization

3.2.1 Cloud value

It was observed that there was significant difference (p=0.01) in cloud value in samples processed by OH and US with commercial samples. Juices processed with high amplitude ultrasound value showed higher cloud value than samples processed with ohmic heating. This is because the cloud value is influenced by the particle size and processing time [26]. Studies suggest that ultrasound breaks linear pectin molecules, reducing its molecular weight influencing the sedimentation rate of the processed food [2], [37]. Commercial juices had the highest cloud value, but this did not influence the sensory analysis carried out by the judges to select the juices with the highest sensory scores.

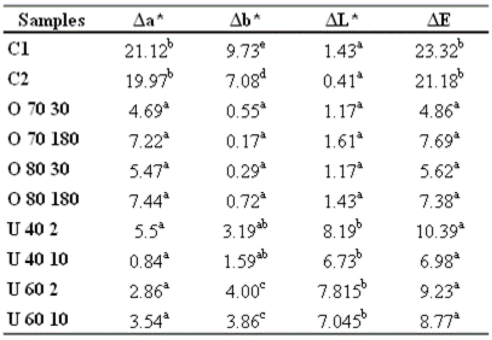
3.2.2 Non-enzymatic browning

The non-enzymatic browning (NEB) was significantly influenced by the type of treatment used (p=0.01). Besides the NEB was influenced by temperature, amplitude level and treatment time (p=0.01) this coincide with those reported in orange juice treated with ultrasound, compared with untreated juice [26]. The samples that presented a higher non-enzymatic browning were the juices commercial. The non-enzymatic browning may result from the condensation of carbonyl groups of sugars with amino acids and ascorbic acid, due to the pasteurization temperature phenomenon known as caramelization [27], [38]. The observed increment in non-enzymatic browning with respect to temperature has been reported in apple cider by some authors [39], [40]. The samples processed with ultrasound at high amplitude also showed high levels of NEB, this is mainly because the ultrasound results in the breakdown of carotenoid pigments in the juice. Similar changes have been reported in sonicated juices of grapejuice, orange juice and apple-cider respectively [2], [26], [39]. The NEB of samples processed by OH did not differ significantly in relation to the raw samples, being this observation in agreement with the reports in orange juice [41], [42].

3.2.3 Colorimetric analysis

Colorimetric analysis of red grapefruit juice processed by OH and US is presented in Table 6. The results shows that all samples presented a positive values of Δa* and Δb* indicating that samples were in range red-yellow. A significant differences in color parameters were observed in comparison with commercial samples. Processed samples showed positive brightness (ΔL*), and a significant differences were observed in samples processed by US. This is consistent with that reported by Tiwari et al. (2009) [26], who mentioned that changes in ΔL* were dependent on the amplitude and processing time. Also due to the action of cavitation, a lysis of cell structures is produced and the release of pigments provokes an increment in juice opacity. ΔE* values did not no indicate significant differences between commercial samples and those treated by OH and US which were statistically equal to each other (p=0.01).

Table 6 Comparison of means of colorimetric analysis of samples of grapefruit juice by Tukey test p = 0.01



Samples	Δa*	Δb*	ΔL*	ΔE
C1	21.12^{b}	9.73^{e}	1.43^{a}	23.32^{b}
C2	19.97^{b}	7.08^{d}	0.41^{a}	21.18^{b}
O 70 30	4.69^{a}	0.55^{a}	1.17^{a}	4.86^{a}
O 70 180	7.22^{a}	0.17^{a}	1.61^{a}	7.69^{a}
O 80 30	5.47^{a}	0.29^{a}	1.17^{a}	5.62^{a}
O 80 180	7.44^{a}	0.72^{a}	1.43^{a}	7.38^{a}
U 40 2	5.5^{a}	3.19^{ab}	8.19^{b}	10.39^{a}
U 40 10	0.84^{a}	1.59^{ab}	6.73^{b}	6.98^{a}
U 60 2	2.86^{a}	4.00^{c}	7.815^{b}	9.23^{a}
U 60 10	3.54^{a}	3.86^{c}	7.045^{b}	8.77^{a}

Some authors reported that US process did not affect the ΔE* values of orange juice [20], [24], [26]. However despite these differences, the color did not influence significantly in sensory analysis, in which the determining factor was the flavor of the sample.

IV. CONCLUSIONS

The samples processed by ohmic heating and ultrasound showed better sensory characteristics in comparison with commercial juices The juice processed by ohmic heating showed a lower non-enzymatic browning. The taste was the determining parameter in the choice of better juice by consumers. Juices processed with ohmic heating showed sensory characteristics more like the natural juice. The best juice was obtanied by processing with OH at 70 °C for 30 s.

Indentations
Nomenclature

O 70 30	Ohmic heating, temperature 70 °C, time 30 s
O 70 180	Ohmic heating, temperature 70 °C, time 180 s
O 80 30	Ohmic heating, temperature 80 °C, time 30 s
O 80 180	Ohmic heating, temperature °C, time 180 s
U 40 2	Ultrasound, amplitude 40 µm time 2 min.
U 40 10	Ultrasound, amplitude 40 µm time 10 min.
U 60 2	Ultrasound, amplitude 60 µm time 2 min.
U 60 10	Ultrasound, amplitude 60 µm time 10 min.
C1	Comercial juice trademark 1
C2	Comercial juice trademark 2
B	Natural juice without treatment

Greek symbols

µm	Amplitude of ultrasound wave
Δa*	Change of color beetween red and green
Δb*	Change of color beetween yellow and blue
ΔL*	Luminosity
ΔE*	Color diference

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