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ORIGINAL RESEARCH PAPER

THE INFLUENCE OF GENTLE PROCESSING OF ORANGE SWEET POTATO ON QUALITY PROPERTIES OF PUREES

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Abstract

Ipomoea batatas L. represents one of the most important tuber crops, after potato, and could be a real aid in preventing food insecurity, and malnutrition or sustaining a healthier lifestyle. Four thermal treatments were used to process the raw sweet potatoes into ready-to-eat products: boiling, steaming and steaming coupled with ohmic heating at two different voltage gradients (17.5 V/cm and 20 V/cm). Proximate composition, phytochemicals content, color parameters, viscosity, and texture as the main quality properties of the orange sweet potato purees were determined. The sample processed through steaming coupled with ohmic heating registered higher values for the total phenolic content (4.60±0.30 - 5.15±0.15 mg GAE/g DW) and total flavonoids content (7.07±0.41 - 7.66±0.88 mg EQ/g DW), compared to the control sample (4.33±0.28 mg GAE/g DW for the and 4.52±0.30 mg EQ/g DW, respectively), when determining the phytochemical profile. Among all the applied heat treatments, the mastication process was significantly improved when combining steaming with ohmic heating. These results are promising for developing new ready-to-eat products containing high nutritive tubers.

Keywords: orange sweet potatoes, puree, steaming, ohmic heating

Introduction

Human nutrition is one of the top concerns of nowadays food specialists. Fruits and vegetables remain the most valuable sources of high-quality nutrients. The multitude of vegetable varieties and their availability recommend them to be used as a constant source of food with important health benefits. One of the most consumed crops in the world is represented by orange sweet potato (*Ipomoea batatas* L.). Consumed for the edible part, represented by the tuber, it remains an important source of carbohydrates and bioactive compounds (Zhang *et al.*, 2023). Compared to potatoes

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(*Solanum tuberosum* L.), which have a glycemic index between 65 and 101, sweet potatoes have a glycemic index only between 63 and 66, which results in a less immediate impact on blood glucose levels. They are also a good source of fibers (1.3–3.8%), antioxidants, minerals such as zinc, potassium, sodium, magnesium, calcium, iron, vitamins (A and C), and pigments (beta-carotene), containing lower levels of fat (0.2%) and protein (0.49–2.24%) compared to potatoes (Selvakumaran *et al.*, 2019).

However, palatability, an essential property in consumers` choice is directly influenced by the processing method. Conventional methods tend to be slow, and the surface of the food is always heated to a considerably higher temperature than the rest of the food. Ohmic heating has the ability to be far more rapid and to process food more thoroughly (Bozkurt and Icier 2010). The ohmic heating is based on direct energy application in the entire volume of foods, ensuring positive effects equivalent to those of the long heat treatment (Zell *et al.*, 2010). On the other hand, steaming, which processes food over a longer time period, provides advantages that include uniform heat distribution and an enhanced water-retaining capacity after thermal treatment (Xu *et al.*, 2016).

The main objective of this study was to contribute to the development of healthy ready-to-eat products by processing a tuber with numerous nutritional properties, such as orange sweet potato, and to study the impact of different processing methods on their quality properties.

Materials and methods

Materials

The orange sweet potatoes were purchased from the Research and Development Station for Plant Culture on Sandy Soils, Dăbuleni, Dolj, Romania, between April and June 2023.

Sample preparation

The orange sweet potatoes were washed, peeled and then cut into slices of 2 cm thickness and about 4–5 cm diameter, each slice being divided into four parts.

For the further preparation steps into purees samples, the following utensils were used: an electric pot LazyPot (Oradea, Romania) of 3 L, 220V/600 W to boil the sweet potatoes, a Zelmer 37Z010 steamer cooker (Warsaw, Poland) of 8.5 L, 900W, with 3 slots, and the ohmic heating batch experimental installation of 10 kW and 50 Hz. A vertical mixer (Bosch ErgoMixx 1000W, Göcklingen, Germany) was finally used for 2 min at 1900 rpm, to produce the purees.

Experimental setup

The slices of raw sweet potatoes (M) were processed until the core centre temperature was 89±1.5 °C by using four methods namely:

(i) boiling in water for 30 minutes (sample coded F),

(ii) steaming for 30 minutes (sample coded S),

(iii) steaming for 20 minutes coupled with ohmic heating at 17.5 V/cm for 3 minutes (sample coded SIO17.5), and

(iv) steaming for 20 minutes coupled with ohmic heating at 20 V/cm for 3 minutes (sample coded SIO20). To turn them into purees, the processed potatoes were blended until puree consistency. The samples were packed into sealed jars and stored at refrigeration temperature (4 °C) until further determinations.

Proximate composition analysis

Moisture (AOAC 925.09), protein (AOAC 979.09), fat (AOAC 923.05), ash (AOAC 923.03) and crude fiber (AOAC 962.09) contents were determined according to the standard procedures described by Association of Official Analytical Chemists (AOAC, 2000) and expressed in grams per 100 g.

Total carbohydrate content was calculated by difference using the Eq. (1) (Rodrigues *et al.*, 2016).

$$\text{Total carbohydrates (\%)} = 100 - (\text{Mo} + \text{Pr} + \text{L} + \text{As} + \text{F}) \qquad (1)$$

where: Mo = moisture, %; Pr = proteins, %; L = lipids, %; As = ash, %; F = crude fiber, %.

Determination of energy value

Total energy was obtained using Atwater conversion factors: fat 37 kJ/g (9 kcal/g), protein and carbohydrates 17 kJ/g (4 kcal/g).

Total energy content (VE) was calculated using Eq. (2) (Zulkifli *et al.*, 2020).

$$\text{VE (kcal/100g)} = (4\times\%\ \text{Protein}) + (9\times\%\ \text{Fat}) + (4\times\%\ \text{Carbohydrate}) \qquad (2)$$

Determination of nutritional value of 10 components (VN_{10})

The nutritional value of orange sweet potato (raw and purees) was calculated considering 10 main constituents of foods: proteins, lipids, carbohydrates, minerals Ca, P, Fe and vitamins A, B_1, B_2 and C (Table 1). The nutritional value of 10 components (VN_{10}) was calculated as indicated by (Ianchici and Zdremțan, 2005):

$$VN_{10} = \frac{1}{10}\left(Pr \cdot K_{Pr} + L \cdot K_L + G \cdot K_G + Ca \cdot K_{Ca} + P \cdot K_P + Fe \cdot K_{Fe} + A \cdot K_A + B_1 \cdot K_{B_1} + B_2 \cdot K_{B_2} + C \cdot K_C\right) \qquad (3)$$

where: Pr – proteins content, g/100 g; L – lipids content, g/100 g; G – carbohydrates content, g/100 g; Ca – calcium content, g/100 g; P – phosphorus content, g/100 g; Fe – iron content, mg/100 g; A, B_1, B_2, C – vitamins content, mg/100 g; K – coefficients corresponding to each nutrient (Table 2) considered for calculating the VN_{10} value.

In Table 1, the content in the main dietary principles (minerals and vitamins) for orange-fleshed sweet potato (raw and cooked) is summarized.

Table 1. Content of minerals and vitamins for orange sweet potato, expressed for 100 g of fresh/cooked product.

Type of treatment	Minerals*, mg/100g Ca	P	Fe	Vitamins*, mg/100g A	B_1	B_2	C
Fresh	0.030	0.047	0.61	0.709	0.078	0.061	2.4
Cooked, puree	0.038	0.054	0.69	0.961	0.107	0.106	19.6

*Source: USDA, FoodData Central (2019), https://fdc.nal.usda.gov/fdc-app.html#/food-details/168482/nutrients, https://fdc.nal.usda.gov/fdc-app.html#/food-details/168483/nutrients, Ca-calcium, P-phosphorus, Fe-iron, A-provitamin A, B_1-thiamin, B_2-riboflavin, C-vitamin C.

In Table 2, the values of the K coefficients necessary to calculate the nutritional value of 10 components are presented.

Table 2. The values of K coefficients, from the VN_{10} formula, for vegetables (according to Ianchici and Zdremțan, 2005).

Coefficient, dimensionless	Food components Pr	L	G	Ca	P	Fe	A	B_1	B_2	C
K	0.69	0.55	0.10	54	60	6.1	27	53	42	0.5

Pr-protein, L-lipids, G-carbohydrates, Ca-calcium, P-phosphorus, Fe-iron, A-provitamin A, B1-thiamin, B_2-riboflavin, C-vitamin C.

Phytochemical Profile

The samples considered in this study were characterized in terms of 2,2-diphenyl-1-picryl-hydrazyl (DPPH) radicals scavenging activity, total polyphenolic and flavonoid content alongside the carotenoid content (β-carotene, lycopene, and total carotenoids),using the method described by Tănase (Butnariu) *et al.* (2023).

The antioxidant activity was as well determined as 2,2′-azinobis(3-ethyl-benzothiazoline-6-sulphonate) ($ABTS^+$) radicals-scavenging activity. The ABTS stock solution was produced by mixing 7 mM ABTS solution and 2.45 mM potassium persulfate in the dark at room temperature of 21°C for 16 h before being used. Further, the solution was diluted with ethanol until the absorbance was 0.7±0.02 at wavelength of 734 nm and was also used as the blank sample. A volume of 0.02 mL of sample was mixed with 1.98 mL ABTS solution, left at rest for 2 hours in the dark and the absorption was read at 734 nm wavelength. The ABTS inhibition was calculated according to the next equation:

$$\text{\% ABTS Inhibition} = \frac{A_{blank} - A_{sample}}{A_{blank}} \times 100 \quad (4)$$

where: A_{blank} represents the absorbance of the blank sample, A_{sample} - absorbance of the sample at 734 nm wavelength.

The carotenoid content was determined using the spectrophotometric methods proposed by Escoto *et al.* (2015).

All determinations were made in triplicate and presented as mean±standard deviation.

Color analysis of the sweet potatoes' purees

Instrumental color measurements of the orange sweet potatoes' purees were conducted with a NR110 3nh colorimeter (Shenzhen 3nh Technology, China) by samples color parameters (L*, a*, b*, Chroma and hue) direct measurements.

Viscosity analysis

A rotational viscometer Brookfield DV–E equipped with a LV3 (Liquid viscosity) (Brookfield Viscometers Ltd, Harlow, UK) was used to determine the apparent viscosity (η). The characteristics of the LV3 spindle are: 12.6 mm diameter and 115 mm height. The viscosity (η) against shear rate (γ) was evaluated to study the rheological behavior of all purees. The values of the dynamic viscosity were measured at 25 °C. The shear rate (γ, s^{-1}) was calculated using the Eq. 5.

$$\gamma = 0.21 \cdot N,\ s^{-1} \tag{5}$$

where: 0.21 – is a spindle constant and N is the rotor speed in rot/s. Three experimental runs were accomplished for each sample, and the resulting shear stress calculated according to Eq.6 was expressed as mean value:

$$\tau = \eta \cdot \gamma,\ Pa \tag{6}$$

Texture analysis

The texture of the sweet potato purees was analysed by Texture Profile Analysis method (TPA), applied with a Brookfield CT3 Texture Analyser. The samples were packed into cylindric plastic containers (40 mm diameter, 38 mm height), covered with aluminium foil and kept in refrigerator for 24 hours. Before testing they were equilibrated to room temperature (about 20°C). The test consisted in a double penetration with an acrylic cylinder (24 mm diameter) to 10 mm depth, with 1 mm/s speed. Load cell was 1000 g and trigger load 0.067 N. Five measurements were done for every sample and the texture parameters were calculated by TexturePro CT v1.5 (Brookfield Engineering Labs. Inc.) software.

Statistical Analysis

The one-way analysis of variance (ANOVA) and Tukey posthoc test were used to identify significant differences ($p < 0.05$) between the samples by using Minitab 19 software. All the experimental data are provided as mean±standard deviation (SD), after each analysis was performed at least twice.

Results and discussion

Proximate composition and nutritional characteristics of orange sweet potatoes puree

The nutritional composition of orange-fleshed sweet potatoes (raw and puree) is summarized in Table 3. Analysing the moisture results one can see that no significant changes were registered between samples. The moisture content of the analysed samples ranged from 78.51±0.17% to 80.59±0.29%. According to the literature, the boiling process is expected to ensure advanced hydration of potatoes` starch granules. This statement is supported by the research of Salamatu *et al.* (2019) which achieved similar results for orange-fleshed sweet potato processed by different cooking methods.

The protein content of the samples was the highest in fresh sweet potatoes (5.52±0.23%) and lower in boiled sample (3.01±0.12%). According to Salamatu *et al.* (2019), the reduction of the protein content of the heat-treated samples, in respect to M sample, could be associated with the leaching of nitrogen compounds induced by the processing methods. The study showed that processing methods such as steaming coupled with ohmic heating are milder than classical cooking methods (boiling and steaming) regarding the protein loss. This effect might be due to the higher latent heat of the steaming process coupled with ohmic heating compared with steam and boiling, which provide a higher temperature and heat penetration during processing, producing protein denaturation (Salamatu *et al.*, 2019).

Table 3. The proximate composition of the raw orange sweet potatoes (M) and puree samples treated through boiling (F), steaming (S), steaming coupled with ohmic heating (SIO17.5), and steaming coupled with ohmic heating (SIO20).

Proximate composition	**Samples**				
	M	**F**	**S**	**SIO17.5**	**SIO20**
Moisture, %	78.51±0.17^{A}	80.59±0.29^{A}	79.71±0.25^{A}	80.01±0.14^{A}	79.54±0.17^{A}
Proteins, %	5.52±0.23^{A}	3.01±0.12^{B}	3.18±0.23^{B}	3.89±0.26^{B}	3.25±0.19^{B}
Fats, %	0.68±0.11^{A}	0.17±0.05^{B}	0.18±0.02^{B}	0.22±0.06^{B}	0.18±0.04^{B}
Ash, %	0.92±0.18^{A}	0.42±0.06^{B}	0.62±0.07^{B}	0.54±0.05^{B}	0.64±0.07^{B}
Crude fiber, %	2.47±0.16^{A}	2.93±0.18^{A}	2.68±0.11^{A}	2.72±0.15^{A}	2.77±0.21^{A}
Carbohydrates, %	11.90±0.43^{A}	12.88±0.38^{A}	13.63±0.47^{A}	12.62±0.54^{A}	13.62±0.45^{A}
VE, kcal/100g	75.80±1.13^{A}	65.09±1.72^{B}	68.86±1.51^{B}	68.02±1.37^{B}	69.10±1.46^{B}
VN$_{10}$	4.06±0.24^{B}	5.88±0.31^{B}	5.90±0.33^{B}	5.92±0.28^{B}	5.91±0.22^{B}

All values are means±standard deviations of triplicate determinations. Statistically significant differences between the samples are marked with superscript letters (A - B) with $p < 0.05$ based on Tukey test. VE-energetical value, VN$_{10}$ – nutritional value.

The fat content of the orange sweet potatoes (raw and puree) samples ranged between 0.17±0.05% and 0.68±0.11%. A decrease in fat content was observed for all samples, regardless of the processing methods, compared to the fresh sample (M). According to Tsado *et al.* (2015), during samples processing the fat might be melted because of the high temperature applied.

The ash content ranged from 0.42±0.06% to 0.92±0.18%, the fresh sample recording the highest value. The lower ash contents registered for the processed samples could be a consequence of the loss of minerals into the processing medium by leaching. Similarly, Agbemafle *et al.* (2017) reported previously a decrease in the ash content of the boiled plantain.

According to Wei *et al*. (2017) the carbohydrate content of raw sweet potatoes plays an important role on the degree of sweetness of processed samples. The obtained results showed that processing methods increased the carbohydrate content of sweet potato puree samples compared to the raw sample. This fact is reflected in the energy value. In accordance with Pirvulescu *et al.* (2008), the nutritional value (VN_{10}) of the orange sweet potatoes (raw and puree) samples ranged between 4.06±0.24 and 5.92±0.33.

Phytochemical analysis

The phytochemical profile was determined by analysing the most relevant components of orange sweet potatoes, mainly: total phenolic content (TPC), total flavonoid content (TFC), total carotenoids (TC), β-carotene and lycopene (Table 4). The antioxidant activity assessed through DPPH assay (Table 4) and as ABTS radical scavenging activity (Figure 1).

Table 4. Phytochemical profile of the raw sweet potato (M) and puree samples treated through boiling (F), steaming (S), steaming coupled with ohmic heating (SIO17.5), and steaming coupled with ohmic heating (SIO20).

Phytochemical Profile	Samples				
	M	**F**	**S**	**SIO17.5**	**SIO20**
Antioxidant activity, µM Trolox/g DW	6.54±0.56^{A}	2.14±0.70^{B}	3.17±0.27^{B}	4.09±0.62^{A,B}	4.22±0.80^{A,B}
TPC, mg GAE/g DW	4.33±0.28^{C}	4.74±0.12^{A,B,C}	4.94±0.05^{A,B}	5.15±0.15^{A}	4.60±0.30^{B,C}
TFC, mg EQ/g DW	4.52±0.30^{C}	6.37±0.32^{B}	7.68±0.63^{A}	7.66±0.88^{A}	7.07±0.41^{A,B}
β-carotene, mg/g DW	1.54±0.02^{D}	1.26±0.06^{E}	2.33±0.02^{C}	3.59±0.01^{A}	3.43±0.04^{B}
Lycopene, mg/g DW	0.57±0.02^{C}	0.58±0.04^{C}	0.73±0.02^{B}	0.99±0.01^{A}	0.96±0.03^{A}
TC, mg/g DW	1.69±0.03^{D}	1.37±0.05^{E}	2.63±0.01^{C}	4.11±0.01^{A}	3.93±0.03^{B}

Statistically significant differences between the samples are marked with superscript letters (A - E) with $p < 0.05$, based on Tukey test. TPC, total phenolic content; TFC, total flavonoid content; TC, total carotenoids; DW, dry weight.

The highest antioxidant activity was measured in the control sample (M), meanwhile a reduction of almost 36-38% was registered for the samples treated by steaming coupled with ohmic heating (SIO17.5 and SIO20), which have higher antioxidant activity values compared to the F and S samples. These results might be explained by the fact that thermal processing through steaming coupled with ohmic heating was milder compared with the conventional ones. The thermal treatments enhanced the extraction of bioactive compounds, the total phenolic and flavonoid contents being higher compared to the control sample (M). Kourouma *et al.* (2019) reported lower values for the phenolic content of orange-fleshed sweet potato treated by steaming (ranging between 1.71±0.03 and 2.25±0.04 mg GAE/g DW) or boiling (from 1.61±0.00 to 1.85±0.02 mg GAE/g DW) compared to their control samples (1.90±0.03 and 2.59±0.06 mg GAE/g DW). This fact might be attributed to a longer processing time in comparison to our study.

Regarding the content of β-carotene, lycopene and total carotenoids, the purees obtained by steaming coupled with ohmic heating (both 17.5V/cm and 20V/cm) scored the highest values. In a study regarding the effects of cooking processes on the carotenoids of orange-fleshed sweet potato, Kourouma *et al.* (2019) registered lower values for the β-carotene content when processing by boiling (from 84.11±3.76 to 135.83±23.83 µg/g DW) or steaming (from 86.39±3.30 to 112.27±13.66 µg/g DW). These differences in values can be due to both the raw material used and the different processing time. Similarly, López-Gámez *et al.* (2021) reported various carotenoid concentrations of products obtained from carrots following exposure to a pulsed electric field or thermal treatment. These variations between investigations are most likely brought on by variations in the processing parameters, such as pulse waveform, electric field intensity and frequency. Additionally, when electro -permeabilization occurs, variations in the particle size of the generated products are a crucial component to be considered because larger cells get damaged before the smaller ones.

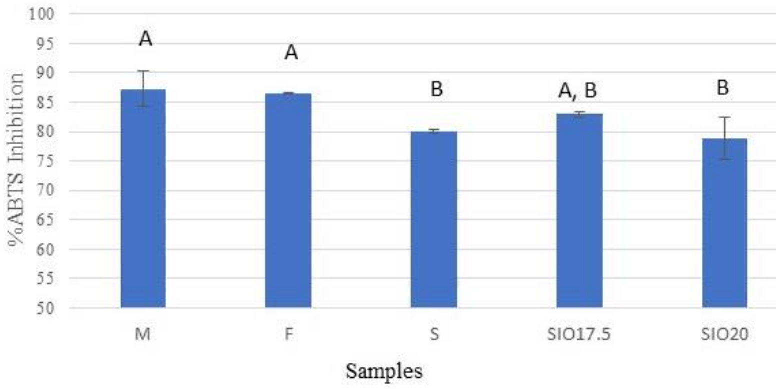

Figure 1. The antioxidant activity of the raw sweet potato (M), and purees samples treated through boiling (F), steaming (S), steaming coupled with ohmic heating (SIO17.5), and steaming coupled with ohmic heating (SIO20). Statistically significant differences between samples are marked with superscript letters (A - B) with p <0.05

Nowadays, the consumption of sweet potatoes has increased worldwide due to the recognition of their nutritional and health benefits (Qin *et al.*, 2022). Analysing the results presented in Figure 1, one can observe that, regardless of the applied treatment, the investigated samples presented rather high antioxidant activity values, the inhibition of the ABTS ranging from 78.83±3.67% (SIO20) to 87.28±3.02% (M). Our results are comparable to those reported by Xu *et al.* (2016), who investigated the cooked purple sweet potatoes, and reported the highest antioxidant activity using ABTS when combining two processing methods, namely microwave and steaming (79.33±0.45 %).

Color analysis

Color could directly influence the consumer's acceptance of a product (Pankaj *et al.*, 2013). The natural pigments are primarily responsible for the specific color of any fruit or vegetable, but the maturity stage, the manipulation and harvest conditions, and especially the thermal treatment can cause important color changes. The main pigment present in the orange sweet potatoes is β-carotene, which is responsible for its light to dark orange color (Alam *et al.*, 2016).

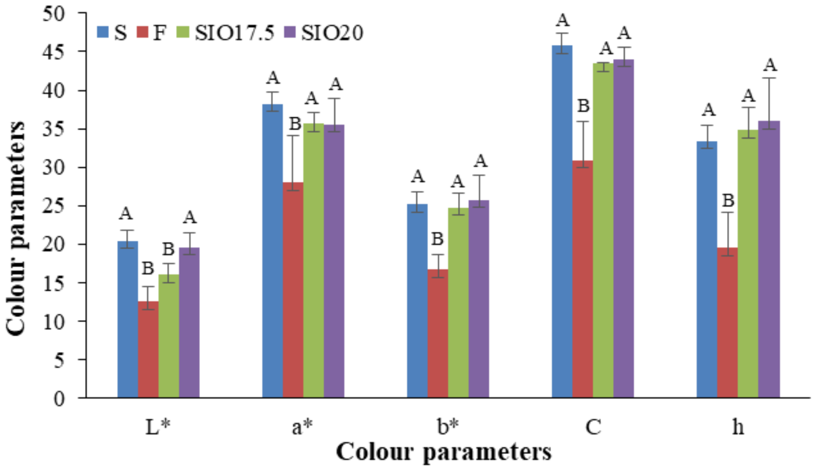

Figure 2. Color parameters for the raw orange sweet potato (M), and puree samples treated through boiling (F), steaming (S), steaming coupled with ohmic heating (SIO17.5), and steaming coupled with ohmic heating (SIO20). Statistically significant differences between the samples are marked with superscript letters (A - B) with $p < 0.05$.

The luminosity (L^*) of the samples varied between 12.54±1.89 (F sample) and 20.41±1.45 (S samples). Therefore, the sample treated through steaming exhibited the highest brightness. The boiled sample (F) and steamed sample (S) registered specific values for the reddish color presence, a* being 27.97±6.17 and 38.22±1.59, respectively. As it was expected the samples treated through steaming coupled with ohmic heating have registered the high values of the a^* parameter (Figure 2). The a^* values observed in the present study were almost 33% higher than the average values reported by Leksrisompong *et al.* (2012) in a study on several varieties of sweet potatoes. The yellowish color of the samples, estimated through measuring the b^* values, is related to the presence of the carotenoids and flavonoids pigments. No important differences were noticed among the b* values measured on the S, SIO17.5 and SIO20 samples (Figure 2.). Anyway, the conventional boiling treatment resulted in significant reduction of the b^* value of the F sample, probably as a consequence of the migration in the boiling water of an important content of yellow pigments. Hue (h) gives indications on the normal perception of the colors and Chroma (C) on the saturation of the color. Analyzing the results presented in Figure 2, it can be observed that the Chroma and Hue values follow a similar trend as in the case of the L*, a* and b* parameters. Our Chroma and Hue results are in agreement with those reported by Tănase (Butnariu) *et al.* (2023) for the orange sweet potato purees.

Viscosity analysis

The viscosity of purees has a special importance with direct implications on purees destinations. Moreover, dynamic rheology is usually applied to estimate the viscoelastic characteristics of pastes or purees (Meher *et al.*, 2019). In Figure 3, both dynamic viscosity dependence on shear rate (a) and shear rate dependence on shear stress are presented (b).

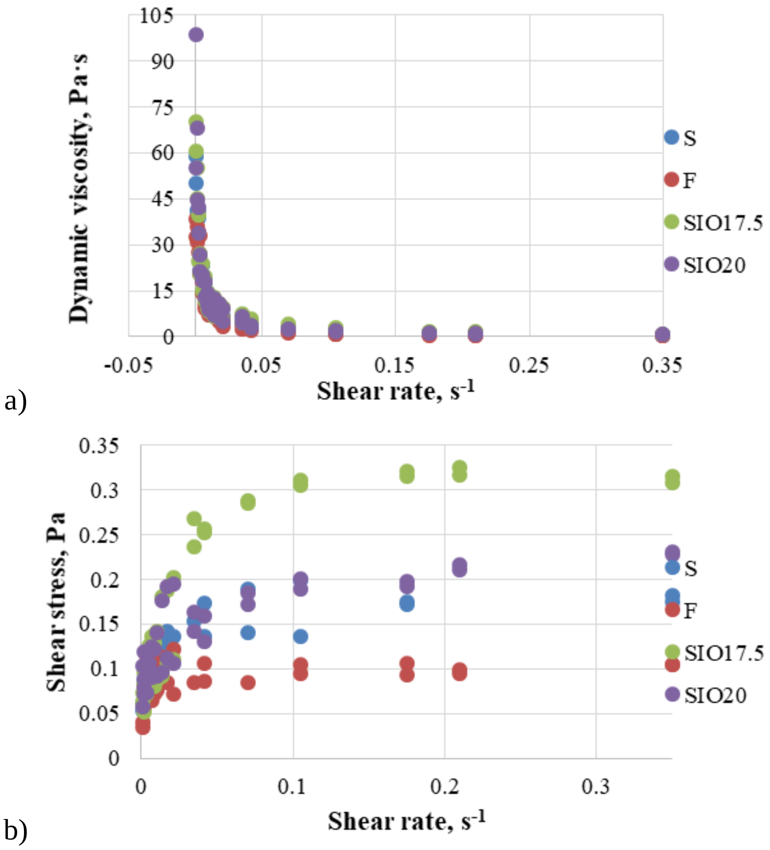

Figure 3. Rheological properties of orange sweet potato purees treated through boiling (F), steaming (S), steaming coupled with ohmic heating (SIO17.5), and steaming coupled with ohmic heating (SIO20). (a) Dynamic viscosity dependence on shear rate, (b) Shear stress dependence on shear rate.

Viscoelastic properties of orange sweet potato purees could be influenced by the variety, postharvest handling condition, or solids content, processing type or temperature (Nabubuya *et al.*, 2017).

All the purees independent of the processing method exhibit a non-Newtonian behaviour, which confirms the pseudoplastic specificity of the samples.

The highest value for the dynamic viscosity (98.7±0.38 Pa·s) was attributed to SIO 20 sample which could be attributed to the water phenomenon evaporation which could occur during the ohmic heating process. This outcome is in accordance with the TPA findings. Almost similar values for the dynamic viscosity ($\eta_S = 58.8 \pm 2.15$ Pa·s, $\eta_{SIO7.5} = 60.7 \pm 2.30$ Pa·s) were registered by the samples treated by steaming and ohmic heating at 17.5 V/cm.

Consequently, the flow curves behavior of the tested samples have taken a systematic trend with stress rate, contrary to the findings reported by Miao *et al.* (2018) for fresh and frozen/thawed mashed potatoes enriched with different proteins.

Texture analysis

The results of the texture analysis are presented in Table 5. The lowest firmness, 1.14 N, was registered for sample F, while for the other samples no significant differences were noticed. The same observation was made for adhesiveness (6.8 mJ for sample F), while for cohesiveness sample F showed the highest value (0.64).

Table 5. Texture parameters of sweet potato purees treated through boiling (F), steaming (S), steaming coupled with ohmic heating (SIO17.5), and steaming coupled with ohmic heating (SIO20).

Texture parameters	**Sample**			
	F	***S***	***SIO17.5***	***SIO20***
Firmness, N	1.14 ± 0.02^{A}	1.50 ± 0.05^{B}	1.37 ± 0.10^{B}	1.54 ± 0.06^{B}
Adhesiveness, mJ	6.80 ± 0.08^{A}	8.59 ± 0.32^{B}	8.28 ± 0.73^{B}	8.21 ± 0.80^{B}
Cohesiveness, -	0.65 ± 0.02^{A}	0.49 ± 0.01^{B}	0.52 ± 0.04^{B}	0.42 ± 0.06^{B}
Springiness, mm	9.24 ± 0.09^{A}	8.93 ± 0.19^{B}	8.14 ± 0.29^{B}	7.14 ± 0.45^{C}
Chewiness, mJ	6.92 ± 0.33^{A}	5.92 ± 0.10^{B}	5.78 ± 0.69^{B}	3.93 ± 0.14^{C}

All values are means±standard deviations of triplicate determinations. Statistically significant differences between the samples are marked with superscript letters (A - C) with $p < 0.05$.

These results could be explained by the amount of water available to be absorbed by the tissue fibres, softening the vegetal material, and making it less adhesive to the testing probe. At the same time, water acts like a binder for the rest of the compounds (starch and proteins), making sample F more cohesive than the others and more difficult to be chewed. When steaming or steaming coupled with ohmic heating is applied, the firmness and adhesiveness of the sweet potato purees increase and become less cohesive and elastic. When 20 V/cm is applied for ohmic heating, water evaporation is favored, and the sample becomes easy to be disintegrated during mastication – the lowest value for chewiness is 3.93 mJ for the SIO20 sample.

Conclusions

The boiling and steaming, eventually coupled with ohmic heating, at two different voltage gradients of 17.5 V/cm and 20 V/cm, influenced in different manner the properties of the puree samples obtained from orange sweet potatoes. The results of the present research revealed that steaming coupled with ohmic heating at 17.5 V/cm was the most feasible type of thermal treatment regarding the processing of orange sweet potato purees in terms of antioxidant activity and phytochemical profile. The puree's viscoelastic properties are not affected by the chosen thermal treatments.

Acknowledgments

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