CARPATHIAN JOURNAL OF FOOD SCIENCE AND TECHNOLOGY

journal homepage: **http://chimie-biologie.ubm.ro/carpathian_journal/index.html**

CHEMICAL COMPOSITION, PHYSICAL AND SENSORY PROPERTIES OF DEHYDROFROZEN YAM CHIPS AS INFLUENCED BY PRE-DRYING CONDITIONS

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https://doi.org/10.34302/crpjfst/2022.14.3.7

Article history:
Received:
1 October 2021
Accepted:
10 July 2022
Published
September 2022

Keywords:
Chips;
Dehydrofreezing;
Fries;
Pre-drying;
Yam.

ABSTRACT

This study investigated the effect of pre-drying conditions on the quality of dehydrofrozen yam chips. Yam tubers were processed into yam chips and pre-dried using two methods, microwave and hot-air drying. Microwave pre-drying was carried out at microwave power 252, 406 and 567 W for 12.5, 7.0 and 5.0 min, respectively, and hot air pre-drying at temperatures 50ºC, 70ºC and 80ºC for 60, 40 and 20 min, respectively. Pre-dried yam chips were frozen for 48 h, thawed and analysed for chemical composition and physical properties. Dehydrofrozen yam chips were deep-fried and subjected to sensory evaluation. Moisture, sugar and amylose contents of chips were 63.59-60.21%, 5.43-7.89% and 23.5-38.03%, respectively. Drip loss of dehydrofrozen yam chips decreased with increase in pre-drying time. Measures of lightness, yellowness/blueness, hue angle, chromaticity and colour intensity were higher in chips pre-dried at high microwave power and air temperature. This study showed that pre-drying conditions affected the quality of dehydrofrozen yam chips.

1. Introduction

White yam (*Dioscorea rotundata*) is a staple food in many African countries where close to 90% of total global output is produced (Etim et al., 2013). In the last few decades, there has been a steady growth in global yam production output from 39.55 million metric tons in 2000 to 58.75 million metric tons in 2012 (Verter and Becvarova, 2015). Yam is richer than many tropical root/tuber crops in carbohydrate, dietary fibre and minerals (Kouassi et al., 2010). According to Alozie et al. (2009), yam makes substantial contribution to protein in the diet than the widely grown cassava.

The moisture content of yam is in tune of 80% or more and this accounts for its high rate of deterioration and spoilage (Torres et al., 2012). It is therefore imperative to convert yam into stable forms such as chips, flour and starch (Karim et al., 2013). Furthermore, yam is relished by its consumers after it is subjected to operations such as boiling, steaming, pounding, frying and roasting (Abioye, 2012; Otegbayo et al., 2012).

In recent times, there have been concerted efforts toward improving the acceptability of yam products at the world market through value addition and development of new products (Kouadio et al., 2013). One of the least explored areas in this context is in the production of dehydrofrozen yam chips.

Dehydrofreezing is a food freezing technique that involves pre-treatment of vegetables by dehydration to an appropriate moisture level prior to freezing (Ramallo and Mascheroni, 2010). Consequently, there is reduction in ice crystal formation in the cell during freezing, therefore, post thawing quality of products such as colour, texture, flavour and nutrients are preserved (Ando et al., 2011). Due to their lower moisture content, less energy is required to freeze partially dehydrated foods compared to energy required for fresh products (Marani *et al.,* 2007).

Successes have been recorded in the use of dehydrofreezing techniques for the production of French fries from potato (*Solanum tuberusum*) (Sanz et al., 2007; Garmakhany et al., 2010) and many fruit and vegetable products (Blanda et al., 2009; Romalo and Mascheroni, 2010; James et al., 2014). The potential of yam in the production of dehydrofrozen yam chips has also been reported (Quansah et al., 2010). However, there is dearth of information on effects of pre-drying conditions on the quality of dehydrofrozen yam chips, hence, the focus of this study. The objective of this study was to determine effects of microwave and hot air pre-drying conditions on the chemical composition, physical and sensory properties of dehydrofrozen yam chips.

2. Materials and methods

2.1. Materials

White yam tubers *(Dioscorea rotundata* Poir*), Ogoja* cultivar, were obtained from the Teaching and Research Farm of Federal University Wukari, Wukari, Nigeria. Average moisture, total sugar, starch and fat contents of the tubers were 83.37%, 4.17%, 70.98% and 0.30%, respectively. Vegetable oil (Golden Penny, Lagos, Nigeria) was procured at PJD Stores, Ilorin, Nigeria. All chemicals used for analyses were of analytical grade.

2.2. Methods

2.2.1. Yam chips preparation

The method described by Quansah et al. (2010) was employed for the production of yam chips. Yam tubers were washed, peeled and cut into rectangular strips of 1 × 1 × 6 cm. The chips were blanched at 80°C for 2 min, cooled to room temperature (28±2°C) and packaged in polyethylene bags (Ziploc, Yantai Bagmont, Shandong, China).

2.2.2. Production of dehydrofrozen yam chips

Two pre-drying methods, microwave oven and hot-air oven, were used. Microwave pre-drying was done based on the method described by Priyadarshini et al. (2013) with modification in microwave power and pre-drying time. Yam chips were pre-dried at different microwave power and time as optimised in a preliminary study (data not presented). Microwave pre-drying was carried out at microwave power 252, 406 and 567 W for 12.5, 7.0 and 5.0 min, respectively. This was done using a laboratory microwave oven (NX-802, Nexus, Beijing, China). Hot air pre-drying was done based on the methodology outlined by Agnieszka et al. (2007) with little modification in temperature and time. Yam chips were pre-dried at different temperature and time as optimised in a preliminary study (data not presented). Hot air pre-drying was carried out at temperature 50, 70, 80°C and time 60, 40 and 20 min, respectively, in a hot-air oven (NL-9023A, Genlab Ltd., Widnes, Cheshire, England). Pre-dried chips were cooled in desiccators.

Freezing of pre-dried yam chips was carried out as described by Agnieszka et al. (2007). Pre-dried yam chips were arranged on a tray and froze at -20°C for 48 h. The frozen chips were thawed at room temperature (28 ± 2°C) for 1 h.

2.2.3. Frying of dehydrofrozen yam chips

Frying of dehydrofrozen yam chips was carried out as described by Agnieszka et al. (2007). Chips were fried in a deep-fat frier (S-616, Saisho, Osaka, Japan) at 170°C for 5 min. Oil was changed after each frying operation. The fried chips were gently blotted with the aid of a fluffy kitchen towel (Fidson, Lagos, Nigeria) to remove surface oil. The chips were cooled to room temperature (28 ± 2˚C) and packaged (Ziploc, China).

2.3. Analyses

2.3.1. Chemical and physical analyses

Moisture, total sugar, starch, amylose, amylopectin and fat contents of dehydrofrozen yam chips were determined using standard methods (AOAC, 2000). Drip loss of dehydrofrozen yam chips and browning index of yam fries were determined using methodologies described by Garmakhany et al. (2010).

A colorimeter (CR-410, Minolta, Osaka, Japan) was used to determine colour order properties of dehydrofrozen yam chips. The equipment was standardized based on the manufacturer's instructions. Subsequently, colour properties were measured and expressed as L* (measure of lightness), a* (measure of redness and greenness), b* (measure of blueness and yellowness), hue angle, chromaticity and colour intensity.

2.3.2. Sensory analysis

Sensory attributes of yam fries were evaluated according to Agnieszka et al. (2007). Fifty panellists who comprised staff and students of the Department of Food Science and Technology, Federal University Wukari were employed. Selection of panellists was based on their familiarity with fries. They were requested to rate the samples based on crispiness, texture, oiliness, taste, colour and general acceptability. Scoring was based on a 9-point hedonic scale where 1 and 9 represented dislike extremely and like extremely, respectively. The analysis was conducted in a well-lighted room with separate booths for each of the panellists.

2.3.3. Statistical analysis

Data were subjected to one-way analysis of variance (ANOVA) using the statistical packages for social science (version 23, Stat-Ease Incorporated, Minneapolis, USA). Difference between means were determined by Duncan Multiple Range Test and significance level was defined at $p < 0.05$.

3. Results and discussion

3.1. Effect of Pre-drying Conditions on Chemical Composition of Dehydrofrozen Yam Chips

Chemical composition of dehydrofrozen yam chips at different pre-drying conditions is presented in Table 1. Moisture content was 60.21-63.59%. This shows that all the pre-drying conditions considered in this study were able to reduce the moisture content of chips to an acceptable level. Krokida et al. (2001) had suggested moisture content of chips to be between 60 and 65% prior to freezing. Dry matter content differs significantly ($p<0.05$) between samples with chips pre-dried at 567 W for 5.0 min and 252 W for 12.5 min having the highest (39.79%) and lowest (36.40%), respectively. Dry matter varied significantly ($p<0.05$) among the chips, depending on their moisture content. Total sugar content of chips ranged from 5.43 to 7.89%, with chips pre-dried at 70^{o}C for 40 min and 567 W for 12.5 min having the lowest and highest, respectively. This could be due to increased hydrolysis of starch to sugar at high temperature. Tocci and Mascheroni (2008) also reported differences in sweetness of fries pre-dried at different conditions and time. Lower starch content was recorded for samples pre-dried at high microwave power and temperature compared to those pre-dried at lower microwave power or air temperature. This could be connected to loss of starch because of intense heat treatment. High amylose and low amylopectin contents were recorded for yam chips pre-dried at elevated air temperature and microwave power. This suggests better starch digestibility of dehydrofrozen yam chips pre-dried at low microwave power and air temperature. According to Sanz et al. (2007), starch digestibility increases with decreasing amylose content. Fat content of dehydrofrozen chips was 0.14-0.25% and varied significantly ($p<0.05$) among the samples. Fat content was lower in chips pre-dried at low heating conditions. This agreed with the report by Oyeyiola et al. (2014) who reported decrease in oil content of chips with increasing pre-drying treatment.

Fat content of dehydrofrozen yam fries is presented in Figure 1. There were variations in fat content of the fries. This result is similar to the findings of Pedreschi and Moyano (2005) who reported variation in oil content of French fries subjected to different pre-drying conditions. Variation in fat content of fries could be due to differences in level of disruption of internal organs caused by differing pre-drying conditions (Pedreschi and Moyano, 2005). Fat content of fries pre-dried at 567 W for 5.0 min, 70^{o}C for 40 min and 80^{o}C for 20 min were 11.8, 11.6 and 11.2%, respectively. This suggests good quality of the fries pre-died at these stated conditions. Agnieszka (2014) had reported that French fries with oil content of 10-12% were of good quality and high consumer acceptability. Higher oil content could result in an oily taste while lower oil content could result in dryness (Agnieszka, 2014).

Figure 2 shows browning index of dehydrofrozen yam fries. Results obtained showed variation in browning index of the fries. Highest browning index was obtained for fries pre-dried at 80ºC for 20 min, followed by 70ºC for 40 min and 406 W for 7.0 min. This could be due to increased browning reaction at these conditions (Rincon and Ker, 2010). Lowest browning index (11) was recorded for fries pre-dried at 567 W for 5.0 min and this could imply a reduction in browning reaction at this condition.

Table 1. Effect of pre-drying conditions on the chemical composition of dehydrofrozen yam chips

Pre-drying methods	**Pre-drying condition**	**Moisture content (%)**	**Dry matter (%)**	**Total sugar (mg/g)**	**Starch (g/100 g)**	**Amylose (g/100 g)**	**Amylopectin (g/100 g)**	**Fat content (%)**
Microwave radiation	252 W for 12.5 min	$63.59^{a}\pm0.9$	$36.40^{d}\pm0.10$	$7.68^{b}\pm0.28$	$68.88^{a}\pm0.42$	$23.59^{d}\pm0.42$	$45.29^{a}\pm0.83$	$0.20^{b}\pm0.09$
	406 W for 7 min	$61.41^{c}\pm0.10$	$38.59^{b}\pm0.01$	$5.68^{e}\pm 0.14$	$56.81^{b}\pm0.45$	$30.65^{b}\pm2.08$	$26.29^{b}\pm1.63$	$0.18^{c}\pm0.01$
	567 W for 5 min	$60.21^{e}\pm0.10$	$39.79^{a}\pm0.01$	$7.89^{a}\pm0.14$	$55.12^{c}\pm0.02$	$38.03^{a}\pm0.04$	$17.09^{c}\pm0.06$	$0.16^{d}\pm0.01$
Hot air oven	50ºC for 60 min	$62.02^{b}\pm0.20$	$37.98^{c}\pm0.08$	$6.88^{d}\pm0.14$	$50.50^{d}\pm0.45$	$23.00^{d}\pm0.41$	$27.50^{b}\pm0.04$	$0.25^{a}\pm0.01$
	70ºC for 40 min	$61.39^{c}\pm0.10$	$38.61^{b}\pm0.01$	$5.43^{f}\pm0.14$	$43.26^{e}\pm1.65$	$29.15^{c}\pm1.12$	$14.11^{d}\pm0.52$	$0.17^{d}\pm0.01$
	80ºC for 20 min	$60.52^{d}\pm0.02$	$39.48^{a}\pm0.08$	$7.15^{c}\pm0.06$	$34.24^{f}\pm0.89$	$30.38^{b}\pm0.54$	$3.86^{d}\pm0.36$	$0.14^{e}\pm0.01$

Values are means ± standard deviations of triplicate scores. Means with different superscripts in column were significantly ($p<0.05$) different.

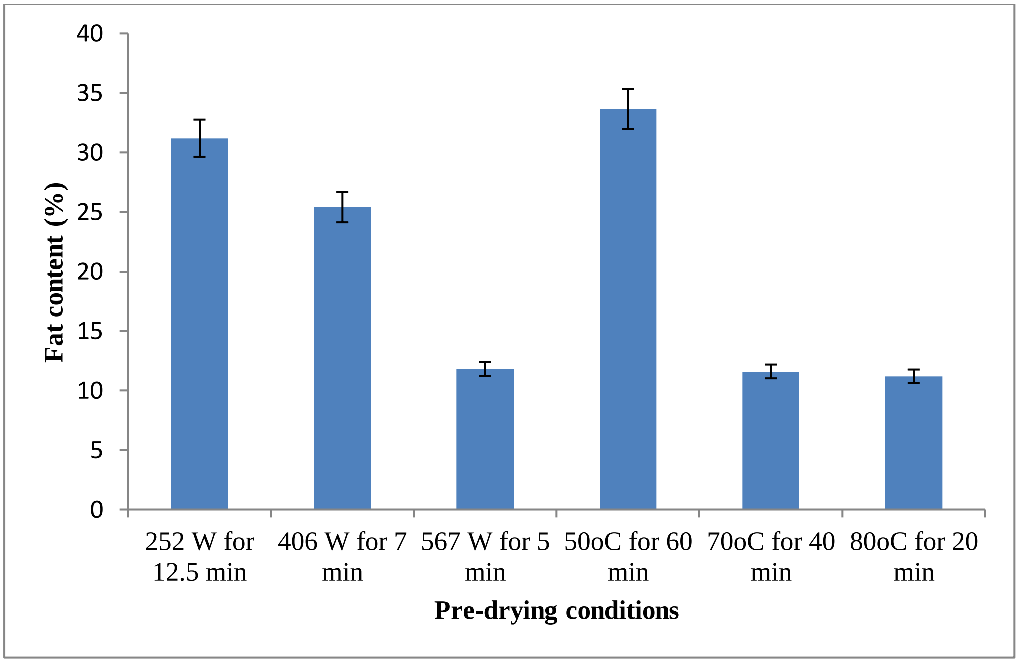

Figure 1. Effect of pre-drying conditions on fat content of dehydrofrozen yam fries

3.2.Effect of pre-drying method on the physical properties of dehydrofrozen yam chips

Percentage drip loss of dehydrofrozen yam chips is presented in Figure 3. There was variation in drip loss of dehydrofrozen yam chips due to different pre-drying conditions. This variation could be due to differences in mechanical behaviour of the chips as a result of differing pre-drying conditions. Marani et al. (2007) had demonstrated variation in mechanical behaviour of fruit and vegetables as a result of differences in pre-drying conditions. From the results obtained, yam fries pre-dried at 567 W for 5.0 min showed highest resistance to mechanical rupture, while chips pre-dried at 252 W for 12.5 min showed least resistance. Low drip loss (18%) recorded for the chips pre-dried at 567 W for 5.0 min could imply reduced cellular damage by microwave radiation at short treatment time. Dehydrofrozen yam chips pre-dried using hot air oven had high drip loss, and hence, low resistance to mechanical rupture. Ramallo and Mascheroni (2010) had reported that microwave pre-drying was more efficient than hot air pre-drying for the preservation of cellular integrity of dehydrofrozen products.

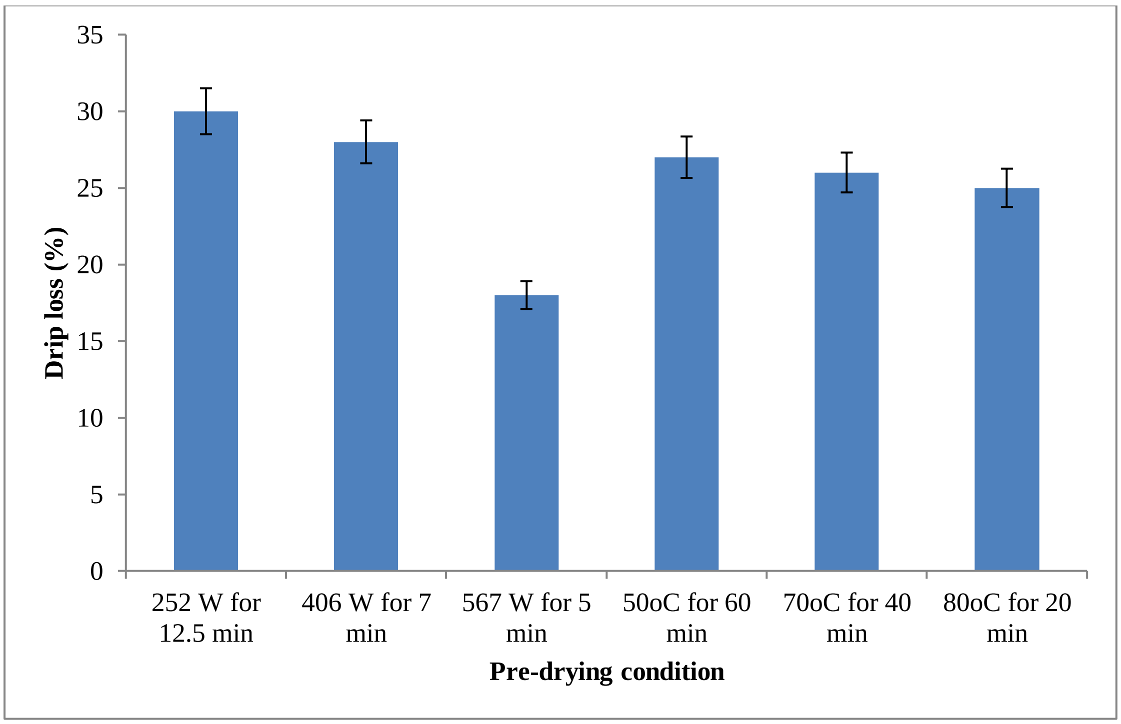

Figure 3. Effect of pre-drying conditions on drip loss of dehydrofrozen yam chips

Colour order properties of dehydrofrozen yam chips are shown in Table 2. Measure of lightness, a* and b* were 60.30-69.35, 1.89-2.52 and 6.36-9.34, respectively. Significantly ($p < 0.05$) higher L* was obtained for chips pre-dried at 567 W for 5.0 min and 50°C for 60 min. This result was consistent with low browning index reported for the chips at these conditions (Section 3.1). Significantly ($p < 0.05$) lower L* was recorded for chips pre-dried at 406 W for 7.0 min, 70°C for 40 min and 80°C for 20 min, and this could probably be due to higher rate of browning at these conditions. Significantly ($p<0.05$) higher a* was recorded for chips pre-dried at 567 W for 5.0 min (2.46) and 406 W for 7.0 min (2.52). This result corroborates the findings of Garmakhany et al. (2010) who reported high a* for pre-dried potatoes strips at high pre-drying temperature. Significantly higher b* was obtained for chips pre-dried at 567 W for 5.0 min (9.34) and 80°C for 20 min. This implies development of golden yellow colouration, which is highly preferred by consumers of fries (Sanz et al., 2007). Hue angle, chromaticity and colour intensity of the chips were 74.92-78.51, 3.89-8.04 and 30.32-47.79, respectively. Chips pre-dried at 567 W for 5.0 min and 406 W for 7.0 min had the highest and lowest hue angle, respectively. Hue angle above 70^o indicates clear transition from red to yellow; hence, chips with high hue angle suggest high development of golden yellow colouration. According to Garmakhany et al. (2010), hue angle is an important parameter in potatoes fries and implies development of golden yellow colour that is highly relished by fried chips consumers. Highest chromaticity and colour intensity were recorded for chips pre-dried at 567 W for 5.0 min. This implies high colour purity of the sample (Correia et al., 2016). Low values obtained for chips pre-dried at 252 W for 12.5 min and 50^{o}C for 60 min indicated low colour purity for chips pre-dried at low temperature and long time. Rincon and Ker (2010) also reported low colour intensity for frozen mango pre-treated for long time.

Table 2. Effect of pre-drying conditions on colour properties of dehydrofrozen yam chips

Pre-drying method	Pre-drying condition	L*	a*	b*	Hue angle (^{o})	Chromaticity	Colour intensity
Microwave radiation	252 W for 12.5 min	64.25^b±0.32	1.89^c± .03	8.79^b±0.06	77.89^b±0.12	5.97^c±0.07	30.32^e±0.31
	406 W for 7 min	60.57^c±1.31	2.52^a±0.16	8.37^b±0.62	74.92^d±0.06	6.78^b±0.62	40.00^b±1.18
	567 W for 5 min	69.35^a±0.28	2.46^a±0.01	9.34^a±0.02	78.51^a±0.42	8.04^a±0.07	49.79^a±0.20
Hot air oven	50^{o}C for 60 min	68.69^a±0.72	1.67^d±0.09	6.36^d±0.14	75.29^d±0.45	3.89^e±0.08	32.49^d±0.73
	70^{o}C for 40 min	62.93^c±0.28	1.91^c±0.08	7.56^c±0.16	75.83^d±0.27	4.93^d±0.18	33.42^d±0.28
	80^{o}C for 20 min	60.30^c±0.16	2.17^b±0.01	9.31^a±0.22	76.89^c±0.27	6.56^b±0.19	34.32^c±0.1

Values are means ± standard deviations of triplicate scores. Means with different superscripts in column were significantly ($p<0.05$) different. L* (measure of lightness), a* (measure of redness and greenness), b* (measure of blueness and yellowness)

3.3. Effect of pre-drying on sensory properties of dehydrofrozen yam fries

The sensory properties of fries as influenced by pre-drying conditions are shown in Table 3. Chips pre-dried at high microwave power and air temperature for short duration were most preferred in terms of crispiness and texture. This might be due to the effect of case hardening during pre-drying operation. Result obtained was in agreement with the findings of Sanz et al. (2007) who reported that French fries pre-dried at high temperature were crispier than those pre-dried at lower temperature. Quansah et al. (2010) also reported that yam fries pre-dried at high temperature for short time produced fries with desired texture. Highest oiliness preference was also recorded for chips pre-dried at high microwave power and air temperature. This could be due to good oil absorption capacity of the samples (Section 3.1). According to Agnieszka (2014), oiliness, which is a perception of oil content of foods, is correlated with oil absorption capacity. Highest taste score was recorded for chips pre-treated at 567 W for 5.0 min. The preference for taste was lowest in chips pre-dried at 80^{o}C for 20 min. A similar trend was observed in panellists' preference for chips colour and general acceptability.

Table 3. Effect of pre-drying conditions on sensory properties of dehydrofrozen yam fries

Pre-drying method	Pre-drying condition	Crispiness	Texture	Oiliness	Taste	Colour	General acceptability
Microwave radiation	252 W for 12.5 min	$7.00^{c}\pm1.00$	$6.88^{a}\pm1.05$	$6.64^{bc}\pm1.66$	$6.68^{b}\pm1.03$	$5.84^{c}\pm1.86$	$6.84^{b}\pm1.67$
	406 W for 7 min	$7.32^{b}\pm1.22$	$7.08^{a}\pm0.81$	$6.72^{bc}\pm1.43$	$6.96^{b}\pm1.02$	$6.28^{c}\pm2.05$	$7.28^{b}\pm0.94$
	567 W for 5 min	$7.44^{a}\pm1.66$	$7.12^{a}\pm1.39$	$7.32^{ab}\pm1.18$	$7.56^{a}\pm0.65$	$8.12^{a}\pm1.13$	$8.24^{a}\pm1.05$
Hot air oven	50^{o}C for 60 min	$6.16^{e}\pm2.06$	$6.04^{b}\pm1.69$	$5.96^{c}\pm2.09$	$5.32^{d}\pm1.75$	$6.04^{c}\pm1.67$	$5.72^{c}\pm1.88$
	70^{o}C for 40 min	$6.84^{d}\pm1.52$	$6.64^{ab}\pm1.63$	$6.84^{abc}\pm1.82$	$6.84^{b}\pm1.46$	$7.64^{ab}\pm1.04$	$7.32^{b}\pm1.14$
	80^{o}C for 20 min	$7.44^{a}\pm1.19$	$7.04^{a}\pm1.24$	$7.72^{a}\pm1.34$	$6.16^{c}\pm0.69$	$7.12^{b}\pm0.78$	$7.24^{b}\pm0.78$

Values are means ± standard deviations of fifty scores. Means with different superscripts in column were significantly ($p<0.05$) different.

4. Conclusions

This study showed that the properties of yam chips varied based on pre-drying conditions. High heat treatment (microwave radiation and air temperature) of yam chips for short duration favoured nutrient retention, physical and sensory properties. Particularly, yam chips pre-dried at 567 W microwave power for 5.0 min showed good results and therefore, recommended.

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