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ORIGINAL PAPER

Effect of Processing on Color, Rheology and Bioactive Compounds of Different Sweet Pepper Purees

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Abstract

Sweet pepper purees (red, yellow and green) were examined for FTIR (Fourier-transform infrared spectroscopy), chemical, bioactive, color and rheological parameters. FTIR technique was used to evaluate the functional groups. FTIR wave numbers are associated with the absorption bands that depicted the presence of several phytocompounds in the purees. Among the chemical parameters, water activity varied non-significantly whereas, total soluble sugars (TSS), sugars and pH increased after processing of the fruits into purees. The presence of bioactive compounds depends on the variety of sweet pepper. The red puree had significantly higher carotenoids, phenolics and antioxidant capacity followed by yellow and green pepper purees. The minimal change was observed in the color of purees during processing. The purees were subjected to different shear rate (1 to 50 s^{-1}) to evaluate the effect on viscosity and shear stress that is desirable for its end use in different food products. All purees show the shear thinning behavior as shear rate increased. Results revealed that heat processing of sweet peppers didn't affect color, sugars, carotenoids, phenolics and antioxidant capacity to a greater extent. The finding will be helpful to manage seasonal bulk production efficiently and make them available as an ingredient in various food products.

Keywords Antioxidant activity · FTIR · Power model · Rheology · Water activity

Abbreviations

ATR	Attenuated total refection
FTIR	Fourier-transform infrared spectroscopy
GSP	Green sweet pepper
RSP	Red sweet pepper
SHU	Scoville heat units
TSS	Total soluble solids
YSP	Yellow sweet pepper

Introduction

Historically, the consumption of fruits and vegetables has been proved to reduce the risk of several diseases such as inflammation, hypertension, diabetes, carcinogenic and cardiovascular diseases [1]. Sweet peppers (*Capsicum annuum*) are a popular vegetable crop that is consumed and cultivated worldwide and their popularity is increasing due to varied aroma, flavor, color and nutritional value [2]. Capsicum species are generally divided into two main groups based on their pungency and measured in Scoville heat units (SHU): non-pungent or sweet fruits (sweet pepper, bell pepper, paprika, sweet chili) and pungent or hot fruits (chili, spicy pepper, hot pepper, hot paprika, cayenne). Pungency, flavor and aroma characteristics make this product an important component in millions of people's routine diets. Capsaicinoids, piperine and other related compounds in addition to their medicinal properties impart pungency to hot peppers [3, 4].

Capsicum fruits vary in shape, size and color among the species. The bright red color of red sweet pepper is ascribed to capsorubin, capsanthin and cryptocapsin while the yellow color is due to β-cryptoxanthin, β-carotene, violaxanthin and zeaxanthin. The green color of sweet pepper is due to its chlorophyll content [5]. In the sweet peppers, flavonoids are ubiquitous polyphenols along with other bioactive compounds. These are abundant in aglycones and glycosides of quercetin, myricetin, kaempferol, luteolin, and apigenin.

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These bioactive compounds exhibit excellent antioxidative, anti-mutagenic, anti-inflammatory and anti-carcinogenic properties. The possible health benefits of these compounds rely on their absorption and metabolism during passage through the small intestine walls into the circulatory system and subsequent transport to the liver in the portal vein. Polyphenols improve the quality of blood vessel walls and regulate the action of various enzymes and cell receptors [6].

Despite their health benefits, the use of sweet peppers is limited as these are highly perishable since the crop shows the signs of deterioration like shriveling, wilting and decay during storage [7]. So it is important to devise processing methods to extend the shelf life along with the retention of nutrients. Various studies reported the shelf life extension and preservation of sweet peppers by different ways such as mild pressure treatments and thermal blanching of yellow sweet pepper [8], processing of red bell pepper into paste [9], preparation of bell pepper based instant chutney powder [10], variation in packaging material and ozone gas treatment improves pepper paste quality [11].

Sweet pepper purees and paste are added in a variety of foods as a flavoring and coloring ingredient and also used as the base ingredient for the development of other products such as sauces, ketchup, etc. [9]. High-temperature processing is the most widely used method for the production of purees and pastes due to its low cost and simple technique. However, the processing of purees resulted in changes in color and bioactive composition. Moreover, only a few studies are available on the preparation of red, yellow and green sweet pepper purees. There is also a need to study the rheological properties of purees that affects its end-use. Therefore, the objective of the present work is to study the effect of processing on rheology, color and bioactive attributes of different colored sweet peppers.

Materials and Methods

Plant Materials

Fresh and good quality red (var. *Inspiration*), yellow (var. *Bachata*) and green (var. *Indra*) sweet peppers were purchased from the commercial green house. Fruits were washed and stored under refrigeration conditions (±4 °C) until further use.

Preparation of Puree

All sweet peppers (500 g) were sliced into 5–8 mm thickness and then blanched at 85 °C for 3–4 min to inactivate enzyme activity. Slices were cooled immediately with fresh cold water. After the drainage of water, purees were obtained by blending the slices separately in the mixer (Philips 750-W Mixer Grinder) and stained through 14 mesh screen to obtain uniform purees (Fig. 1). After that, purees were poured in the sterilized glass containers (500 ml) and stored under refrigeration conditions (±4 °C) until further analysis.

Chemical Analysis

Raw fruits and purees of red, yellow and green sweet peppers were analyzed for water activity, TSS, pH, total and reducing sugars [12], color and FTIR (see Supplementary Material for additional details).

Bioactive Analysis

All the samples of sweet peppers were analyzed for carotenoid, chlorophyll and ascorbic acid by following the standard method [12]. For bioactive analysis, samples were extracted using methanol by following the procedure of Kaur et al. [13]. The total phenols and flavonoids of samples were measured by the method described by Aludatt et al. [14] and Bagul et al. [15], respectively with slight modifications. The *in vitro* antioxidant was measured by DPPH [14], reducing power assay [16] and metal chelating activity [17] (see Supplementary Material for additional details).

Rheological Measurements

Rheological measurements were carried out using MCR 74 rheometer (Anton Paar, GmbH, Germany) with stainless steel plate-plate (PP 50) geometry. The 2 g sample was placed and compressed to a gap size of 1 mm. The steady shear (η vs. γ) and (τ vs. γ) experiments were conducted at increasing strain rate values ranging from 1 to 50 s^{-1}. The power model has been employed to describe the rheological properties of the purees using SPSS 18.0 statistical software (see Supplementary Material for additional details).

Statistical Analysis

The results of all analysis were expressed as the mean ± S.D. of three replicates. The results of all the samples were expressed on 12% moisture content. The data were subjected to ANOVA followed by Duncan's multiple range tests with $p \leq 0.05$ significance level on SPSS 18.0 statistical software (SPSS Inc.).

Results and Discussion

FTIR Spectra of Sweet Pepper Purees

FTIR spectra and characteristic peaks of all purees (red, yellow and green) are presented in Table 1 and Fig. 2. FTIR

Fig. 1 Image of (**a**) red (**b**) yellow and (**c**) green sweet pepper purees

spectroscopy was applied to identify the functional bonds in different sweet pepper purees. All samples which showed the absorption bands in the range of 3273–3310 cm^{-1} indicate the presence of hydroxyl groups. The peak ranging between 2920 and 2924 cm^{-1} (aliphatic C-H stretch) and 913–958 cm^{-1} (stretching C-CH, C-OH) represents the presence of carbohydrates. Whereas, CH_3 asymmetrical/ symmetrical stretch (1379–1396), asymmetrical C-O-C stretch (1242–1247 cm^{-1}), stretching CH-CH, C-CH and C-OH (1027–1052 cm^{-1}), show the presence of phenolic compounds. The highest peak (wave-number) among different functional groups was observed in red followed by yellow and green puree. The interpretation of the functional group was done according to the previous studies [18, 19].

Effect of Processing on the Chemical Parameters of Sweet Peppers

The small difference was observed in the chemical parameters of the purees during processing as depicted in Table 2. The water activity of fresh sweet peppers was 0.855 ± 0.01 (red), 0.850 ± 0.01 (yellow) and 0.846 ± 0.01 (green). These results confirm that peppers are highly perishable due to their high water activity. Non-significant ($p \leq 0.05$) variation was observed in water activity between the fresh and processed samples. The TSS of sweet peppers ranged between 5.40 (green) to 6.40 (red). The TSS of the sweet peppers was in line with values obtained by Alsadon et al. [20]. However, significant ($p \leq 0.05$) upsurge of TSS was observed in purees samples irrespective of the variety of sweet pepper. This may be contributed to the release of sugars during processing due to the disintegration of the structure of the fruit. The pH of the food is also an important parameter that acts as a hurdle for enzymatic and microbial action, and enhances the shelf life of the food products [21]. The pH of pepper varied from 4.80 ± 0.01 (yellow) to 5.40 ± 0.02 (green). Variation in the pH of the purees indicates the loss of volatile organic acid during the processing of sweet peppers. Similarly, little but significant ($p \leq 0.05$) increase was observed in total sugar content of purees after processing from 6.29 ± 0.03 to 6.34 ± 0.02 (red), 6.11 ± 0.05 to 6.18 ± 0.02 (yellow), 5.78 ± 0.04 to 5.84 ± 0.02 mg/100 g (green). However, reduction in soluble sugars was observed due to the loss of some water-soluble sugars during processing [22].

Table 2 shows the color values of fresh sweet peppers and after subjecting it to heat treatment. Color of purees is highly desirable since purees are utilized as a coloring agent in the development of various products [9]. The values for the L*,

Table 1 FTIR spectra (wave-number cm^{-1}) of red, yellow and green sweet pepper purees

Functional groups	RSP	YSP	GSP
Hydroxyl group, H-bonded OH stretch (water)	3289.6	3273.0	3309.8
Aliphatic C- H stretch (carbohydrates)	2922.3	2924.2	2920.4
CH_2 asymmetrical/symmetrical stretch	2855.0	2854.0	2853.0
C=O stretch	1620.1	1619.7	1606.0
CH_3 asymmetrical/symmetrical stretch, (phenols)	1396.3	1381.5	1379.5
Asymmetrical C-O-C stretch, Aromatic -O-H, C-O stretch (alcohols, phenols)	1247.0	1242.0	1247.4
Stretching (CH-CH), C-O stretching (phenols)	1051.3	1052.4	1027.0
Stretching C-CH, C-OH (carbohydrates)	922.3	913.7	958.1
Aromatic phosphates (P-O-C) stretch, C-O epoxy and oxirane ring	866.3	866.6	806.9
Skeletal C-C vibrations	777.5	817.9	769.2
Out-of-plane CH bending	700.0	776.4	728.3

RSP, Red sweet pepper; *YSP*, Yellow sweet pepper; *GSP*, Green sweet pepper

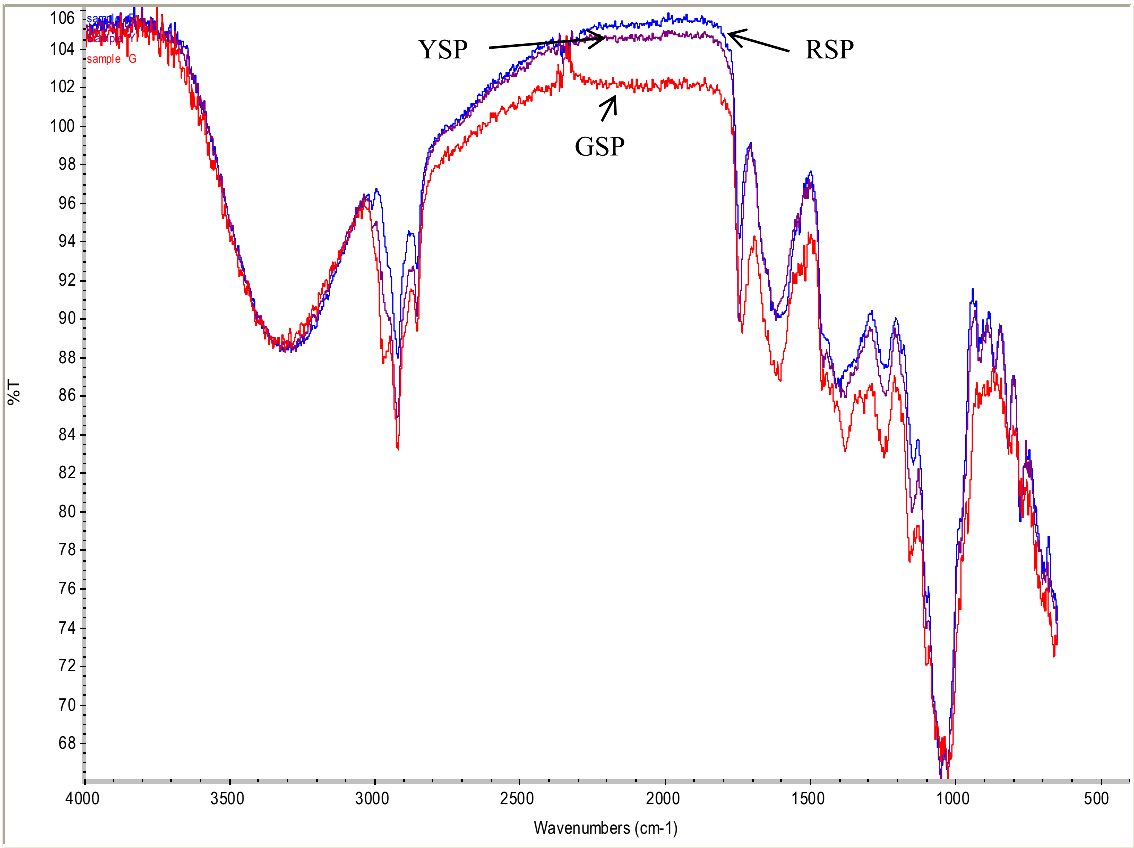

Fig. 2 FTIR spectral (cm^{-1}) of sweet red (RSP), yellow (YSP) and green (GSP) pepper purees

Table 2 Chemical and bioactive composition of fresh sweet peppers and purees

Parameters	RSP	RSP puree	YSP	YSP puree	GSP	GSP puree
Water activity	0.855 ± 0.02^{aA}	0.858 ± 0.02^{A}	0.850 ± 0.01^{bA}	0.848 ± 0.02^{A}	0.846 ± 0.02^{cA}	0.850 ± 0.02^{A}
TSS (º brix)	6.40 ± 0.01^{aA}	7.00 ± 0.01^{B}	6.30 ± 0.01^{bA}	7.00 ± 0.01^{B}	5.40 ± 0.01^{cA}	6.00 ± 0.01^{B}
pH	5.20 ± 0.01^{aA}	5.27 ± 0.02^{B}	5.08 ± 0.01^{bA}	5.23 ± 0.01^{B}	5.40 ± 0.02^{cA}	5.53 ± 0.02^{B}
Total sugars (Glu mg/100 g)	6.29 ± 0.03^{aA}	6.34 ± 0.02^{B}	6.11 ± 0.05^{aA}	6.18 ± 0.02^{B}	5.78 ± 0.04^{aA}	5.84 ± 0.02^{B}
Reducing sugars (Glu mg/100 g)	3.86 ± 0.04^{aA}	3.71 ± 0.02^{B}	3.74 ± 0.03^{aA}	3.57 ± 0.02^{B}	3.41 ± 0.06^{aA}	3.32 ± 0.02^{B}
Carotenoids (mg/100 g)	745.34 ± 0.04^{aA}	734.36 ± 0.07^{B}	648.59 ± 0.05^{aA}	640.28 ± 0.06^{B}	11.31 ± 0.09^{aA}	10.44 ± 0.05^{B}
Chlorophyll (mg/g)	5.23 ± 0.05^{aA}	4.56 ± 0.04^{B}	6.14 ± 0.06^{aA}	4.87 ± 0.08^{B}	15.08 ± 0.11^{aA}	13.87 ± 0.07^{B}
Vitamin C (AAE mg/100 g)	188.21 ± 0.04^{aA}	145.26 ± 0.07^{B}	167.32 ± 0.03^{aA}	121.57 ± 0.05^{B}	120.34 ± 0.07^{aA}	81.56 ± 0.05^{B}
Total phenols (GAE mg/100 g)	803.25 ± 0.11^{aA}	786.52 ± 0.11^{B}	785.65 ± 0.11^{aA}	744.32 ± 0.11^{B}	611.75 ± 0.11^{aA}	598.36 ± 0.11^{B}
Flavonoids (QE mg/100 g)	376.32 ± 0.11^{aA}	351.28 ± 0.11^{B}	412.52 ± 0.11^{aA}	396.54 ± 0.11^{B}	303.55 ± 0.11^{aA}	271.65 ± 0.11^{B}
In vitro antioxidant activity						
DPPH (%)	78.32 ± 0.07^{aA}	73.21 ± 0.03^{B}	73.45 ± 0.04^{aA}	67.46 ± 0.05^{B}	29.58 ± 0.06^{aA}	22.36 ± 0.04^{B}
Reducing power assay (AAE mg/100 g)	478.85 ± 0.05^{aA}	451.36 ± 0.07^{B}	454.12 ± 0.09^{aA}	437.56 ± 0.08^{B}	375.29 ± 0.08^{aA}	368.84 ± 0.05^{B}
Metal chelating activity (EDTA mg/100 g)	205.47 ± 0.07^{aA}	188.57 ± 0.05^{B}	185.64 ± 0.09^{aA}	169.47 ± 0.09^{B}	125.25 ± 0.10^{aA}	107.82 ± 0.05^{B}
Colour						
L*	13.5 ± 0.07^{aA}	17.21 ± 0.07^{B}	49.86 ± 0.07^{aA}	53.14 ± 0.07^{B}	36.79 ± 0.07^{aA}	38.87 ± 0.07^{B}
a*	56.32 ± 0.07^{aA}	53.41 ± 0.07^{B}	7.98 ± 0.07^{aA}	6.32 ± 0.07^{B}	-15.24 ± 0.07^{aA}	11.87 ± 0.07^{B}
b*	8.37 ± 0.07^{aA}	9.75 ± 0.07^{B}	53.21 ± 0.07^{aA}	50.14 ± 0.07^{B}	23.59 ± 0.07^{aA}	20.47 ± 0.07^{B}

Values are expressed as mean ± SD ($n = 3$); RSP- Red sweet pepper; YSP-Yellow sweet pepper; GSP-Green sweet pepper

Mean values within a row with different letters are significantly different ($p \leq 0.05$); Small letters shows significant difference between fresh samples whereas, capital letters shows significant difference between fresh and puree samples a*, and b*coordinates of the sweet pepper was 13.50 ± 0.07, 56.32 ± 0.11, 8.37 ± 0.11 (red), 49.86 ± 0.08, 7.98 ± 0.07 and 53.20 ± 0.09 (yellow) and 36.79 ± 0.11, −15.24 ± 0.13, 23.59 ± 0.11 (green), respectively. Processing causes little but significant ($p \leq 0.05$) change in color parameters (L*, a* and b*) of sweet peppers. The retention of the red and yellow color of the purees indicates the stability of carotenoids during processing. Whereas, in the case of green sweet pepper, after processing remarkable change was observed. The L* (38.87 ± 0.10) and a* (−11.87 ± 0.08) coordinate of the puree elevates whereas, b* (20.47 ± 0.12) coordinate decreased, which indicates the color turned to yellowish as compared to fresh sweet pepper related to the degradation of chlorophyll at blanching temperature. These findings were in agreement with the findings of Kaur et al. [13] who reported the degradation of the color of green pepper at high temperature.

Effect of Processing on the Bioactive Parameters of Sweet Peppers

The carotenoids and chlorophylls of sweet peppers are an important quality index as these are susceptible to oxidation and isomerization reactions during processing hence, affects the color and nutritional value of the product [23]. For carotenoids, the minor loss was observed showing that the processing did not negatively affect the carotenoids in the purees (Table 2). These results were in accordance with the study of Provesi et al. [24] who reported the stability of carotenoids in pumpkin puree after heating. Retention of carotenoids may also be attributed to the inactivation of enzymes, which are responsible for the degradation of carotenoids. However, chlorophyll oxidation takes place at a high temperature which results in loss of green color and chlorophyll content of sweet pepper puree [13]. The ascorbic content of fresh sweet peppers was 188.21 ± 0.04 (red), 167.32 ± 0.03 (yellow) and 120.34 ± 0.07 mg/100 g (green). After processing, a significant decrease was observed in ascorbic acid among all the purees. This is due to the high susceptibility of ascorbic acid to the chemical and enzymatic reactions during the processing of food products [13].

Phytochemicals have been associated with antioxidant and anticancer properties [1] hence, retaining of these compounds through the processing is very important. The study of raw fruits confirmed that sweet peppers are abundant in phenolics and other antioxidant compounds. After processing, red and yellow purees showed a loss of about 2–3% of phenolics, while 5–6% of decrease was observed in green purees. The retention of phenolics is more significant during wet heating than dry heating. This retention was may be due to breakdown cell walls and weaken the bonding forces between phenolics, flavonoids and the tissue matrix during heating, which enhances the release of phytochemicals from the matrix [25]. From Table 2, it can be seen that the flavonoid content of yellow puree was higher as compared to red and green purees. These results were agreement with the study of Ribeiro et al. [26] who reported the stability of bioactive compounds during the processing of fruit Smoothie.

The *in vitro* antioxidant activity was assessed in terms of DPPH, reducing power assay and metal chelating activity. Antioxidant maintains the integrity and functioning of the cells by scavenging the free radicals [6]. The highest antioxidant activity was determined by reducing power assay, *i.e.*, 478.85 ± 0.05 (red), 454.12 ± 0.09 (yellow) and 375.29 ± 0.08 mg/100 g (green). As expected, the antioxidant activity of red and yellow sweet pepper was 2.7 and 2.5-fold higher than that of green sweet pepper. The antioxidant activity of

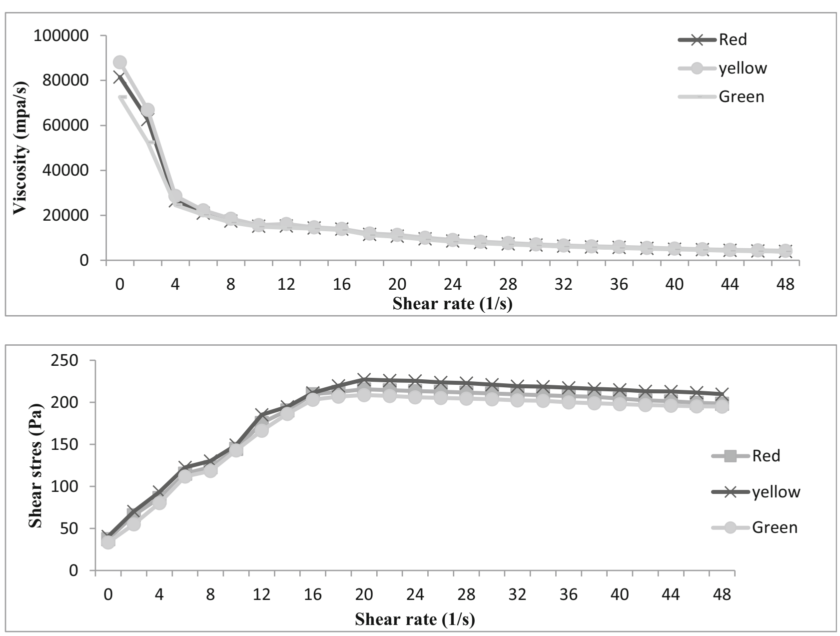

Fig. 3 Rheological characteristics (**a**) steady shear (η vs. γ) (**b**) (τ vs. γ) of sweet pepper purees (red, yellow and green)

sweet peppers may be attributed to flavonoids, ascorbic acid, carotenoids, and phenolics. After processing, little but significant loss was observed in all samples. These results were comparable with the findings of Nguyen et al. [27], who reported the loss of antioxidant activity of plant material at high temperature processing.

Effect of Processing on the Rheological Characteristics of Sweet Peppers

The Fig. 3a represents the viscosity of sweet pepper (red, yellow and green) purees at different shear rate (1 to 50 s^{-1}). The highest values of viscosity were shown by yellow (89,000 mpa s^{-1}) puree due to high TSS value followed by red (78,000 mpa s^{-1}) and green (76,000 mpa s^{-1}) purees. It was observed that the viscosity decreased as the shear rate increased, which indicates the pseudoplastic nature of purees. This viscosity reduction of the purees could be the result of the molecular structure breakage caused by the arrangement of molecular constituents and generated hydrodynamic forces. All sweet pepper purees showed a shear-thinning behavior as observed in other fruit purees [26, 28]. The second graph (Fig. 3b) showed the value of shear stress (τ) versus shear rate (γ). It can be observed that there is non- linear relationship between the shear stress and shear rate, which characterize the non-Newtonian behavior of the purees. These results were in accordance with the studies of Ribeiro et al. [26], who reported the shear-thinning behavior of apple puree.

The data was well fitted ($R^2 > 0.98$) to the power model as shown in Table S1. The behavior index was less than 1 in all the purees, confirmed the non-Newtonian behavior characteristic of the puree samples. Similar behavior was observed for other fruit purees [26, 28].

Conclusion

This study demonstrates that the bioactive compounds of sweet pepper purees were well preserved during processing, presenting the retention of carotenoids (93–98%), ascorbic acid (68–77%), phenolics (94–98%), flavonoids (90–95%) and antioxidant activity (90–92%) in all sweet pepper purees. The sweet pepper purees show shear thinning behavior with pseudoplastic characteristics ($n < 1$). This study concludes that processed sweet pepper purees were rich in bioactive and chemical compounds, thus seasonal bulk can be handled by processing to make them available as an ingredient in various food products.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Human or Animal Studies This article does not contain any studies with human or animal subjects.

References

1. Paredes-López O, Cervantes-Ceja ML, Vigna-Pérez M, Hernández-Pérez T (2010) Berries: improving human health and healthy aging, and promoting quality life-a review. Plant Foods Hum Nutr 65: 299–308
2. Melgar-Lalanne G, Hernández-Álvarez AJ, Jiménez-Fernández M, Azuara E (2017) Oleoresins from *Capsicum* spp.: extraction methods and bioactivity. Food Bioprocess Technol 10:51–76
3. Meckelmann SW, Riegel DW, van Zonneveld M, Ríos L, Peña K, Mueller-Seitz E, Petz M (2015) Capsaicinoids, flavonoids, tocopherols, antioxidant capacity and color attributes in 23 native Peruvian chili peppers (*Capsicum* spp.) grown in three different locations. Eur Food Res Technol 240:273–283
4. Mihăilă B, Dinică RM, Tatu AL, Buzia OD (2019) New insights in vitiligo treatments using bioactive compounds from *Piper nigrum*. Exp Ther Med 17:1039–1044
5. Cervantes-Paz B, Yahia EM, Ornelas-Paz JDJ et al (2012) Effect of heat processing on the profile of pigments and antioxidant capacity of green and red jalapeño peppers. J Agric Food Chem 60:10822–10833
6. Panche AN, Diwan A, Chandra SR (2016) Flavonoids: an overview. J Nutr Sci 5:1–15
7. Bayogan ER, Salvilla R, Majomot AMC, Acosta J (2017) Shelf life of two sweet pepper (*Capsicum annuum*) cultivars stored at ambient and evaporative cooling conditions. South Western J Hort Bio Environ 1:1–15
8. Castro SM, Saraiva JA, Domingues FM, Delgadillo I (2011) Effect of mild pressure treatments and thermal blanching on yellow bell peppers (*Capsicum annuum* L.). LWT-Food Sci Technol 44:363–369
9. Gogus F, Ozel MZ, Keskin H, Yanık DK, Lewis AC (2015) Volatiles of fresh and commercial sweet red pepper pastes: processing methods and microwave assisted extraction. Int J Food Prop 18: 1625–1634
10. Sharma R, Joshi VK (2015) Development and evaluation of bell pepper (*Capsicum annuum* L.) based instant chutney powder. Indian J Nat Prod Resour 5:262–267
11. Uzel AR (2018) Preservation of sweet red pepper paste quality: effect of packing material, ozone gas and protective agent use. Food Sci Technol (Campinas) 38:698–703
12. Ranganna S (1999) Vitamins. In: Ranganna S (ed) Handbook of analysis and quality control for fruits and vegetables. Tata Mcgraw Hill, New Delhi, pp 105–118
13. Kaur R, Kaur K, Ahluwalia P (2019) Effect of drying temperatures and storage on chemical and bioactive attributes of dried tomato and sweet pepper. LWT - Food Sci Technol 117:108604. https://doi.org/10.1016/j.lwt.2019.108604
14. Aludatt MH, Rababah T, Alhamad MN et al (2017) Profiles of free and bound phenolics extracted from *Citrus* fruits and their roles in biological systems: content, and antioxidant, anti-diabetic and anti-hypertensive properties. Food Funct 8:3187–3197
15. Bagul MS, Ravishankara MN, Padh H, Rajani M (2003) Phytochemical evaluation and free radical scavenging properties

of rhizome of *Bergenia ciliata* (Haw.) Sternb. Forma *ligulata* Yeo. J Nat Remed 3:83–89
16. Athukorala Y, Kim KN, Jeon YJ (2006) Antiproliferative and antioxidant properties of an enzymatic hydrolysate from brown alga, Ecklonia cava. Food Chem Toxicol 44:1065–1074
17. Naithani V, Singhal AK, Chaudhary M (2011) Comparative evaluation of metal chelating, antioxidant and free radical scavenging activity of TROIS and six products commonly used to control pain and inflammation associated with arthritis. Int J Drug Dev Res 3: 208–216
18. Coates J (2006) Interpretation of infrared spectra, a practical approach. Encyclopedia of analytical chemistry: applications, theory and instrumentation
19. El Kaaby Ekhlas A, Al Hattab Zahra N, AI-Anny Jenan A (2016) FT-IR identification of capsaicin from callus and seedling of chilli pepper plants *Capsicum annuum* L. *in vitro*. Int J Multidiscip Curr Res 4:1145–1146
20. Alsadon A, Wahb-Allah M, Abdel-Razzak H, Ibrahim A (2013) Effects of pruning systems on growth, fruit yield and quality traits of three greenhouse-grown bell pepper (*Capsicum annuum* L.) cultivars. Aus J Crop Sci 7:1309
21. Quarcoo PC, Wireko-Manu FD (2016) The effect of steam and hot water blanching on some quality attributes of cocoyam leaf. MOJ Food Process Technol 2:164–168
22. Zhang Y, Kahl DH, Bizimungu B, Lu ZX (2018) Effects of blanching treatments on acrylamide, asparagine, reducing sugars and colour in potato chips. J Food Sci Technol 55:4028–4041
23. Kim HG, Bae JH, Jastrzebski Z, Cherkas A, Heo BG, Gorinstein S, Ku YG (2016) Binding, antioxidant and anti-proliferative properties of bioactive compounds of sweet paprika (*Capsicum annuum* L.). Plant Foods Hum Nutr 71:129–136
24. Provesi JG, Dias CO, de Mello Castanho Amboni RD, Amante ER (2012) Characterisation and stability of quality indices on storage of pumpkin (*Cucurbita moschata* and *Cucurbita maxima*) purees. Int J Food Sci Technol 47:67–74
25. Azeez L, Adebisi SA, Oyedeji AO, Adetoro RO, Tijani KO (2019) Bioactive compounds' contents, drying kinetics and mathematical modelling of tomato slices influenced by drying temperatures and time. J Saudi Soc Agric Sci 18:120–126
26. Ribeiro OL, Almeida ACS, de Carvalho CWP et al (2018) Effect of processing on bioactive compounds, physicochemical and rheological characteristics of juçara, banana and strawberry smoothie. Plant Foods Hum Nutr 73:222–227
27. Nguyen VT, Van Vuong Q, Bowyer MC et al (2015) Effects of different drying methods on bioactive compound yield and antioxidant capacity of *Phyllanthus amarus*. Dry Technol 33:1006–1017
28. Gouvêa RF, Ribeiro LO, Souza ÉF, Penha EM, Matta VM, Freitas SP (2017) Effect of enzymatic treatment on the rheological behavior and vitamin C content of *Spondias tuberosa* (umbu) pulp. J Food Sci Technol 54:2176–2180