Vegetos (2023) 36:181–187
https://doi.org/10.1007/s42535-022-00506-z

RESEARCH ARTICLES

The impact of various pre-treatments on the physiochemical attributes and storage stability of *Persea americana*

R. Anusha[1] · **Jyoti Prabha Bishnoi**[1]

Received: 12 April 2022 / Revised: 10 October 2022 / Accepted: 12 October 2022 / Published online: 8 November 2022

Abstract

This research aimed to evaluate the changes in the chemical constituents of *Persea americana* (West Indian race) after subjecting it to different pre-treatments and its storage stability for 6 months at 4 °C and − 20 °C. Pre-treatments were performed on ripened avocados at 70 °C using water, steam, 2% brine and 2% brine plus 2% citric acid. The avocado pulp's carbohydrate, protein, fat, and acidity were 10.75%, 2.57%, 13.63% and 0.30%, respectively. All the chemical constituents in the pulp stored at 4 °C were significantly reduced by the sixth month, while the pulp stored at – 20 °C maintained its chemical constituents. The fresh avocado pulp had higher L* and b* values. The 'L' value decreased on refrigerated storage, reaching 38 in the sixth month. Of all the pre-treatments, 2% brine and 2% citric acid for 3 min preserved the green color and brightness of the pulp, preventing enzymatic browning even after 6 months under refrigerator conditions. The water and steam pre-treatments added to the product's acid stability, extending its shelf life over the other treatments. Thus, the ideal duration and pre-treatment temperature for preparing West Indian race avocado pulp was 70 °C for 3 min since this treatment retard enzymatic browning and preserves the pulp's organoleptic features. This study revealed that it is technically possible to preserve fruit for 6 months if it is treated appropriately.

Keywords Avocado · Chemical constituents · Pre-treatments · *Persea americana* · Storage stability · West Indian race

Introduction

Persea americana Mill. Lauraceae is a fruit indigenous to Central America and Mexico and is now cultivated in tropical and subtropical locations worldwide (Cowan and Wolstenholme 2016). The common name for this fruit is "avocado," which is also known as "alligator pear" and "butter pear" (Duarte et al. 2016). More than 500 avocado varieties are available all around the world. However, most of them are not commercially feasible owing to various factors, including development time, protein and fat content, tolerance issues, and damages during shipping (Hurtado-Fernández et al. 2018). The three ecological races are Mexican, Guatemalan and West Indian. Each race has distinct leaves, fruits and blooming features and some types have exterior skins with brown-black hints. The fruit may weigh up to 500 g and the ovoid-shaped seed size becomes larger as the fruit develops (Shikwambana 2016).

Avocados are popular because of their rich, creamy, velvety texture and a mild taste. The high-fat content gives a rapid feeling of "fullness," which reduces overeating and acts as a weight-loss tool. The monounsaturated fatty acids (oleic and palmitoleic acids) speed up the metabolic rate compared to saturated fatty acids. When the fruit ripens, the palmitic acid concentration falls and oleic acid content increases (Villa-Rodríguez et al. 2011), making oleic acid (45%) the primary fatty acid in avocado (Nnaji and Okereke 2016). The fruit contains 9% of carbohydrates, of which 7% constitute the fiber part, making it a low carbo plant food that favors the diabetic group. The pulp has a more significant proportion of insoluble (70%) and soluble fibers (30%) (Nnaji and Okereke 2016). The spongy mass of fibre enables consumers to fulfil their appetites and also assists in food passage through the alimentary canal by supporting the muscular activity of the colon, lowering the danger or incidence of constipation (Princewill-Ogbonna et al. 2019).

Avocado's global output will be 8.06 million tons in 2020. Mexico is the world's largest producer, contributing 45% of

✉ R. Anusha
anusha14r@gmail.com

Jyoti Prabha Bishnoi
jpbishnoi@jpr.amity.edu

[1] Amity Institute of Biotechnology, Amity University Rajasthan, Jaipur, India

total world production. The avocado market is expected to reach 23 million dollars by the end of 2027. The USA is the number one importer, while Mexico, Peru, Colombia and Chile are the top-ranking exporter countries (Nations 2021). The comment, "avocados are a challenging crop to obtain maximum quality", is an often-overlooked fact. Nowadays, customers have more access from harvesting to distribution operations. Post-harvest temperature management significantly impacts preserving quality and educating the farmers about it would reduce rotting. This issue may be handled by processing the versatile fruit into semi-processed intermediate goods, like pulp, which is still nutritious. Just like in any other sector, these stored commodities will then have the opportunity to be transformed into valuable things when processors or customers require them.

Avocado pulp is extremely perishable due to the presence of enzymes that promote quick darkening when exposed to oxygen. These browning enzymes are denatured by a combination of time and temperature during heat treatment (Moon et al. 2020). The ideal pre-treatment parameters for the production of Hass avocado pulp using high-caliber raw material have been determined (Salvador-Reyes and Paucar-Menacho 2019). However, these estimates are of little use for the West Indian race since it has a different fruit size and diameter; therefore, their heating time is different. Looking at the significance of the fruit and the knowledge gap about this fruit, the present study attempts to evaluate the influence of pre-treatment on the chemical composition of West Indian race avocado pulp.

Methods and materials

Preparation of samples

Mature avocado fruits *cv*. Pollock was procured from the local growers adjoining the Kodaikkanal region, Tamilnadu, during 2020–2021. The mature fruit was ripened within 8 days of harvesting.

Process of elaboration

Mature, ripe avocados were chosen, washed and then subjected to various pre-treatments as shown in Fig. 1.

The pre-treatments were carried out for 3 min. To prevent heat burn on avocado, it is immediately submerged in cold water after pre-treatment. Each pre-treatment was performed in triplicates. The pulp collected was stored in PET containers at 4 °C and − 20 °C. The analysis was performed on alternate months for 6 months.

Avocado pulp's quality characteristics

During storage, variations in the quality characteristics of experiments were observed. The pulp was evaluated for physicochemical parameters (carbohydrates, proteins, fat, titratable acidity and browning) (AOAC 2004) and sensory characteristics (color and appearance, taste, texture and overall acceptability). A preference analysis test was conducted with 20 customers aged 19–28, utilizing a 9-point hedonic scale. The overall acceptability of prepared products was based on the mean score of all sensory characteristics. These data were then subjected to multivariant analysis of variance (MANOVA) at $p \leq 0.05$ using SPSS version 16, where the chemical constituents are considered dependent and treatments as the independent variable (Table 1).

Table 1 The pre-treatments on avocado fruit

Experimental Code	Treatments	Temperature
T1	Control	Room temperature
T2	Water blanching	70 °C
T3	Steam blanching	70 °C
T4	2% Brine	70 °C
T5	2% Brine and Citric acid	70 °C

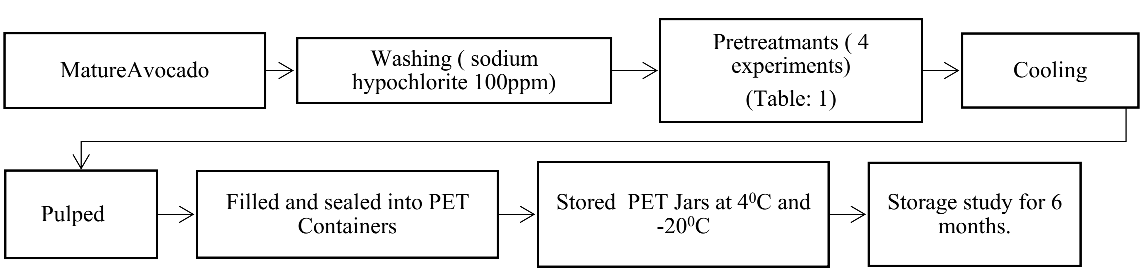

Fig. 1 Elaboration process of avocado pulp preparation

Table 2 Yield efficiency of the West Indian race avocado

Fruit parameters	Percentage
Fruit weight (g)	264.71 ± 7.44
Seed weight (g)	39.94 ± 5.35
Peel weight (g)	27.87 ± 4.25
Pulp weight (g)	195.25 ± 6.22
Seed yield (%)	15.64 ± 0.52
Peel yield (%)	10.44 ± 0.27
% Recovery	**73.50 ± 0.65**

Results and discussion

Avocado pulp output was 73.76% on average. The remainders, such as seeds and peel, accounted for 15% and 10.52%, respectively Avocado pulp yield varies from 52.9 and 81.3% of the total fruit weight (Tango et al. 2004). Kruger et al. (1995) observed Hass avocado pulp yield to 71.37%. While Nnaji and Okereke (2016) stated that the pulp makes up 65% of the fruit, the seed is 20% and the skin is 15%. Krumreich et al. (2018) noticed the pulp yield as 71.89%, whereas Ejiofor et al. (2018) evaluated the pulp yield of Hass avocados as 71.37%. Salazar-López et al. (2020) noticed the pulp yield as 73%. Galvao et al. (2014) evaluated three different variants: Fortuna, Collinson and Barker, whose pulp was found to be 75%, 69.5% and 73%, respectively. A study on avocado pulp yields from several cultivars revealed that Fuerte and Hass types had the best performance, with 69.8%, since they have a lighter and smaller seed than other varieties (Jimenez et al. 2021). Salvador-Reyes and Paucar-Menacho (2019) estimated the average flesh output for Hass avocados to be 79.23%. West Indian race avocados had a larger seed and peel weight than other varieties, the fruit weight was also higher, resulting in a higher pulp yield (Table 2).

The avocado pulp had a high moisture level of 67%. These data imply that West Indian race avocado fruit should be adequately handled to retain quality and increased shelf life. The present study's findings agreed with those of (da Vinha et al. 2013), who revealed that the peel, pulp, and seed of Hass avocado fruit exhibited a high moisture content (> 50%). There was no significant difference in the moisture percentage among the treatments; however, when the treated samples were stored for the shelf-life study and were thawed for additional research, their moisture percentage increased. The moisture content increased greater in refrigerated samples than in frozen ones (Table 3).

Table 4 indicates the change in carbohydrate content during refrigerated and deep freezer storage. Though untreated samples of West Indian race avocado had a carbohydrate level of 10.75%, after six months at 4 °C, it substantially decreased to 6.32%. The treatment T_5 followed a similar pattern, but the T_2 retained carbohydrates at 8.87% after 6 months. However, after 6 months in a deep freezer, the

Table 3 Effect of pre-treatments on moisture content in avocado pulp and its stability during storage

	Storage at 4 °C				Storage at – 20 °C			
Treatments	0	2	4	6	0	2	4	6
T1	67.70 ± 0.67	68.91 ± 0.47	70.80 ± 0.67	71.03 ± 0.43	67.70 ± 0.67	68.74 ± 0.60	68.66 ± 0.72	68.03 ± 0.71
T2	67.61 ± 0.55	68.41 ± 0.45	70.54 ± 0.52	72.40 ± 0.34	67.61 ± 0.55	68.11 ± 0.35	68.71 ± 0.44	68.97 ± 0.14
T3	66.9 ± 0.55	67.11 ± 0.43	69.89 ± 0.37	70.59 ± 0.43	66.9 ± 0.55	67.3 ± 0.23	67.89 ± 0.11	67.96 ± 0.46
T4	67.13 ± 0.95	68.61 ± 0.48	71.40 ± 0.24	72.99 ± 0.75	67.13 ± 0.95	67.49 ± 0.85	68.33 ± 0.41	68.13 ± 0.15
T5	67.88 ± 0.32	69.21 ± 0.62	70.94 ± 0.52	71.33 ± 0.49	67.88 ± 0.32	68.04 ± 0.44	68.58 ± 0.59	68.98 ± 0.74

*Results are presented as mean ± standard derivation

**The values are mentioned in percentage

Table 4 Effect of pre-treatments on carbohydrates in avocado pulp and its stability during storage

	Storage at 4 °C				Storage at – 20 °C			
Treatments	0	2	4	6	0	2	4	6
T1	10.75 ± 0.32	9.00 ± 0.42	8.29 ± 0.71	6.32 ± 0.66	10.75 ± 0.32	9.81 ± 0.36	9.28 ± 0.52	7.93 ± 0.62
T2	10.39 ± 0.47	9.81 ± 0.41	9.10 ± 0.60	8.87 ± 0.25	10.39 ± 0.47	10.05 ± 0.56	10.16 ± 0.43	10.14 ± 0.23
T3	10.13 ± 0.59	9.17 ± 0.25	8.40 ± 0.47	7.76 ± 0.38	10.13 ± 0.59	10.12 ± 0.15	10.06 ± 0.06	9.98 ± 0.11
T4	10.10 ± 0.32	8.50 ± 0.40	8.00 ± 0.45	7.46 ± 0.40	10.10 ± 0.32	9.42 ± 0.39	9.13 ± 0.34	9.03 ± 0.15
T5	10.23 ± 0.58	8.60 ± 0.28	7.31 ± 0.36	6.57 ± 0.29	10.23 ± 0.33	9.28 ± 0.08	9.02 ± 0.06	8.73 ± 0.36

*Results are presented as mean ± standard derivation

**The values are mentioned in percentage avocado pulp preserved the same percentage of carbohydrates in T_2 (10.14%). The decrease in the carbohydrates may result from the breakdown of the polysaccharides into simpler components (Nnaji and Okereke 2016).

The fat content of the avocado from the West Indian race is 13.63%, which dropped to 11.82% by the sixth month. There was a significant difference in the fat percentage between the treatments during storage (Table 5). For all pre-treatments, the fat content decreased when kept at 4 °C. While the fat in the avocado pulp in the deep freezer was also reduced to 12% except for T2 treatment, which was maintained at 13%. The hydrolysis of triacyl glycerides results in the accumulation of free fatty acids, which can be explained by the activity of lipase enzymes and phospholipase. Similar studies were reported by Lurie et al. (1987), Kolodyaznaya et al. (2019) and Flores et al. (2017).

Concerning the protein content, the untreated pulp had a protein level of 2.57% (Table 6). The protein decreased significantly during refrigerated storage and was cut down to 1.41%. All of the pre-treatments in the refrigerator followed the same pattern. However, for storage at – 20 °C except for T_2, all pre-treatments show a slight decline. The Maillard reaction strongly depends on the storage conditions such as temperature, water activity, time and compositions. Within these factors, temperature and carbohydrate content have the most significant impact on the extent of the Maillard reaction Garcia-Amezquita et al. (2014), Gullón et al. (2016), Norwood et al. (2017). When stored, several amino acids in protein powders can undergo deamidation, transamidification, dehydration, β-elimination reaction, and isomerization (Geiger and Clarke 1987; Gerrard 2002). These reactions will also result in changes in protein content. The results were in agreement with other studies reported by Isah (2017), Patras et al. (2011), Bekele et al. (2020) and Aimi Azira et al. (2021).

The acidity of the pre-treated samples ranged from 0.30 to 0.38% on day zero (Table 7). The change in acidity was more significant for refrigerated storage than deep freezer. The acidity of the T2 treatment was lower when compared to other treatments. It is reported that acidity increases as the storage time increase. The increase is due to the conversion of complex carbohydrates into simpler ones and later, a rise in acidity evidenced its conversion. The other reason Calvo-Garrido et al. (2008) suggested is the release of acids in the vacuoles. Comparable studies were carried out in avocado puree by Jacobo-Velázquez and Hernández-Brenes (2012), Parasnis et al. (2000) in papaya chutney, Daisy et al. (2004), Ghimire (2022) in dehydrated aonla, Sharma et al. (2006) in dehydrated apple rings, Sra et al. (2014) in dehydrated carrot slices.

After quick pulping, the pulp displayed greater L* and b* values in T_1 samples. The 'L' value in refrigerated storage decreased with time, reaching 38 in the sixth month, whereas the a-value varied from -9.93 on the first day to + 8.44 on

Table 5 Effect of pre-treatments on fat content in avocado pulp and its stability during storage

	Storage at 4 °C				Storage at – 20 °C			
Treatments	0	2	4	6	0	2	4	6
T1	13.63 ± 0.60	13.38 ± 0.42	12.52 ± 0.46	11.82 ± 0.16	13.63 ± 0.60	13.27 ± 0.38	12.74 ± 0.53	12.45 ± 0.70
T2	13.30 ± 0.66	12.50 ± 0.50	11.78 ± 0.78	11.76 ± 0.38	13.30 ± 0.66	13.26 ± 0.53	13.19 ± 0.28	13.01 ± 0.08
T3	13.31 ± 0.68	12.83 ± 0.32	12.31 ± 0.80	11.79 ± 0.48	13.31 ± 0.68	12.99 ± 0.33	12.97 ± 0.32	12.64 ± 0.47
T4	13.33 ± 0.40	12.90 ± 0.16	12.39 ± 0.66	11.77 ± 0.73	13.33 ± 0.40	13.19 ± 0.28	12.90 ± 0.22	12.60 ± 0.51
T5	13.34 ± 0.22	13.02 ± 0.23	12.24 ± 0.37	11.95 ± 0.78	13.34 ± 0.22	13.22 ± 0.28	12.99 ± 0.05	12.46 ± 0.41

*Results are presented as mean ± standard derivation

**The values are mentioned in percentage

Table 6 Effect of pre-treatments on protein content in avocado pulp and its stability during storage

	Storage at 4 °C				Storage at – 20 °C			
Treatments	0	2	4	6	0	2	4	6
T1	2.57 ± 0.42	1.68 ± 0.16	1.59 ± 0.14	1.41 ± 0.20	2.57 ± 0.42	2.07 ± 0.13	1.96 ± 0.13	1.95 ± 0.14
T2	2.35 ± 0.27	2.14 ± 0.26	1.51 ± 0.21	1.22 ± 0.13	2.35 ± 0.27	2.22 ± 0.22	2.09 ± 0.14	2.05 ± 0.09
T3	2.11 ± 0.15	1.91 ± 0.12	1.75 ± 0.25	1.38 ± 0.31	2.11 ± 0.15	2.05 ± 0.15	1.71 ± 0.34	1.44 ± 0.46
T4	2.17 ± 0.24	1.97 ± 0.32	1.71 ± 0.19	1.46 ± 0.19	2.17 ± 0.24	2.12 ± 0.22	1.84 ± 0.10	1.68 ± 0.19
T5	2.04 ± 0.50	1.97 ± 0.50	1.61 ± 0.48	1.36 ± 0.37	2.04 ± 0.50	1.83 ± 0.23	1.69 ± 0.38	1.59 ± 0.26

*Results are presented as mean ± standard derivation

**The values are mentioned in percentage

Table 7 Effect of pre-treatments on acidity in avocado pulp and its stability during storage

Treatments	Storage at 4 °C				Storage at − 20 °C			
	0	2	4	6	0	2	4	6
T1	0.30 ± 0.05	0.58 ± 0.09	0.86 ± 0.12	1.05 ± 0.11	0.30 ± 0.05	0.43 ± 0.11	0.58 ± 0.10	0.65 ± 0.12
T2	0.33 ± 0.10	0.41 ± 0.04	0.57 ± 0.12	0.84 ± 0.09	0.33 ± 0.10	0.37 ± 0.09	0.49 ± 0.10	0.50 ± 0.07
T3	0.38 ± 0.06	0.47 ± 0.06	0.75 ± 0.06	0.90 ± 0.07	0.38 ± 0.06	0.41 ± 0.07	0.52 ± 0.09	0.58 ± 0.06
T4	0.34 ± 0.06	0.52 ± 0.11	0.65 ± 0.11	0.93 ± 0.06	0.34 ± 0.06	0.45 ± 0.06	0.51 ± 0.08	0.74 ± 0.07
T5	0.38 ± 0.09	0.53 ± 0.16	0.84 ± 0.10	1.00 ± 0.13	0.38 ± 0.09	0.45 ± 0.05	0.64 ± 0.06	0.75 ± 0.17

*Results are presented as mean ± standard derivation

**The values are mentioned in percentage

Table 8 Effect of pre-treatments on avocado pulp color and its storage stability at 4 °C

Months		0	2	4	6
T1	L	81.24	69.24	50.79	38.19
	a	− 9.93	2.42	4.87	8.44
	b	64.39	56.81	37.63	20.65
T2	L	79.38	65.15	59.34	52.27
	a	− 9.87	− 6.08	3.99	6.84
	b	63.24	54.80	42.73	31.68
T3	L	78.8	69.42	60.75	51.38
	a	− 2.83	− 0.30	4.83	7.69
	b	61.35	50.00	41.36	33.89
T4	L	76.37	66.47	59.08	57.47
	a	− 8.92	− 7.10	3.89	5.12
	b	62.03	54.83	46.74	37.54
T5	L	77.19	70.03	65.39	59.83
	a	− 8.48	− 0.07	2.18	4.64
	b	62.89	43.96	40.39	39.45

the sixth (Table 8). While among the treatments, the T_5 had a better L value (59.83) in the sixth month than all other pre-treatments. The main finding was that the browning of the avocado pulp was only evident on the crust, while the pulp retained its color in the inner portions of the container (Fig. 2). The intensity of browning depends on the factors combined to preserve the purees, the packaging material and its atmosphere. Soliva et al. (2000) and Salvador-Reyes and Paucar-Menacho (2019) reported similar studies in this aspect. On the other hand, the samples in the freezer showed relatively minor color changes.

The sensory evaluation of the pulp was performed only on the first day of pre-treatments. The data (Table 9) revealed that treatment T5 showed the highest score, while treatment T3 reported the minimum score. On statistical evaluation by analysis of variance (ANOVA), T5 (2% Brine and 2% citric acid) had no significant difference from the control (T1), while all other treatments had a significant effect on their organoleptic characteristics. The results imply that the T5 treatment is the most acceptable with reference since it is similar to the untreated avocado pulp. This indicates that consumers prefer avocado pulp with intense color. There were no variations in preference concerning taste and texture. Latapi and Barrett (2006) reported that brine and citric acid treatment would stabilize the color and texture and prevent the leaching out of essential constituents than other pre-treatments.

The findings of the purchase intention survey reveal that customers favored the 'T5' and control samples. In comparison, a significant proportion of them said that they would not purchase avocado pulp from treatment 'T3'. The current study established that avocados grown in Kodaikanal, Tamilnadu state, had a different composition than those grown in other geographical places. This variance might be explained by the temperature and soil conditions in which it flourishes. According to the study, avocado fruit has a greater concentration of most chemical components. Additionally, it would be a beneficial dietary supplement.

Conclusion

The current study's findings led us to infer that West Indian race avocados are feasible for pulp production due to their high pulp output of 73.76%. Additionally, the pre-treatments accompanied with 2% brine and 2% citric acid for 3 min preserved the green color and brightness of the pulp, preventing enzymatic browning even after 6 months under refrigerator conditions. The 'T2' and 'T3' pre-treatments added the product's acid stability, extending its shelf life more than the other treatments. Thus, the ideal duration and pre-treatment temperature for preparing West Indian race avocado pulp was 70 °C for 3 min since this treatment retard enzymatic browning, thus preserving the pulp's organoleptic features (taste, smell, and color). The chemical contents of the pulp at – 20 °C did not change significantly between the control and pre-treated avocado pulp; however, the browning effect had a significant difference. This study revealed that it is practically viable

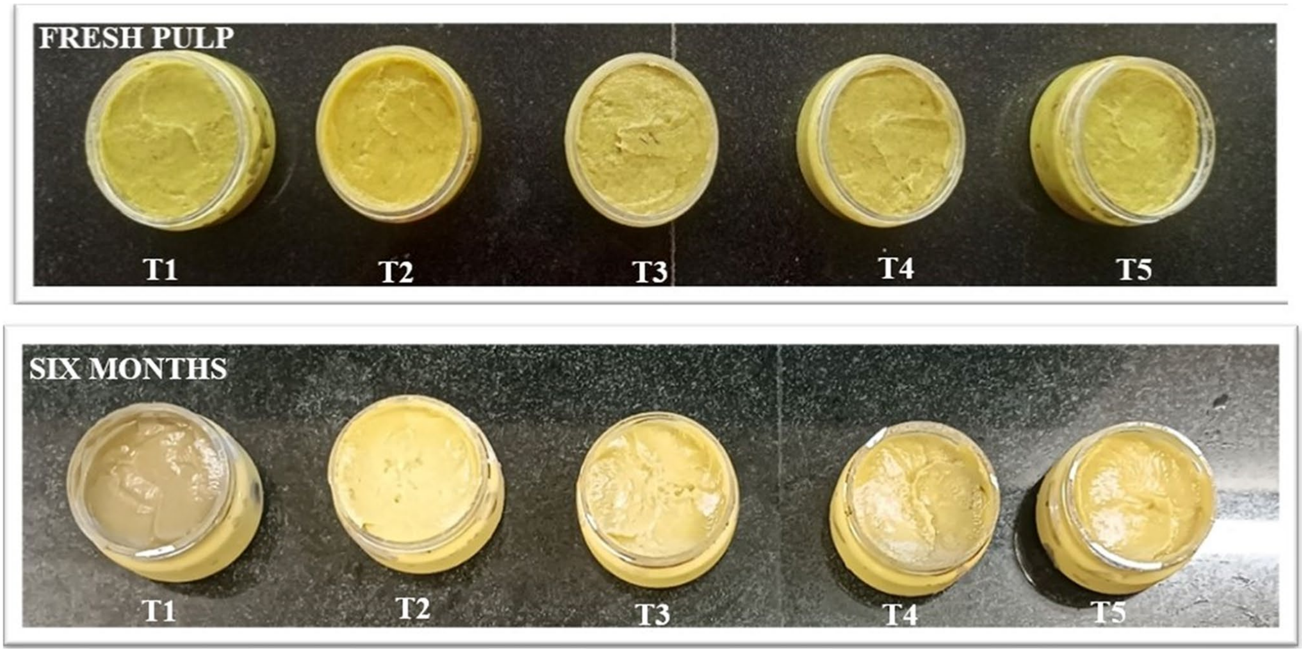

Fig. 2 Changes in pulp color on zero-day and at 6 months

Table 9 Changes in the organoleptic quality (9 Point scale) of pre-treated avocado pulp

Pre-treatments	Sensory characteristics				
	Color and appearance	Taste	Texture	Mouthfeel	Overall acceptability
T1	8.9	8.5	8.2	8.5	8.5
T2	7.5	7.8	7.9	8.2	7.9
T3	6.5	7.8	7.8	7.9	7.5
T4	7.4	7.4	7.7	8.1	7.7
T5	8.1	7.9	7.9	8.1	8.0

to conserve fruit for 6 months when handled appropriately. As a result, customers will have access to avocados throughout the year, which will aid in developing high-value goods, resulting in increased revenue for growers and businesses.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s42535-022-00506-z.

Author contributions We, RA and Dr. JPB declare that this work was done by the authors named in this article and all liabilities pertaining to claims relating to the content of this article will be borne by the authors". The conception and design, analysis and interpretation of data, the drafting of the article, was performed by RA, while the critical revision and evaluation were performed by Dr. JPB.

Declarations

Conflict of interest No conflict of interest associated with this work.

References

Aimi Azira S, Wan Zunairah WI, Nor Afizah M, Nor-Khaizura MAR, Radhiah S, Ismail Fitry MR, Nur Hanani ZA (2021) Prevention of browning reaction in banana jam during storage by physical and chemical treatments. Food Res 5(5):55–62. https://doi.org/10.26656/fr.2017.5(5).046

AOAC (2004) Approved methods of association of official analytical chemists (11 th edit)

Bekele M, Satheesh N, J.A S (2020) Screening of Ethiopian mango cultivars for suitability for preparing jam and determination of pectin, sugar, and acid effects on physico-chemical and sensory properties of mango jam. Sci Afr 7:e00277. https://doi.org/10.1016/J.SCIAF.2020.E00277

Calvo-Garrido J, Carilla-Latorre S, Lázaro-Diéguez F, Egea G, Escalante R (2008) Vacuole membrane protein 1 is an endoplasmic reticulum protein required for organelle biogenesis, protein secretion, and development. Mol Biol Cell 19(8):3442–3453

Cowan AK, Wolstenholme BN (2016) Avocado (Aballero, Finglas, & Toldrá (eds.); first). Academic Press, Oxford.

da Vinha A, Moreira J, Barreira S (2013) Physicochemical parameters, phytochemical composition and antioxidant activity of the algarvian avocado (*Persea americana* Mill.). J Agric Sci 5(12):100–109

Daisy P, Averal HI, Modilal RD (2004) Curative properties of Phyllanthus extracts in alloxan diabetic rats. J Trop Med Plants 5:21–27

Duarte PF, Chaves MA, Borges CD, Mendonça CRB (2016) Avocado: characteristics, health benefits and uses. Ciência Rural 46:747–754

Ejiofor NC, Ezeagu IE, Ayoola MB, Umera EA (2018) Determination of the chemical composition of avocado (*Persea americana*) seed. Adv Food Technol Nutr Sci Open J. https://doi.org/10.1714/aftnsoj-se-2-107

Flores G, Blanch GP, del Castillo MLR (2017) Effect of post-harvest methyl jasmonate treatment on fatty acid composition and phenolic acid content in olive fruits during storage. J Sci Food Agric 97(9):2767–2772. https://doi.org/10.1002/jsfa.8104

Galvao M de S, Narain N, Nigam N (2014) Influence of different cultivars on oil quality and chemical characteristics of avocado fruit. Food Sci Technol (Campinas) 34(3):539–546. https://doi.org/10.1590/1678-457x.6388

Garcia-Amezquita L, Martinez-Alvarenga MS, Olivas G, Zamudio-Flores P, Acosta C, Sepulveda DR (2014) Effect of Maillard reaction conditions on the degree of glycation and functional properties of whey protein isolate—maltodextrin conjugates. Food Hydrocolloids 38:110–118. https://doi.org/10.1016/j.foodhyd.2013.11.006

Geiger T, Clarke S (1987) Deamidation, isomerization, and racemization at asparaginyl and aspartyl residues in peptides. Succinimide-linked reactions that contribute to protein degradation. J Biol Chem 262(2):785–794

Gerrard JA (2002) Protein–protein crosslinking in food: methods, consequences, applications. Trends Food Sci Technol 13(12):391–399

Ghimire AS (2022) Effect of pretreatmant and drying temperatures on quality characteristics of dehydrated amla (*Phyllanthus emblica*). Department of Food Technology Central Campus of Technology Institute of~….

Gullón B, Montenegro MI, Ruiz-Matute AI, Cardelle-Cobas A, Corzo N, Pintado ME (2016) Synthesis, optimization and structural characterization of a chitosan–glucose derivative obtained by the Maillard reaction. Carbohyd Polym 137:382–389

Hurtado-Fernández E, Fernández-Gutiérrez A, Carrasco-Pancorbo A (2018) Avocado fruit—*Persea americana*. Exotic Fruits. https://doi.org/10.1016/b978-0-12-803138-4.00001-0

Isah A (2017) Physicochemical, sensory and microbiological properties of syrup and jam prepared from locust bean fruit pulp in storage. Asian J Biotechnol Bioresour Technol 1(3):1–8. https://doi.org/10.9734/ajb2t/2017/35639

Jacobo-Velázquez DA, Hernández-Brenes C (2012) Stability of avocado paste carotenoids as affected by high hydrostatic pressure processing and storage. Innov Food Sci Emerg Technol 16:121–128. https://doi.org/10.1016/j.ifset.2012.05.001

Jimenez P, Garcia P, Quitral V, Vasquez K, Parra-Ruiz C, Reyes-Farias M, Garcia-Diaz DF, Robert P, Encina C, Soto-Covasich J (2021) Pulp, leaf, peel and seed of avocado fruit: a review of bioactive compounds and healthy benefits. Food Rev Intl 37(6):619–655. https://doi.org/10.1080/87559129.2020.1717520

Kolodyaznaya VS, Kiprushkina EI, Shestopalova IA, Broyko YV, Rumiantceva ON, Albulov AI, Rogozina EA (2019) Changes in the fatty acid composition of avocado fruit treated with preparations during storage. Progress Chem Appl Chitin Derivat 24:75–83. https://doi.org/10.1525/PCACD.24.006

Kruger FJ, Stassen PJC, Snijder B (1995) The significance of oil and moisture as maturity parameters for avocados. Proc World Avocado Congress III:285–288

Krumreich FD, Borges CD, Mendonça CRB, Jansen-Alves C, Zambiazi RC (2018) Bioactive compounds and quality parameters of avocado oil obtained by different processes. Food Chem 257(March):376–381. https://doi.org/10.1016/j.foodchem.2018.03.048

Latapi G, Barrett DM (2006) Influence of pre-drying treatments on quality and safety of sun-dried tomatoes. Part I: use of steam blanching, boiling brine blanching, and dips in salt or sodium metabisulfite. J Food Sci 71(1):S24–S31

Lurie S, Sonego L, Ben-Arie R (1987) Permeability, microviscosity and chemical changes in the plasma membrane during storage of apple fruit. Sci Hortic 32(1–2):73–83. https://doi.org/10.1016/0304-4238(87)90018-5

Moon KM, Kwon EB, Lee B, Kim CY (2020) Recent trends in controlling the enzymatic browning of fruit and vegetable products. Molecules 25(12):1–15. https://doi.org/10.3390/molecules25122754

Nations FAOU (2021) Food outlook—biannual report on global food markets: Jun 21. FAO. https://books.google.it/books?id=eNkzEAAAQBAJ

Nnaji JC, Okereke OB (2016) Proximate composition and physicochemical properties of three avocado (*Persea americana*) varieties in Umuahia, Nigeria. J Appl Chem Sci Int 5(4):195–200

Norwood E-A, Pezennec S, Burgain J, Briard-Bion V, Schuck P, Croguennec T, Jeantet R, Le Floch-Fouéré C (2017) Crucial role of remaining lactose in whey protein isolate powders during storage. J Food Eng 195:206–216

Parasnis AS, Gupta VS, Tamhankar SA, Ranjekar PK (2000) A highly reliable sex diagnostic PCR assay for mass screening of papaya seedlings. Mol Breeding 6(3):337–344

Patras A, Brunton NP, Tiwari BK, Butler F (2011) Stability and degradation kinetics of bioactive compounds and colour in strawberry jam during storage. Food Bioprocess Technol 4(7):1245–1252

Princewill-Ogbonna I, Ogbonna P, Ogujiofor I (2019) Proximate composition, vitamin, mineral and biologically active compounds levels in leaves of *Mangifera indica* (Mango), *Persea americana* (Avocado pea), and *Annona muricata* (Sour sop). J Appl Sci Environ Manag 23(1):65–74. https://doi.org/10.4314/jasem.v23i1.11

Salazar-López NJ, Domínguez-Avila JA, Yahia EM, Belmonte-Herrera BH, Wall-Medrano A, Montalvo-González E, González-Aguilar GA (2020) Avocado fruit and by-products as potential sources of bioactive compounds. Food Res Int 138:109774. https://doi.org/10.1016/j.foodres.2020.109774

Salvador-Reyes R, Paucar-Menacho LM (2019) Optimization of the blanching time and temperature in the manufacture of Hass avocado pulp using low quality discarded fruits. Braz J Food Technol 22:1–17. https://doi.org/10.1590/1981-6723.24418

Sharma KD, Kaushal BBL et al (2006) Evaluation of apple cultivars for dehydration. J Food Sci Technol-Mysore 43(2):177

Shikwambana K (2016) Effect of harvest time, post-harvest storage and ripening temperature on fruit quality of reed avocado cultivar. University of Limpopo

Soliva RC, Elez P, Sebastián M, Martín O (2000) evaluation of browning effect on avocado purée preserved by combined methods. Innov Food Sci Emerg Technol 1(4):261–268. https://doi.org/10.1016/S1466-8564(00)00033-3

Sra SK, Sandhu KS, Ahluwalia P (2014) Effect of treatments and packaging on the quality of dried carrot slices during storage. J Food Sci Technol 51(4):645–654

Tango JS, Carvalho CRL, Soares NB (2004) Physical and chemical characterization of avocado fruits aiming its potencial for oil extraction. Rev Bras Frutic 26:17–23

Villa-Rodríguez JA, Molina-Corral FJ, Ayala-Zavala JF, Olivas GI, González-Aguilar GA, Villa-Rodr'iguez JA, Molina-Corral FJ, Ayala-Zavala JF, Olivas GI, González-Aguilar GA (2011) Effect of maturity stage on the content of fatty acids and antioxidant activity of "Hass" avocado. Food Res Int 44(5):1231–1237. https://doi.org/10.1016/j.foodres.2010.11.012