The Effects of Processing and Preservation on the Sensory Qualities of Prickly Pear Juice

Kgatla T.E., Howard S.S, and Hiss D.C.

Abstract—Prickly pear juice has received renewed attention with regard to the effects of processing and preservation on its sensory qualities (colour, taste, flavour, aroma, astringency, visual browning and overall acceptability). Juice was prepared by homogenizing fruit and treating the pulp with pectinase (*Aspergillus niger).* Juice treatments applied were sugar addition, acidification, heat-treatment, refrigeration, and freezing and thawing. Prickly pear pulp and juice had unique properties (low pH 3.88, soluble solids 3.68 ^{o}Brix and high titratable acidity 0.47). Sensory profiling and descriptive analyses revealed that non-treated juice had a bitter taste with high astringency whereas treated prickly pear was significantly sweeter. All treated juices had a good sensory acceptance with values approximating or exceeding 7. Regression analysis of the consumer sensory attributes for non-treated prickly pear juice indicated an overwhelming rejection, while treated prickly pear juice received overall acceptability. Thus, educed favourable sensory responses and may have positive implications for consumer acceptability.

Keywords—Consumer acceptability, descriptive test, Prickly pear juice

I. Introduction

PRICKLY pear (*Opuntia spp*) is a wild fruit that grows under arid conditions [1]. It belongs to the *Cactaceae* family and originated in tropical America, but the genetic diversity in its species is more pronounced in the semi-arid Mexican plateaus [2]. It is also found in Southern Italy, Central and South America, Israel, South Africa, Sicily and throughout warm and sub-tropical climates. Prickly pear cultivars produce green, yellow, purple and red fruits [3]-[6] In South Africa, prickly pear is picked, dethorned, peeled and eaten without further processing. Unprocessed prickly pear fruit has little pulp juice and many hard seeds that are thought to be the cause of constipation in consumers. Prickly pear varieties such as *Skinner Court*, *Morado,* and *Gymno Carpo* are generally sweet, but *Algeria*, which is smaller with a red-pink colour, has a bitter taste. However, *Algeria* has higher vitamin C content than the other varieties. This attribute of *Algeria*, notwithstanding the fact that people dislike its bitter taste, has prompted the need for processing technologies to increase the utilization of its fruit. One of the most frequently utilized fruit production technologies is juice processing. Juices are much appreciated for their nutritive value, and modern technologies along with Good Manufacturing Practice (GMP) allow the production of juices that closely emulate the raw fruit from which they are derived [7]. The production of fruit juices involves the transformation of organized, whole, solid tissue into a semi-fluid system of cells and fragments of plant cell walls suspended in cellular liquid [8]. Juice stability depends on the raw material, processing conditions, packaging material and storage conditions. These factors could cause microbiological, enzymatic, chemical and physical alterations that damage the sensorial and nutritional characteristics of the juice [9]. Consumers demand original juice with minimal processing, a juice with no sugar added, and also a juice which resembles the original fruit. Processing is well established as an essential strategy for modern food preservation in order to meet growing consumer demands for safe products.

Processing and preservations methods applied in the fruit juice industry include thermal and non-thermal pulsed electric field systems [10]-[15]. Ultrasound is another non-thermal technology which has attracted increased interest by researchers and industry, particularly when applied in conjunction with heat and thermosonication [16]-[18], heat and pressure, and mano-thermosonication [19]-[20], [15]. Another approach to food processing and preservation is exposure to ultrasonic waves, based on cavitation causing temperature and pressure peaks as well as formation of free radicals [21]. Combining ultrasound in a hurdle technology can potentially enhance the overall quality of minimally processed foods [22]-[28], [15]. Non-thermal processing methods are highly sophisticated, but very expensive to small-scale processors as compared to thermal processing (pasteurization). Pasteurization inactivates spoiling microorganisms efficiently, but may also degrade taste, colour, flavour and nutritional quality of foods [29]-[30]. Other preservation methods include sugar adjustment to enhance the level of sweetness and acidification to lower the pH and water activity of juice products. All these preservation methods variously alter the pathogenic and spoilage microorganisms in juices, but may also affect their sensory properties and result in consumer rejection of the juice product. Beyond satisfying their nutritional needs, the juices people choose and the amounts they drink depend largely on juice quality. Product quality encompasses a composite of characteristics that determine the degree of significance, acceptability and excellence. However, quality can be a highly subjective indicator. Moreover, the successful marketing and sales of many juice products are influenced by

Tsietsie Ephraim Kgatla, University of Venda, Department of Food Science and Technology, P/Bag X5050, Thohoyandou: Phone:0159628287; Fax 015 962 4749; E-mail: Ephraim.kgatla@univen.ac.za

Howard S.S, University of Limpopo, Department of Human Nutrition,P/bag X1106, Sovenga, 0727, howards@UL.ca.za

Hiss D.C , University of the Western Cape, Department of Medical Biosciences, P/Bab X17, Belville, 7535, dhiss@uwc.ac.za

.

their sensory attributes which may originate from manufacturing or processing steps.

Meilgaard [31] defined sensory evaluation as a scientific discipline used to evoke, measure, analyze and interpret reactions to the characteristics of juice and materials as they are perceived by the senses of sight, smell, taste, touch and hearing. Sensory evaluation is imperative to ensure compliance with the quality and marketability requirements of food products. This scientific strategy takes into account the relationship from two types of data, namely, sensory tests with consumers and with trained analytical panels, respectively. The relationship makes it possible to determine the sensory profile best adapted to the concept of product quality in the target market, enabling food companies to establish control activities, improve quality and develop new products. The sensorial aspect is directly related to consumer demand for the juice in the search for similarity to available and recently processed juices. The alteration in natural juices intensifies continuously after extraction, and may potentially result in the development of undesirable flavour and colour [32]. In view of the above considerations, the present study evaluated the effects of processing and preservation on the sensory properties and consumer acceptability of prickly pear juice.

II. Experimental Design

2.1 Prickly Pear Processing

Although Algeria prickly pear fruit is not readily available on the market, it is found in abundance at Botlokwa-Matoks village in the Limpopo Province of South Africa where the researchers harvested the mature, ripe fruits. The prickly pear fruit was dethorned by removing the glochids, sweeping them on grass and rinsing them with tap water. The fruit was stored in plastic bags and transported to the Food Science laboratory. Prickly pear fruit was carefully selected and sorted using criteria of homogeneity in terms of red-purple colour, maturity and ripeness. Fruits that were low in quality (defective, damaged and darkest purple colour which was indication of overripeness) were removed. Cleaning of prickly pear fruit involved dethorning for the second time under running tap water followed by a cold water rinse to reduce the field heat, and rubbing the fruit surface with a tablecloth to remove the hair thorns. The prickly pear fruit was stored in a cold room (7^{o}C) for up to 48 hours before juice extraction.

2.2 Juice Making Process

Juice extraction was performed two days after storage. Prickly pear fruit was crushed using a blender with a speed setting of 500 rpm to produce prickly pear pulp from which a sample was taken for further analysis. Pectinase from *Aspergillus niger* was added to prickly pear pulp and the mixture incubated for 1 hour in water bath at 50^{o}C in order to increase the yield in juice, reduce the processing time, improve the extraction of some components (aroma, colour), and to obtain the partial or total liquefaction of the plant tissues. Prickly pear pulp was diluted with water to increase the liquefaction of pulp to facilitate passage through 80 to10 micrometer sieve sizes. The final juice was collected in the receiver and transferred to litre packets. A sample of the prickly pear juice was analyzed for soluble sugar, and the remainder dispensed into sterilized bottles and kept in a cold room for further analysis. ^{o}Brix -adjustment was done by adding white sugar in mass prickly pear juice until 17 ^{o}Brix was attained. The adjusted prickly pear juice sample were analyzed for pH and filled in bottles which were sterilized by submerging in a waterbath at 100^{o}C. The bottles were then tightly closed kept in a cold room (7 ^{o}C) for one day prior to other analyses.

Acidification was achieved by adding citric acid to the prickly pear juice until the pH adjusted from 3.8 to 3.4. Acidified prickly pear juice samples were analyzed for sugar level and filled in sterilized bottles and tightly closed and kept in a cold room. The remaining prickly pear juice was transferred into sterile bottles and tightly closed to prevent oxidation of sample. Heat-treatment was achieved by submerging the sample of prickly pear juice in a water bath at 72^{o}C for 10 minutes. The prickly pear juice was aliquoted in equal portions into three sterilized bottles. Individual aliquots were kept in the cold room (7^{o}C), the refrigerator (4^{o}C) and the freezer (-5^{o}C), respectively. Thawing of prickly pear juice was achieved by using a thawing-cycle method in which the frozen juice was transferred from the freezer to refrigerator for 24 hours before the analyses. Samples of separately stored prickly pear juice portions were used in physicochemical analyses.

2.3 Physicohemical Analyses

The pH of prickly pear juice samples was measured using a glass electrode connected to a standard pH-Meter PHM82 (Radiometer, Copenhagen, Denmark). Total soluble sugar in the prickly pear samples was determined using an Atago refractometer [33].

2.4 Ethical Considerations

Students and staff members at the University of Limpopo were recruited to this study. Only those who returned their consent forms and underwent screening were allowed to participate in the study. A screening process that involved an interview using a structured questionnaire was conducted after an application for human experimentation at the University of Limpopo was approved by its ethics committee.

2.5 Recruiting and Screening for Sensory Panelists

Internal recruiting methods were used to recruit students and staff members of the University of Limpopo as described above. Screening of the sensory evaluators was done to determine their personal aspects such as potential reliability as panel judges (which also depended on their aptitude for foods), availability, and interest in food and health related conditions. Individuals with colds were rejected because they were deemed unable to evaluate foods accurately. Potential panelists were surveyed to determine if they had food allergies or sensitivities using the guideline from ISO standard procedures and the method illustrated by Jellinek [34].

2.6 Selection of Sensory Panelists

A taste panel was selected according to ISO standards and procedures [35] described [36]. Screened prospective panelists were subjected to a series of tests to evaluate their ability to distinguish among four basic parameters, namely, recognition of primary taste, ranking of taste intensity, triangle testing, and discrimination and descriptive testing. The tests were constructed to give a qualitative indication of the concentration at which tastes were recognized. Selection tests were conducted at 11:00 am. Prospective panelists were requested not to eat, drink or smoke for at least one hour before the testing. Prospective panelists who were successful in recognizing primary taste were then tested for their ability to rank a series of solutions in increasing order of taste intensity. Only those who were able to meet the desired criteria were selected for the series of triangle tests. Finally, those who were able to complete the triangle testing successfully were chosen as panelists. Members of the panel were omitted on the basis of their performance during the selection period. Prospective panelists were then trained for discrimination and descriptive testing.

2.7 Training of Panelists

Training of panelists was done strictly according to prescribed procedures [37]-[38]. Panelists for discrimination and descriptive testing were trained before the experiment. The important functions of the training period were to show the judges that effort and concentration were essential in the evaluation of prickly pear juice and to develop a common understanding of terminology in general as well as specific procedures among the panelists. Panelists were asked to refrain from eating a meal for at least 60 min, and smoking, snacking or chewing gum for 20 min before test sessions. The training period was started by explaining the problem to arouse interest among the panelists [39]. Standard references were used to help panelists to define terms and understand the range of a scale and to reduce the time required for training. Multidimensional descriptors were used in the training of panelists. Odour, flavour, texture, colour, and appearances of samples were presented at different concentrations, using the same scale for all variables. Panelists were required to indicate the stimuli they perceived from the sample variables in terms of the intensity of each attribute. Panelists were familiarized with the discipline of sensory analysis and explanation given based on theory. Such training was considered necessary since the panelists presumably were not as familiar with the organoleptic attributes of red-purple prickly pear compared to green prickly pear.

2.8 Ranking Test

A ranking test was conducted to determine the lowest concentration of substance that can be detected (absolute and detection threshold) or the lowest concentration of substance required for identification of the substance (recognition or identification threshold). The threshold test involved the evaluation of acuity for the four basic tastes, odour notes or variations in concentration of some constituent of food. The taste threshold was assessed by adding small amounts of salt, sugar, acid and caffeine to distilled water. In this method a series of samples of ascending concentration of test material was presented to the panelists. Each sample was an odd sample in a triangle test in which water samples were the like samples. Threshold was the point at which the panelists began to correctly identify the odd sample (detection and correctly identify recognition) taste and odour [40].

2.9 Triangle Test

The triangle test was conducted to detect the overall difference of the solution by observing and smelling different blended juices. Panelists each received three samples, two of which were duplicates. The panelists were asked to identify the odd sample [31].

2.10 Rating Test

Seven trained panelists conducted the sensory profile of prickly pear juice. Non-treated prickly pear juice was rated first and used as the reference, because of its sensory characteristics and reliance to prickly pear. Reference marks were provided for each attribute. Sensory profile qualities evaluated were aroma, flavour, sweetness, colour, visual browning and astringency intensity. Each quality other than visual browning was charted on a 10-cm continuous vertical line with anchor words on each end (e.g., not sweet, and very sweet). Panelists were asked to place a mark and the sample number on the line for each juice treatment to indicate their intensity rating. Five prickly pear juice treatments and untreated juice were presented to the panelists. Five treated juices were rated against untreated ones. Panelists rinsed their mouths with water between the sample testing. The distance of each mark from the anchor words on the line was measured in centimeters. The highest rating for all qualities was 10 and the lowest was zero.

2.11 Acceptability of 9–Point Hedonic Test

This test was used to determine the effects of processing and preservation of prickly pear juice on its sensory acceptability. The prickly pear juice was presented to prospective consumers (panelists who were familiar with prickly pear fruit) who scored the prickly pear juice products according to acceptability on a 9-point Hedonic scale. The Hedonic rating scale was used to determine the consumer acceptability of prickly pear juice. An evaluation form with a 9-point rating scale ranging from “Dislike Extremely” to “Like Extremely” was used by participants to assess the acceptability of the sensory qualities (appearance, taste, colour, and smell), and the overall acceptability of prickly pear juice [41]. The consumer test panel comprised 30 members. Participants were supervised during the test session and individual assessment was followed throughout the test, i.e., communication between panelists was not allowed. Daylight conditions were used throughout the testing period. Cold samples of prickly pear juice were divided into porcelain containers coded with 3-digit numbers and served in a randomized fashion to minimize bias. Panelists were first familiarized with the evaluation forms before they could complete the rating.

TABLE I
SENSORY SCREENING FOR SUITABLE PANELISTS FOR PRICKLY PEAR JUICE EVALUATION

TEST	PROSPECTIVE PANELISTS TESTED	PROSPECTIVE PANELISTS PASSED
1	45	30
2	30	12
3	12	7

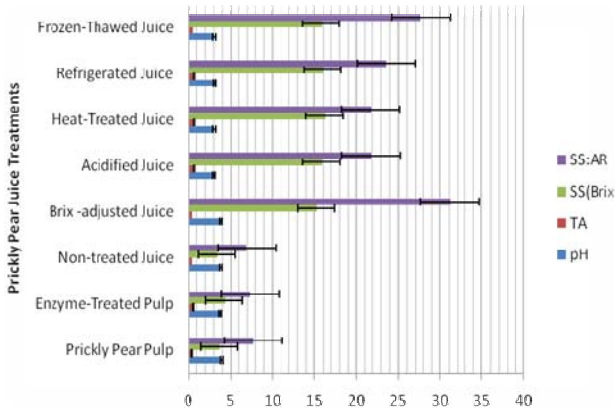
Test 1: Recognition of primary tastes; Test 2: Ranking of taste intensity; Test 3: Triangle test

2.12 Statistical Analyses

The standard repeatability deviation was calculated as the average of the standard deviation in the session with each juice treatment. A panelist was considered repeatable when the standard repeatability deviations were less than or equal to the reference value in 50% of the total number of parameters analyzed. Reproducibility was calculated as the square root of the variances between sessions plus the variance due to repeatability. The variance between sessions was considered as the variance corresponding to the average of the values recorded in the sessions. A panelist was considered as qualified in reproducibility when 50% of the standard reproducibility deviations value was less than or equal to the reference. The SAS [42] computer software was used for statistical and correlation analyses. Significance at $p \leq 0.05$ was applied to the data sets obtained from the sensory analyses. is a statistical technique that shows whether and how strongly pairs of variables are related.

III. RESULTS

The physicochemical analyses are presented in Figure 1. Prickly pear pulp had a higher pH value of 3.9 compared to enzyme-treated pulp and the other juice treatments. No pH differences were observed among enzyme-treated pulp, non-treated juice and Brix-adjusted juice. A significant ($p<0.05$) decrease in pH was observed after acidification due to the addition of citric acid to prickly pear juice. Refrigerated and frozen-thawed prickly pear juice samples showed no significant difference in pH at $p<0.05$. A decrease in titratable acidity was observed after sieving, when the juice was produced. Despite the variation in total titratable acidity of the products, values were relatively low, from 0.5 to 0.73, showing that all prickly pear juice treatments could be recommended for consumption. Soluble solids (SS) content varied from 3.6 to 16 ^{o}Brix. Prickly pear juice had a lower SS and soluble solids to acid ratio (SS:acid ratio) prior to the juice treatment applied. The SS:acid ratio of non-treated juice and treated prickly pear juice varied mainly as a function of the amount of sugar added. These parameters were similar to most juices produced from common fruits, such as apple and strawberry. The presence of citric acid reduced the SS:acid ratio balance values. It is logic that the SS content dropped when other dissolved components were added.



TA: Titratable acidity; SS: Soluble solids (^{o}Brix),
SS: AR: Sugar acid ratio (%). Non-treated prickly pear juice is the standard.

Fig. 1 Physicochemical Parameters of Prickly Pear Juices

The results of the selection and training of panelists are presented in Table 1. Sensory analysis for colour and taste responses as well as acceptability of prickly pear juice were carried out by presenting non-treated and treated samples to panelists under controlled conditions and then recording their evaluation using a standardized questionnaire. Selection and training conditions as well as evaluation were carried out using standard methods. Fourty five individuals were randomly selected and given pre-training. Prospective panelists who were successful in screening test 1 were then tested for their ability to detect the odd sample in a series of solutions in increasing order of intensity. Again, only those who were able to meet the desired criteria were selected for subsequent tests. It was found that only 30 panelist out of the initial 45 were successful in all three tests. These 30 panelists were selected to carry out the acceptability test. Of this 30, only 12 were suitable to carry out rating tests which analyzed specific sensory attributes using the same questionnaire as was used for the screening test. Twelve panelists were subjected to a repeat Triangle test to evaluate their ability to detect the different characteristics of prickly pear juice using the relevant questionnaire. It was found that only seven panelists were successful in the triangle test. These seven potential panel members attended the training session, to familiarize themselves with the terms used in sensory evaluation. The trained panelists carried out the sensory profiling of prickly pear juice characteristics.

Descriptive terms were generated by the researcher and panelists during training sessions. Non-treated prickly pear juice was used as a standard reference for the purpose of this study. The results are presented in Table II. Physiochemical analysis showed that the reference standard for sweetness was low with 3.38 ^{o}Brix while bitterness which was stimulated by acid was high at 0.48 with pH 3.79. Astringency was described as a high sensation of the characteristic shrinking effect of non-treated prickly pear juice on the tongue surface, flavour as low and colour as light reddish purple. The organoleptic descriptions of prickly pear juices differed from those of the reference. The colour of prickly pear juices retained a recognizable reddish purple with different shades. Refrigerated and frozen-thawed juice samples had the same colour as non-treated prickly pear juice. Heat treatment affected the aroma of prickly pear juice as shown by the change in the aroma of the juice to a medicinal smell. The non-treated prickly pear juice had a bitter flavour whereas treated juice had a sweet taste. This difference can be ascribed to the fact that treated juice had added sugar to improve its taste. The results are presented in Fig. 2.

TABLE II
THE SENSORY DESCRIPTION OF PRICKLY PEAR JUICE

TREATMENTS	ORGANOLEPTIC DESCRIPTIONS		
	COLOUR	AROMA	FLAVOUR
Prickly Pear Juice	Reddish Purple	Fresh Prickly Pear	Bitter
Brix-Adjusted	Slightly Dark Purple	Fresh Prickly Pear	Very Sweet
Acidified	Reddish Purple with Violet Shade	Prickly Pear with Acid	Bittersweet
Heat-Treated	Red-Purple with Blue	Medicine	Syrupy Sweet
Refrigerated	Reddish-Purple	Slightly Medicine	Sweet
Frozen-Thawed	Reddish-Purple	None	Sweet

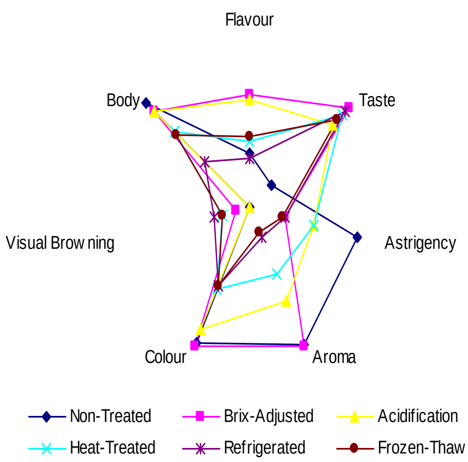


Fig. 2 Spider Plot for Sensory Profile of Prickly Pear Juice

All prickly pear juice treatments were rated higher than the reference sample, except the refrigerated prickly pear juice. Brix-adjusted and acidified prickly pear juices were rated higher and were not significantly different to each other at $p<0.05$ using Duncan's multiple variance test. Only flavour and taste were rated much higher, while body and astringency were not. The taste non-treated prickly pear juice was rated lower than treated prickly pear juice, this was not surprising because all prickly pear juice treatments, except the reference, had added sugar to improve their taste. The reference was rated 2.14 whereas other juice treatments were in the range of 8-10. All prickly pear juice treatments rated lower in astringency compared to the reference. The reference was rated 8.28 whereas juice treatments were between the ranges of 2.51-4.85. ^{o}Brix- adjusted and the reference rated equally at 2.71. Acidified and heat-treated prickly pear juice were 4.85 each, this was higher than ^{o}Brix-adjusted, refrigerated and frozen-thawed prickly pear juices. Frozen-thawed prickly pear juice was rated the lowest compared to all the treatments. ^{o}Brix-adjusted prickly pear juice had a higher rating than the reference. Frozen-thawed juice was rated the lowest with a score of 1.71 compared to the reference of 9.28. Colour sensory profiles of prickly pear juices were significantly different. The rating ranges were between 9.42-5.28. ^{o}Brix-adjusted juice had higher ratings than the reference, whereas others juice treatments were lower and all received very close scores. Heat-treated, refrigerated and frozen-thawed prickly pear juices were not significantly different from each other. This implies that heat treatment has the ability to fix or stabilize the colour of prickly pear juice. Visual browning of non-treated prickly pear juice was similar to acidified juice with a rating of zero. Other juice treatments were rated in the range of 1-2.71. Body of the reference was rated to 10 and ^{o}Brix-adjusted and acidified had 9.14, heat treatment 7.28, refrigerated 4.42 and frozen-thawed prickly pear 7. It can therefore be concluded that processing and preservation improved the aroma, flavour and taste of prickly pear juice, but had a little effect on its colour and body.

Table III, Shows the correlation between the seven sensory attributes for the different prickly pear juice treatments scores. These correlation matrices were notable in that they affected each other in terms of the acceptability of the juice. Despite the extremes negative r values of astringency that influenced the acceptability rating of taste at -0.8, which in simpler terms is the square of the coefficient of variation in one variable that was related to the variation in the other by 64%. It was also found that colour and aroma had the highest, but positive correlation at 64%, whereas visual browning and colour had a moderate negative correlation at 49%. This indicates that the visual browning had a negative influence on the colour perception of prickly pear juice. Body, flavor and astringency had no correlation since the value of r is closer to zero.

Table IV shows the acceptability of non-treated and different treatments of prickly pear juice as evaluated by non-trained panelists (consumers). This evaluation focused on the effects of processing and preservation on consumer acceptability of specific attributes on non-treated and treated prickly pear juice. All prickly pear juice treatments had high acceptability scores for sweetness, acidity, colour, taste and overall acceptability. Non-treated prickly pear juice received a low overall acceptability and low scores on attributes like sweetness, acidity, and taste, but scored similar for colour compared to treated juice. However, some juice treatments such as heating, refrigeration, and freezing-and-thawing obtained low acceptability scores for aroma attributes.

TABLE III
CORRELATIONS COEFFICIENTS FOR THE CONSUMER SENSORY ATTRIBUTES FOR THE PRICKLY PEAR JUICE

ATT	FL	TA	AST	AR	COL	VB	BD
FL	1						
TA	0.4	1					
AST	-0.2	0.8	1				
AR	0.3	-0.5	0.5	1			
COL	0.5	-0.4	0.4	0.8	1		
V B	0.5	0.5	-0.6	-0.7	-0.7	1	
BD	0.3	-0.4	0.3	0.7	0.8	0.6	1

TABLE IV
OVERALL ACCEPTABILITY OF PRICKLY PEAR JUICE VARIATIONS

Treatment	Dependent Variables					
	Sw	Aci	Ar	Tas	Col	Accep
Non-Treated	1.3[c]	1.7[c]	5.4[b]	1.8[c]	7[a]	1.3[c]
Brix-Adjusted	7.1[b]	7.1[a]	5.4[b]	7[a]	6.1[b]	7.2[a]
Acidification	7.6[a]	7[a]	7[a]	6.4[b]	7.2[a]	7.6[a]
Heat-Treated	7.3[a]	5.9[b]	2.9[c]	59[b]	6.9[a]	6.2[b]
Refrigerated	7.[b]	6.1[b]	2.9[c]	6.2[b]	7[a]	6.1[b]
Frozen-Thawed	7.2[b]	6[b]	3[c]	6.2[b]	6.8[a]	6.3[b]

Sw: sweetness, Aci, Acidity, AR: aroma, Tas: Taste, Col:colour, Accep:Acceptance. Superscripts within columns and treatments with the same letters are not significantly different at $p<0.05$

IV. DISCUSSION

The aim of this study was to investigate the effects of processing and preservation on the organoleptic attributes of prickly pear juice. Colour, flavour, body, taste and aroma are generally regarded as the most important parameters in the sensorial evaluation of food quality. As such, treated prickly pear juice was judged to have a high food quality by virtue of the high rating assigned to its flavour and taste characteristics in the sensory profile. It is important to balance the sugar:acid ratio of the juice to improve its acceptability. Treated-prickly pear juice had low visual browning and astringency attributes - a sensory profile that was highly acceptable as browning affected the colour stability and astringency the taste of the juice as it shrunk the tongue surface. Heat-treated prickly pear juice samples scored low in the aroma intensity rating sensory profile, which may be attributed to the destruction of the pigments responsible for aroma. A significant difference in acceptability of non-treated and treated prickly pear juice was observed. In particular, treated prickly pear juice containing higher sugar of 15 ^{o}Brix had a good sensory acceptance with values near or superior to 7. Non-treated prickly pear juice was extremely rejected by the judges, presumably be due to the low sugar and bitter-to-sour taste caused by its high acid content, and also to the imbalance of sugar:acid ratio indicated by low soluble solids:acid ratio values. Saenz and Sepulveda [7], in similar evaluation, found that the panelists rated the non-treated prickly pear with higher score acceptability than treated prickly pear juice. However, this was unexpected because the prickly pear used was sweet, and had a high pH of 5.4 and very low titratable acidity which gives juice a better taste compared to the bitter non-treated prickly pear juice evaluated in this study. Treated prickly pear juice retained the recognizable red purple colour characteristics. This presented a clear advantage of the red-purple prickly pear for the production of juice. Heat treatment affected the aroma of prickly pear juice, but acidification improved the liking of prickly pear juice aroma. This was expected because most fruit aromas are formed by acids and volatile compounds that contribute to flavour.

In addition, it was observed that different treatments affected the light and bright red-purple colour of prickly pear juice. Light and bright colours are due to betalian pigments, and their stability throughout processing is of a major importance since they give the juice an attractive colour. Colour differences that occured were probably due to changes in the betalian pigments and the development of furfural and hydroxyl-methylfurfural compounds [43]. In this study, the colour of prickly pear juice was likewise altered by methods of preservation. Heat-treated juice was darker, confirming previous observations [43]-[45]. Similar results were reported on prickly pear juice blends [46]-[47]. Thus, the results in this study corroborate previous assertions that prickly pear pigment stability is an important consideration in juice making despite the fact that sensory evaluation showed no significant differences in the acceptability of the visual colour of prickly pear juices [45], [48]. The colour stability was not a problem in prickly pear juices because the recognizable red-purple colour was retained. Browning could perhaps have occurred when enzymes called polyphenolases, which occur naturally in the fruit tissue, catalyzed the oxidation of phenols, also naturally present in the fruit, to form compounds called quinones. The malanoidins which constitute the brown pigment were low in treated prickly pear juice sample as indicated. Browning was less of a problem since colour stability was greater and browning occurs to a lesser extent in an acidic or low pH medium [49]-[50]. This could be due to ascorbic acid content of prickly pear juice, because ascorbic acid inhibits the browning reaction by reducing the quinones back to the original phenol compounds. The little browning that occurred in the prickly pear juice could be due to the presence of oxygen, because in the presence of oxygen, the phenols can be readily being converted to quinones [51]-[52].

V. CONCLUSION

This study demonstrated that it is possible to produce a quality good prickly pear juice with favourable physicochemical properties that provided a technological alternative to increase the utilization of this fruit and its consequent contribution to a healthy diet. Juice treatments caused a visual colour change and affected the prickly pear flavour. Nevertheless, the unique and attractive reddish purple colour of this fruit remained stable throughout processing and preservation. ^{o}Brix-adjustment had a positive influence on sweet taste and sensory acceptance of the juice, but initiated little browning which is caused by the Maillard reaction that could limit the storage temperature of prickly pear juice. The ascorbic acid content of the juice and acidification of prickly pear juice protected the natural colour and exhibited anti-browning. Sugar addition and acidification improved the flavour and increased the liking of prickly pear juice. The attractive sensorial qualities of prickly pear juice suggest potential for its commercial exploitation. This study concludes that processing and preservation have positive effects on the organoleptic quality attributes of prickly pear juice and affect the flavour attributes. Further studies would be worthwhile to establish the changes in the volatile compounds that occur during processing and preservation of prickly pear juice as these changes may impact on juice quality and ultimately the feasibility of larger-scale production.

ACKNOWLEDGMENT

There are many people to thank, as no research pursuit is solitary. This research would not have been all that exciting without the intense proficiency of the sensory panelists. The authors wish to you all for sacrificing your weekends, attending the sensation of this project and enduring the liters of prickly pear juice that you ingested.

REFERENCES

[1] C. Saenz, Cactus Pear Juices, Paris: Annals of the 22nd IFU Symposium Paris. 2001.
[2] A. Frati, Medical Implication of Prickly Pear Cactus, Annals of the 22nd IFU Symposium Paris, Paris. 1989.
[3] P. Nobel, C. Russel, P. Felker, J. Medina and E. Acuna, Nutrient Relations and Productivity of Prickly Pear Cacti, Agronomy Journal vol. 79, pp550-555. 1987.
[4] J. Kuti, Growth and Composition, Changes during the Development of Prickly Pear. Journal of Horticultural Science vol. 67, pp861-868. 1992.
[5] G. Barbera, P. Inglese and E. Pimienta-Barrios, Agro Ecology Cultivation and Uses of Cactus Pear, FAO Plant Production and Protection Paper no 132, Rome: Food and Agriculture Organization of the United Nations .1995.
[6] Y. Mizrahi, A. Nerd and P. Nobel Cacti as Crops, Horticultural Review vol. 18, pp291-320. 1997.
[7] C. Saenz and E. Sepulveda, Physical and Sensory Characteristics of Fruit Juice. Paris: Annals of the 22nd IFU Symposium Paris. 1999.
[8] C. Contarelli and G. Lanzarini, Biotechnology Applications in Beverage Production. London: Elsevier. 1989.
[9] R. Correa-Neto and J. Flarida, Factors Que Influen Na Qualidade Do Suco De Laranja. Ciencia e Technologia de Alamantos vol. 19, no. 1, pp153-160. 1999.
[10] C.E. Sizer and V.M. Balasubramaniam, New intervention processes for minimally processed juices, Food Technol vol. 53, no. 10, pp 64–67.1999.
[11] H .Zhang, C.B. Streaker and H.W. Yeom, Design, construction and evaluation of a sanitary pilot plant system pulsed electric field. In: A.J. Welti-Chanes, G.V. Barbosa-Cánovas and J.M. Aguilera, Editors, Engineering and Food for the 21st Century, Boca Raton, USA: CRC Press, pp795–808. 2002.
[12] G.A. Evrendilek , and Q.H. Zhang,, Effects of pH, temperature, and pre-pulsed electric field treatment on pulsed electric field and heat inactivation of Escherichia coli O157:H7. Journal of Food Protection vol. 66no. 5, pp755–759. 2003.
[13] M.O. Amiali, J. Ngadi, P. Smith and G.S.V. Raghavan, Synergistic effect of temperature and pulsed electric field on inactivation of Escherichia coli O157:H7 and Salmonella enteritidis in liquid egg yolk, Journal of Food Engineering vol. 79, no. 2, pp689–694. 2007
[14] S. Toepfl, V. Heinz and D. Knorr, High intensity pulsed electric fields applied for food preservation, Chem Eng Process vol. 46, no. 6, pp537–546. 2007.
[15] M. Walkling-Ribeiro, F. Noci, D.A. Cronin, J.G. Lyng and D.J. Morgan, Shelf life and sensory evaluation of orange juice after exposure to thermosonication and pulsed electric fields, Food and Bioproducts processing, pp102-107. 2009.
[16] A. Baumann, S.E. Martin, and H. Feng, Power ultrasound treatment of Listeria monocytogenes in apple cider, Journal Food Prot vol. 68, no. 11,pp 2333–2340. 2005.
[17] A. López-Malo, E. Palou, M. Jiménez-Fernández, S.M. Alzamora. and S. Guerrero, Multifactorial fungal inactivation combining thermosonication and antimicrobials, Journal Food Eng vol. 67 no. 1- 2, pp 87–93. 2005.
[18] E. Ugarte-Romero, H. Feng and S.E. Martin, Inactivation of Shigella boydii 18IDPH and Listeria monocytogenes Scott A with power ultrasound at different acoustic energy densities and temperatures, Journal of Food Sci vol. 72, no. 4, pp103–107. 2007.
[19] P.M. Álvarez, , R. Virto and S.Condón, Inactivation of Salmonella senftenberg 775W by ultrasonic waves under pressure at different water activities, Int Journal Food Microbiol vol. 108, no. 2, pp216–225. 2006.
[20] A. Vercet, J. Burgos and P. Lopez-Buesa, Manothermosonication of heat-resistant lipase and protease from Pseudomonas fluorescens: effect of pH and sonication parameters, Journal of Dairy Res vol 69, no. 2, pp 243–254. 2002.
[21] P. Piyasena, E. Mohareb and R.C. McKellar, Inactivation of microbes using ultrasound: a review, Int Journal of Food Microbiology vol. 87, no. 3, pp207–216.2003.
[22] L. Leistner, Basic aspects of food preservation by hurdle technology, Int J Food Microbiol vol. 55, no.1–3, pp 181–186. 2000.
[23] A.M. Hodgins, G.S. Mittal and M.W. Griffiths, Pasteurization of fresh orange juice using low-energy pulsed electrical field, Journal of Food Science vol. 67 no. 6, pp 2294–2299.2002.
[24] A.I.V. Ross, M.W. Griffiths, G.S. Mittal and H.C. Deeth, Combining nonthermal technologies to control foodborne microorganisms, Int J Food Microbiol vol. 89, no. 2–3,pp125–138. 2003.
[25] S.Q. Li, Q.H. Zhang, Z.T. Jin, E.J. Turek and M.H. Lau, Elimination of Lactobacillus plantarum and achievement of shelf stable model salad dressing by pilot scale pulsed electric fields combined with mild heat, Innovative Food Science and Emerging Technologies vol. 6, no. 2,pp125–133. 2005.
[26] A. Rivas, D. Rodrigo, A. Martinez, G.V. Barbosa-Cánovas and M. Rodrigo, Effect of PEF and heat pasteurization on the physical-chemical characteristics of blended orange and carrot juice, LWT – Food Science and Technology vol. 39, no.10,pp 1163–1170. 2006.
[27] E. Huang, G.S. Mittal and M.W. Griffiths, Inactivation of Salmonella enteritidis in liquid whole egg using combination treatments of pulsed electric field, high pressure and ultrasound, Biosyst Eng vol.94 no.3 pp 403–413. 2006.

[28] M. Walkling-Ribeiro, F. Noci, D.A. Cronin, J. Riener, J.G. Lyng and D.J. Morgan, Reduction of Staphylococcus aureus and quality changes in apple juice processed by ultraviolet irradiation, pre-heating and pulsed electric fields, Journal of Food Eng. Vol. 89, no. 2, p 267–273. 2008.

[29] B.L. Qin, F.J. Chang, G.V. Barbosa-Cánovas and B.G. Swanson, Nonthermal inactivation of Saccharomyces cerevisiae in apple juice using pulsed electric fields, Lebensm-Wiss Technol vol. 28, no. 6, pp 564–568. 1995.

[30] A.V. Charles-Rodríguez, G.V. Nevárez-Moorillón, Q.H. Zhang and E. Ortega-Rivas, Comparison of Thermal Processing and Pulsed Electric Fields Treatment in Pasteurization of Apple Juice.Food Bioproducts and processing vol. 85, pp93-97. 2007.

[31] M. Meilgaard, G.V. Civille and B.T. Carr, Sensory Evaluation Techniques, 3rd edition. New York: CRC Press, pp10- 47 1999.

[32] M.G. Roig, J.F. Bello, Z.S. Rivera, L.L. Lioyd and J.F. Kennedy, Non Enzymatic Browning in Single Strength Reconstituted Citrus Juice in Tetrabrile Cartons, Biotechnology Program vol. 12, pp281-285. 1996.

[33] J. Darias-Martín, G. Lobo-Rodrigo, J. Hernández-Cordero, E. Díaz-Díaz and C. Díaz-Romero Alcoholic Beverages from Black Mulberry. Food Technol. Biotechnol. Vol. 41 no.2, pp173–176. 2003.

[34] G. Jellinek, Sensory Eveluation of Food Theory and Practice, Deerfield Beach, Florida: VCH Publisher, pp85-120. 1985.

[35] ISO 6658, Sensory analysis methodology general guidance, International Organization for Standardization Database. 2005

[36] M. Meilgaard, G.V. Civille and B.T. Carr, Sensory Evaluation Techniques, 4th edition. New York: CRC Press, pp 1-39 2007.

[37] ISO 6658, Sensory analysis methodology general guidance, International Organization for Standardization Database. 1993.

[38] ISO 6658, Sensory analysis general guidance, for the selection, training and monitoring of assessors, International Organization for Standardization Database. 2008.

[39] M.P. Penfield and A.M. Campbell, Experimental Food Science in: Selection and Training of Panels. San Diego, California: Academic Press, pp 59-71. 1990.

[40] T.L. Harry and H. Hildegard, Sensory evaluation principles and practices, New York: Chapman, pp 30-67. 1998.

[41] M.C. Gacula, Statiscal Method in Food and Consumer Research, London: Academic Press. 1984.

[42] SAS, SAS Users Guide: Statistics. U.S.A: SAS Institute, Cary, North Carolina. 1997.

[43] T.T. Fang, H.E. Chen and L.M.J. Chiou, Effects of Heat Treatment and Subsequent Storage on the Quality of Passion Fruit Juice, XIX Symposium of the International Federation of Fruit Juice Producers, Fruit Juice for Europe. 1986.

[44] A.R. Isaacs, B.F. Bradly and S.M. Nottingham, The Storage Stability of Passion Fruit Concentrate, Food Technology in Australia vol. 40,pp318-323. 1988.

[45] C. Saenz, E. Costell and C. Calvo, Effect of Thermal Treatment on the Rheological Behaviour and Colour Parameters of Passion Fruit Juice, XI International Congress of Fruit Juice, Report of Congress, Sao Paulo. 1991.

[46] E. Sepulveda and C. Saenz Chemical and Physical Characteristics of Prickly Pear (Opuntia ficusindica). Revista de Agroquimica y Tecnologia de Alimentos vol. 30, pp551-555. 1990.

[47] C. Saenz, E. Sepulveda, C. Calvo and E. Araya, Colour Changes in Concentrated Juices of Prickly Pear (Opuntia Ficus Indica) During Storage at Different Temperatures. Lebensmittel - Wissenchaft Und Technologie vol. 26, pp417-421. 1993.

[48] U. Merin, S. Gagel, G. Popel, S. Bernstein and I. Rosenthal Thermal Degradation Kinetics of Prickly Pear Fruit Red Pigment, Journal of Food Science vol. 52, pp484-486. 1987.

[49] Y. Margalist, Red wine color in: Concepts in wine chemistry, South San Francisco: The Wine Appreciation Guild Ltd. 1997.

[50] B.W. Zoecklein, K.C Fugelsang, B.H. Gump and F.S. Nury, Influence of pH in Winemaking in: Production Wine Analysis, New York: Van Noststrand Reinhold VI.1990.

[51] A.A. Ahmed, G.H. Watrou, G.L. Hargrove and P.S. Dimick, Effects of Fluorescent Light on Flavor and Ascorbic Acid Content in Refrigerated Orange Juice and Drinks, Journal Food Technology vol. 39, pp332-339. (1976).

[52] J. Ryley and P. Kajda, Vitamins in Thermal Processing in Food Chemistry, Blackie Academic and Professional 49:119. 1994.