JOURNAL OF AGROBIOTECHNOLOGY 2019, VOL 10(2):51-63
e-ISSN: 2180-1983
https://journal.unisza.edu.my/agrobiotechnology/index.php/agrobiotechnology/index

Effect of Different Processing Methods on the Physicochemical Properties and Sensory Evaluations of Sweet Potatoes Chips

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Received: 05/08/2019, Accepted: 07/11/2019, Available online: 14/11/2019

ABSTRACT

Sweet potatoes is a popular root vegetable and highly nutritious. It is highly perishable and the need of processing required to enable it to be shelf stable. However, some processing methods have been degrading nutrient content of the sweet potatoes while increasing the fat content. Hence, the main aim of this research is to identify sweet potato chips which are nutritious and have acceptable organoleptic properties. Thus, the research also conducted to compare the physicochemical and sensory analysis on two types of sweet potatoes based on different processing methods. The processing methods used were deep-fry, freeze-dry, sun dry, air-fry and oven bake methods. The results obtained comparing both types of sweet potatoes mostly did not show statistical significant difference. The physicochemical analysis which shows the nutrition value of sweet potatoes based on different processing methods produced results where the freeze-dried samples tend to have the highest values of ash (1.77 g/100 g), crude protein (5.65 g/100 g) and crude fiber content (3.56 g/100 g). Adversely, freeze-dried samples provided small amount of fat content for both type of sweet potato which are 1.51 g/100 g compared to other samples. However for the sensory acceptance, deep-fried was most acceptable by the panelist with the score of range 5 to 6 in the seven-hedonic scale test. Whereas, the deep-fried sample showed lowest value for the chemical analysis where for ash both type of sweet potatoes (1.19 g/100 g), crude protein (3.74 g/100 g) and crude fiber content (1.62 g/100 g). However, the deep-fried samples had highest fat content for both type of sweet potatoes which are 45.85 g/100 g. Concerning the physical attributes, the sun dried samples had the highest hardness value whereas the freeze-dried samples had the lowest fracturability value which made it least sensory acceptance. Color analysis indicated that orange-fleshed sweet potato (OFSP) retained its colour, but purple-fleshed sweet potato (PFSP) leached its color. Overall, the oven baked samples had moderate amount of ash, crude fiber and crude protein. Besides, it consist lower fat content compared to deep-fried samples. Moreover, oven baked samples obtained similar sensory attributes score of range 5 to 6 as deep-fried samples.

Keywords: Orange-fleshed sweet potato, purple-fleshed sweet potato, processing, physicochemical, sensory

INTRODUCTION

Sweet potato or scientifically known as *Ipomoea batatas L. Lam*, is the second most major root tuber and the seventh most major food crop of the world. Sweet potatoes have a variety of beneficial characteristics such as high yield with less inputs, short growth duration, high dietary value and tolerance to different stresses in manufacturing. Orange fleshed sweet potato is presently growing as a very significant component of tropical tuber plants with a huge opportunity to be taken as a regular diet in the consumer food chain to deal with the deficiency of vitamin A. The tubers are rich in starch, sugars, minerals and vitamin A in the form of β-carotene, apart from inexpensive energy source (Mitra, 2012). While purple fleshed sweet potatoes are widely in trend for the high antioxidant content which is the anthocyanin.

However, the processing method plays an important role in maintaining the nutritional value and also the organoleptic qualities as well in order to sustain the developing technological world. Freeze-drying uses a high vacuum to remove water from a solid phase (ice) to a vapor phase without passing through a liquid phase (Mujumdar, 2015). In freeze-drying process, no heat damage occurs since the material remains frozen and drying takes place at low temperature. In many countries including China and India, thousands of tons of sweet potatoes are dried every year in the form of chips or slivers by traditional sun drying. The major part of this dried product is then sent on to starch or alcohol factories for further processing (Sablani & Mujumdar, 2014). Furthermore, the air-frying method combines infrared heat techniques without using oil (Caetano et al., 2017). The fine oil droplets content in the heated hot air of air-frying system dehydrates the potatoes produces the characteristics of traditionally produced French fries, but with a reduced fat absorbed in the product (Teruel et al., 2015).

Deep-fat frying is a unit operation in which food is immersed and cooked in hot oil. Heat and mass transfer, simultaneously occur combining short cooking times with distinctive features such as colour, taste, aroma, crust and texture. Essentially, frying is a process of dehydration in which high oil temperature (160 to 180 °C) enables rapid heat transfer and a short cooking time. Finally, oven drying is one of the common food dehydration method. It is a method in which heated air is blown over the surface of food with the help of fans to remove most of the moisture content from the food. The drying of wet materials induces a number of physicochemical changes in the product, often reflected by colour (Jimoh et al., 2009). The main aim of this research is to identify sweet potato chips which are nutritious and have acceptable organoleptic properties. Thus, the proximate value, sensory acceptance and physical properties of sweet potato chips processed using different methods were determined.

MATERIALS AND METHODS

Materials

In this research, orange and purple-fleshed sweet potatoes purchased from a local farmer in Besut, Terengganu were used. Fresh sweet potatoes was graded for its quality based on physical appearance for the defects of sweet potatoes such as, black rot, ring rot, circular spot, souring, scruf, dry rot, fusarium surface rot, fusarium root rot, rhizopus soft rot. This helps to ensure that there is no significant error to be found in the analysis carried out.

Samples preparation

For the preparation of sweet potato before processing, it was washed thoroughly to remove the deposited dirt and graded based on its quality mentioned above. The sweet potato skin was peeled as only the flesh was used in this study. Then, the sweet potato was sliced using the semi-automated slicer. The thickness was ensured to be 2.5 mm and diameter 2 to 3 cm each to give consistent results of analysis. After that, the sweet potato was soaked in cold water for 5 minutes to remove excess potato starch. They were then immersed in 0.2% sodium metabisulphite for 15 minutes. Finally, the sweet potato slices were rinsed, drained and arranged in separated five trays before the processing procedures.

Processing procedures

Five different processing methods were used such as freeze-drying, oven baking, sun drying, deep-frying and air-frying.

Sun drying

Sweet potato slices were placed on a cooling rack and dried under the sun for two days continuously for seven hours starting from 9.00 a.m. till 4.00 p.m at about 32°C.

Freeze-drying

The sweet potato slices were freezed in the lab freezer (VirTis Genesis 35L Pilot Lyophilizer) at about – 40 ^{o}C. The samples were loaded, the product and condenser chamber was closed. After that, the vacuum was used to preseal the chamber and it was allowed to run for around 30 seconds or until the pressure drop to 500 torr. Then, the sample was freezed. Once frozen, the condenser button and the vacuum button was pressed and the samples are dried for 48 hours. Finally, once the drying process completed the vacuum and the condenser system was closed and the sample was removed.

Oven baking

The rack was positioned in upper third of oven and the oven was preheated to 180 ^{o}C. Initially, the baking sheet was sprayed with non-stick spray and the potato slices were arranged in a single layer, being sure not to overcrowd. It was baked at 180 ^{o}C for 20 minutes or until tender and golden brown, while it was turned occasionally. The sweet potatoes was let to cool 5 minutes.

Air-frying

The air-fryer (Philip, VIVA HD9220) was first preheated to 160 ^{o}C. The sweet potatoes was separated into two batches for cooking. An even layer of sweet potatoes was placed in the fry basket, inserted in the air fryer, and cooked until golden, about five minutes. The step was repeated with remaining sweet potatoes.

Deep-frying

Firstly, the oil was poured according to the level and the fryer was let to heat to desired temperature of 180 ^{o}C. The sweet potatoes was then put in the heated oil and fried for 90 seconds or until it was fully cooked with sufficient browning. The fried sweet potatoes were cooled.

Physical properties analysis of processed sweet potatoes

For the study of sweet potatoes, the texture analysis was done to determine the texture differences of the product as affected by the processing methods. Besides, the color analysis was also conducted to see the color changes of the product due to processing.

Texture analysis

The texture of sweet potato was analyzed by using Texture Analyzer TA-XT Plus. Firstly, the texture analyzer was fit with a 3 point bend rig (P5/S) probe. Then, the sample was placed on the middle of texture analyzer.

The probe head was adjusted to the surface of processed sweet potatoes of each batch. The samples was then be compressed to a return distant of 30mm, return speed 10 and contact force 5. Lastly, the maximum compression force (g) of the sweet potato samples was taken for the hardness and fracturability test.

Color analysis

The colors of potato chips was determined by using Chroma Meter Minolta Model CR-400. It was express in terms of L*, a* and b* where L*=100 (white), L*=0 (black), +a*=red, -a*=green and +b* =yellow, -b* =blue. The Chroma Meter was first calibrated prior to analysis by using white calibration plate. The potato chips were placed vertically and the measurements was made directly on the top surface. Lastly, the reading was recorded.

Chemical analysis of processed sweet potatoes

The proximate composition (moisture, ash, crude protein, crude fiber, and crude fat) of the samples was determined according to the official method as described by AOAC (1995). The moisture content of the samples was determined by oven drying (AOAC Method 977.11), while ash content was investigated by dry ashing (AOAC Method 923.03). Crude protein content was quantified by Kjeldahl's method (AOAC Method 955.04). Crude fiber content was analyzed using gravimetric method (AOAC Method 991.43), and crude fat content was determined according to the Soxhlet method (AOAC Method 960.39).

Sensory evaluation

Hedonic scale test was conducted based on randomly picked evaluators of 65 volunteers. This test was carried out in the Sensory Analysis Laboratory in the individual booths to give privacy for the evaluators to do the sensory. These evaluations had the acceptability scale varying from 7 (like very much) till 1 (dislike very much). The acceptability level was based on texture, taste, appearance and aroma of the processed sweet potatoes. The panels was given water to rinse, a pencil, five samples and score card. The panels were asked to rinse their mouth every time they taste the next sample.

Statistical analysis

The data was obtained from the analysis of proximate composition, physical properties and sensory evaluations was used to conduct statistical analysis. The data was run through SPSS (Statistical Package for Social Sciences) software to conduct on way ANOVA test of Turkey test for the samples produced by different processing methods since they have more than three samples and comparative paired T test was conducted to compare results obtained for orange and purple fleshed sweet potatoes as it only consist of two samples using 95 % confidence level.

RESULTS AND DISCUSSION

Effect on texture profile analysis

The attributes measured were hardness and fracturability of the samples. Table 1 shows the comparison of hardness value of orange and purple fleshed sweet potato based on different processing methods. The results obtained show the increasing trend of hardness from freeze-dried sample, deep-fried sample, oven baked sample, air-fried sample and finally the highest hardness level was for the sun dried. A greater hardness value indicates that the material requires a higher force treatment for breaking where the value increases and it is termed as brittle.

Frying occurs rapidly where heat transfer coefficients associated with hot frying oil are much higher and is a much more efficient process of heat transfer than baking (Tuta & Palazoğlu, 2017). Although it has been reported that not all starch may gelatinize in case of rapid dehydration (Teruel et al., 2015) all starch was able to gelatinize even within the limited time of frying. In frying process, existence of oil acts as a plasticizer in the system and provides flexibility to the product (Skarra et al., 1988). Limited heat transfer due to the low heat transfer coefficient may not have generated energy requirement for all starch gelatinization during baking, air-frying and sun drying process that makes the texture harder than deep-fried chips.

Similar results were also obtained for the purple fleshed sweet potatoes with exception where the air-fried and oven baked sample did not show any significant difference ($p>0.05$). According to Sajeev et al. (2012), the textural properties of all white, cream and orange fleshed sweet potatoes show almost similar textural properties. However, thermal softening of tubers during cooking becomes the main cause of textural differences due to the the physicochemical changes occurring to the cell wall materials, such as reduction in hydrostatic pressure, gelatinization of starch and solubilization of pectin material in the middle lamella, cell separation, and an associated loss of turgor (Reeve, 2007).

Table 1. Texture profile analysis of sweet potatoes chips based on different processing methods of two types of sweet potatoes.

Composition	Deep Fried	Oven Baked	Freeze Dried	Sun Dried	Air Fried
		Orange-Fleshed Sweet Potatoes			
Hardness	$501.82^{b} \pm 46.90$	$703.52^{c} \pm 81.23$	$179.86^{a} \pm 8.73$	$1168.12^{e} \pm 57.60$	$912.33^{d} \pm 32.55$
Fracturability	$13.66^{b} \pm 0.78$	$15.71^{c,d} \pm 0.79$	$9.21^{a} \pm 0.41$	$17.3^{d} \pm 1.19$	$15.11^{b,c} \pm 0.72$
		Purple-Fleshed Sweet Potatoes			
Hardness	$579.30^{b} \pm 21.74$	$811.81^{c} \pm 97.71$	$183.25^{a} \pm 41.31$	$1321.31^{d} \pm 147.50$	$799.94^{c} \pm 33.69$
Fracturability	$14.09^{b} \pm 0.65$	$15.49^{c} \pm 0.34$	$10.72^{a} \pm 0.13$	$17.31^{d} \pm 0.69$	$15.97^{c,d} \pm 0.70$

Values (a-d) with different superscript are statistically significant from each other ($p<0.05$).
Presented data are mean value of triplicate value with ± standard deviation shown in error bars.

Table 1 also presents the fracturability value of both orange and purple-fleshed sweet potatoes subjected to different processing methods. Fracturability relates to the ability to break food into pieces when it is bitten using the incisors. The highest fracturable sweet potato chips were from freeze-dried samples, which are due to the porous texture produced by freeze drying are easily broken and little force is required to break it. Whereas, the lowest fracturable sweet potato chips with highest force required is the sun dried potato chips which relates to the slow dehydration process that produces low gelatinization of starch causing the hard texture which are difficult to be broken.

Effect on color analysis

The comparison of color of L*, a* and b* of orange fleshed sweet potatoes based on different processing methods is shown in Table 2. It was found that the lightness of freeze dried sample is the highest, while air fried sample has the lowest lightness. Whereas, the redness value is the highest for freeze-dried and lowest for the deep-fried sample. Comparing the yellowness value is also the highest for the freeze-dried sample and lowest for the air-fried and oven baked samples. However, all the processed sweet potatoes retained the orange color due to the pre-treatment with sodium metabisulphite. However, freeze-dried sample retained the most because it does not involve any heat process.

According to Tuta and Palazoğlu (2017), lightness (L*) , redness (a*) and yellowness (b*) values of oven baked chips were higher than their fried counterparts which is similar with the results obtained in this research. The color have high correlation with the processing method and temperature of the methods used. The presence of oxygen during baking causes ascorbic acid oxidation in addition to Maillard reaction which results in greater color change. Leeratanak et al. (2006) reported that higher degree of ascorbic acid loss occurs due to the low convective heat transfer coefficient of air. During frying, color change occurs only via Maillard reaction as there is no oxygen exists in the frying oil. For that reason, lighter color of chips during frying was observed in present study. Besides, the color of air-fried chips tend to become dark due to oxidation as it is exposed to air and thus the lightness, a and b value are low.

Table 2. Color analysis of sweet potatoes chips based on different processing methods of two types of sweet potatoes.

Composition	Deep Fried	Oven Baked	Freeze Dried	Sun Dried	Air Fried
			Orange-Fleshed Sweet Potatoes		
L*	$10.87^{c} \pm 0.26$	$16.92^{b} \pm 0.47$	$47.64^{d} \pm 0.47$	$18.10^{c} \pm 0.41$	$8.90^{a} \pm 0.83$
a	$1.58^{a} \pm 0.15$	$4.29^{b} \pm 0.45$	$37.10^{d} \pm 0.83$	$13.23^{c} \pm 0.74$	$5.22^{b} \pm 1.07$
b	$9.90^{b} \pm 0.53$	$15.09^{a} \pm 0.95$	$46.66^{d} \pm 0.94$	$17.41^{c} \pm 0.50$	$8.39^{a} \pm 1.38$
			Purple-Fleshed Sweet Potatoes		
L*	$6.54^{b} \pm 0.57$	$17.35^{a} \pm 0.23$	$60.62^{e} \pm 0.50$	$44.85^{d} \pm 0.16$	$40.82^{c} \pm 0.49$
a	$5.93^{b} \pm 0.16$	$18.46^{d} \pm 1.49$	$5.83^{b} \pm 0.01$	$8.17^{c} \pm 0.08$	$1.21^{a} \pm 0.03$
b	$21.86^{d} \pm 0.34$	$19.33^{c} \pm 1.55$	$7.31^{a} \pm 0.02$	$6.14^{a} \pm 0.05$	$14.09^{b} \pm 0.25$

Values (a-d) with different superscript are statistically significant from each other ($p<0.05$).
Presented data are mean value of triplicate value with ± standard deviation shown in error bars.

Table 2 also shows statistically significant different values ($p<0.05$) for the samples of purple fleshed sweet potatoes. Purple fleshed sweet potatoes (PFSP) have a high level of anthocyanins in their tissues and skins, resulting in purple color (Yoshinaga et al., 1999; Truong et al., 2010; Kim et al., 2012). Anthocyanins are water soluble pigments as well as sensitive to heat. This indicates that the anthocyanins in PFSP can be significantly changed during cooking either by leaching or heat denaturation.

The lightness value for the freeze-dried samples was the highest because as the freeze-drying methods is done under vacuum condition there is no oxidation reaction occurs. Valentina et al. (2016) stated that during freeze-dry processing, at low temperature, freeze-drying removes water by sublimation of ice and prevents enzymatic browning reactions. A high L* value for freeze dried sample was obtained as the browning was not promoted due to less oxygen and lower temperature during freeze-drying process. According to Ceballos et al. (2012), the conservation of color is considered indications of quality in dried fruits given that non-enzymatic browning processes develop during the drying process. Freeze-dried fruits better maintain red and yellow colors than fruits dried using traditional methods (Shishehgarha et al., 2001). However, statement by Shishehgarha was different from the results as the anthocyanin leaches due to soaking in sodium metabisulphite and cold water causing low a and b values. This was mainly due to high affinity of anthocyanin to water (Garretson et al., 2018).

Effect on chemical analysis

The results obtained for the chemical analysis are tabulated in Table 3. It can be seen that the moisture content for the raw material was the highest since it has not undergone dehydration process. However, processing methods have caused the reduction of moisture content due to dehydration. Moisture content is an indicator of product quality. It is related to the perishability and therefore, inadequate levels may lead to large losses in chemical stability and microbiological contamination (Ordóñez, 2005). Capézio et al. (1993) stated that moisture content is a determinant of root quality. High quality potatoes contain high dry matter. Other than that, most of the moisture content of processed sweet potatoes was similar between the samples with some comparison consist of statistically significant difference ($p<0.05$) such as oven baked and deep-fried samples together with the raw sweet potatoes shown obvious result. The deep-fried samples consist of higher moisture content (6.43 g/100 g) compared to oven baked samples with much lower moisture content (3.71 g/100 g). This was due to the processing techniques itself where during frying due to high temperature and direct immersion in the oil, the crisp outer layer was formed first before the moisture content can be released and thus providing high moisture content where the results obtained supports the previous study of Moradi et al. (2009). They also reported that, the slower temperature changes in oven baking method causing it to have lower moisture content.

Besides, the different in the moisture content of raw material was due to the variation in the variety and cultivation. This statement also supported by research of Alam et al. (2016), where they reported that variations in the moisture content among the sweet potato varieties can be due to the differences in the genetic composition and cultivation practices. In comparison with other roots and tubers, the sweet potato has a high moisture content and thus, has a low dry matter content. However, the trend line for processing methods comparison was still the same which is increasing from freeze-dried, sun dried, air-fried, oven baked, deep-fried and raw material samples.

Ash content in food is referred to any inorganic material such as minerals. The results obtained are shown in Table 3, where there were statistical significant different ($p<0.05$) results between samples of different processing methods. The highest amount was found in the raw sweet potatoes (2.16 gram for orange fleshed sweet potatoes and 2.55 gram per 100 gram for purple fleshed sweet potatoes) followed by freeze-dried, sun dried, oven baked and air-fried samples that are almost similar and the least amount in deep-fried samples (1.19 gram for orange fleshed sweet potatoes and 1.48 gram per 100 gram for purple fleshed sweet potatoes). According to Hassan et al. (2007), the results of various dehydration methods used have significantly increased the ash, fiber and mineral content of the leaves of *Gynandropsis gynandra*. Ash is the inorganic residue remaining after the water and organic matter have been removed by food. The ash content is measure of the total amount of mineral present within a food, whereas the mineral content is a measure of amount of specific inorganic compounds present in the food.

The increase in the ash and fiber contents observed in this study could be as a result of the removal of moisture which tends to increase the concentration of nutrients (Morris et al., 2004). However, the values of ash in processed sweet potato chips slightly decreased due to the leaching of the minerals during soaking in cold water and sodium metabisulphite. This is also the reason for the deep-fried samples has the lowest amount of mineral content as it is further immersed in hot oil for frying purpose that leaches out the mineral content from the sample but it is certainly not destroyed by heat. This statement is supported by Morris et al. (2004) who stated that, minerals are not destroyed by heating and they have a low volatility compared to other food components but it may loss through leaching. El-Adawy (2002) also stated that the decrease in ash content might be due to their diffusion into the water. Based on comparison of ash content in orange fleshed sweet potatoes and purple fleshed sweet mostly there were no statistical significant difference ($p>0.05$) as the results were almost similar which might be due to similar cultivation nutrients supplied to the plants.

Table 3. Chemical analysis of sweet potatoes chips based on different processing methods of two types of sweet potatoes.

Composition (g/100g)	Raw Material	Deep Fried	Oven Baked	Freeze Dried	Sun Dried	Air Fried
			Orange-Fleshed Sweet Potatoes			
Moisture	$78.40^{d} \pm 0.61$	$6.43^{c} \pm 1.16$	$3.71^{b} \pm 0.61$	$1.50^{a} \pm 0.32$	$2.80^{a,b} \pm 0.39$	$3.06^{a,b} \pm 0.62$
Ash	$2.16^{c} \pm 0.16$	$1.19^{a} \pm 0.19$	$1.41^{a,b} \pm 0.24$	$1.77^{b,c} \pm 0.05$	$1.73^{b} \pm 0.06$	$1.31^{a} \pm 0.07$
Crude Protein	$5.98^{e} \pm 0.22$	$3.74^{a} \pm 0.10$	$3.95^{a,b} \pm 0.12$	$5.65^{d} \pm 0.10$	$4.26^{b,c} \pm 0.02$	$4.49^{c} \pm 0.02$
Crude Fiber	$2.91^{b,c} \pm 0.41$	$1.62^{a} \pm 0.37$	$2.58^{a,b,c} \pm 0.48$	$3.56^{c} \pm 0.06$	$2.91^{b,c} \pm 0.10$	$2.09^{a,b} \pm 0.06$
Fat	$1.27^{a} \pm 0.03$	$45.85^{c} \pm 1.60$	$6.01^{b} \pm 0.47$	$1.51^{a} \pm 0.09$	$1.42^{a} \pm 0.09$	$1.63^{a} \pm 0.18$
			Purple-Fleshed Sweet Potatoes			
Moisture	$82.84^{c} \pm 0.42$	$3.36^{b} \pm 0.32$	$2.79^{b} \pm 0.32$	$1.23^{a} \pm 0.19$	$1.32^{a} \pm 0.35$	$1.44^{a} \pm 0.33$
Ash	$2.55^{c} \pm 0.38$	$1.48^{a} \pm 0.05$	$1.92^{a,b} \pm 0.07$	$2.00^{b} \pm 0.06$	$1.96^{b} \pm 0.02$	$1.91^{a,b} \pm 0.06$
Crude Protein	$5.37^{e} \pm 0.38$	$2.83^{a} \pm 0.17$	$3.45^{b} \pm 0.25$	$4.98^{d,e} \pm 0.07$	$3.92^{b,c} \pm 0.03$	$4.49^{c,d} \pm 0.16$
Crude Fiber	$4.19^{b} \pm 0.16$	$3.74^{a,b} \pm 0.14$	$4.08^{b} \pm 0.11$	$5.83^{d} \pm 0.09$	$4.62^{c} \pm 0.18$	$3.62^{a} \pm 0.05$
Fat	$1.81^{a} \pm 0.18$	$44.21^{c} \pm 1.36$	$7.13^{b} \pm 0.16$	$1.53^{a} \pm 0.21$	$1.48^{a} \pm 0.08$	$1.52^{a} \pm 0.62$

Values (a-e) with different superscript are statistically significant from each other ($p<0.05$).
Presented data are mean value of triplicate value with ± standard deviation shown in error bars.

For the crude protein value, most of the samples tested provided statistical significant difference ($p<0.05$) where the trend increasing in protein content from deep-fried, oven baked, sun dried, air-fried, freeze-dried and raw sweet potatoes. Table 3 shows that the crude protein content decreases from the amount found in the raw sweet potatoes compared to the processed sweet potatoes where the value of protein content for the raw sweet potatoes was the highest at value 5.98 gram per 100 gram. Ramasamy et al. (1999) stated that a general decrease was found in crude protein content for all preparations which shows similar results as in this research. The researchers also mentioned that, this could be attributed to leaching losses, especially from the boiled products, chips and battered cakes, of soluble proteins and other non-proteinous nitrogen soluble compounds and to non-enzymatic browning occurring in the chips. The interaction between protein and carbohydrates or lipid oxidation products during cooking may lead to nutritional unavailability of protein (Manay and Shadaksharaswamy, 1987).

Based on the results obtained, the freeze-dried samples had highest value of crude protein (5.65 gram per 100 gram from orange fleshed sweet potatoes and 4.98 gram per 100 gram for purple fleshed sweet potatoes) followed by air-fried samples, sun dried, oven baked and the least in deep-fried samples (3.74 gram per 100 gram from orange fleshed sweet potatoes and 2.83 gram per 100 gram for purple fleshed sweet potatoes). Swaminathan (1986) also reported that roasting, baking and frying adversely impact the nutritional value of food proteins, primarily due to the Maillard reaction. Akpan and Umoh (2004) reported that the reduction in the protein content of foods on heat application may caused by the tannins that form complexes with protein, thus reducing the amount of protein. The application of moist heat to proteins also causes coagulation and shrinking and thus, the principal effect of heating is denaturation. Besides, comparing the protein content of orange and purple fleshed sweet potatoes for the processing methods shown statistical significant differences ($p<0.05$) where this are mainly due to the difference in cultivations of the plants where there is differences in soil content and also fertilizer used (Alam et al., 2016).

Crude fiber is the amount of soluble fiber content found in food samples. The results in Table 3, shows that overall the amount of crude fiber increases due to dehydration method as compared to raw sweet potatoes with statistical significant difference ($p<0.05$) between samples. The highest amount of crude fiber was found in freeze-dried samples with amount 3.56 and 5.83 gram per 100 gram of orange and purple fleshed sweet potatoes. El-Adawy (2002) stated that, crude fiber was significantly ($p < 0.05$) increased by cooking treatments which could have been due to protein-fiber complexes formed after possible chemical modification induced by cooking of dry seeds. This supports the reasoning behind the increase of fiber content in the samples. However, the amount of fiber in deep-fried and air-fried samples reduced from the original content of the raw material which were due to solubility of the fiber during the soaking step. Ramasawmy et al. (1999), stated that it may be reasonable to assume that these losses were due to leaching of soluble fibers from the tubers into the cooking water, or into the oil. Besides, according to Ishida et al. (2000), the difference in fiber content in varieties of sweet potatoes are due to genetic of the plant itself and cultivation differences.

The fat content is one of the key quality control parameters for feed and food. Comparing the fat content as shown in Table 3, only the oven baked and deep-fried samples have shown statistical significant difference ($p<0.05$) as deep-fried sample shown the highest fat content value (45.85 gram for orange fleshed sweet potatoes and 44.21 gram per 100 gram for purple fleshed sweet potatoes). This was due to the immersion of oil for deep-frying has affected the oil uptake of the fried sweet potato chips promoting the fat content. As for the oven baked samples also had higher fat content if compared to air fried, sun dried and freeze dried samples due to the grease oil applied as a base in baking pan which has contributed to the fat content level. This statement is supported by Tuta and Palazoğlu (2017) who stated that due to their oil content ranging from 35% to 45% by weight for deep fried potato chips, they have a negatively perceived image. Moreira et al. (1995) also supported by stating that in most cases, the absorbed oil tends to accumulate on the fried food surface during frying and migrates to the inner side of foods during cooling, causing a high fat content. Besides, the air-fried, sun dried, freeze-dried and raw sweet potato does not show any statistical significant difference ($p>0.05$) in the results. Moreover, even the comparison of fat content between orange and purple fleshed sweet potatoes did not show any statistical significant difference ($p>0.05$). This was because crops of similar family did not show any difference of fat content.

Sensory evaluation

Sensory evaluation was the method used to determine the sensory acceptability of orange and purple fleshed sweet potatoes processed in different methods with 65 panelist. The seven scale hedonic test was used for the test of this sensory evaluation. Based on the results obtained for the control sample as shown in the Table 4, there is statistical significant difference ($p<0.05$) between the samples of different processing methods where the most acceptable sweet potato chips was for the deep-fried sample with scale 6.2 followed by oven baked sample with scale 5.8, air-fried sample of scale 4.8, sun dried sample of scale 2.4 and freeze-dried sample of scale 2.2.

However, there was no statistical significant difference ($p>0.05$) between deep-fried and oven baked samples and also between freeze-dried and sun dried samples as they fall in the same range. This was mainly due to the attractive color, aroma and crisp texture of the deep-fried samples that attracted the panelist. Salvador et al. (2009), stated that the texture (crispness) in potato chips is one of the most important quality indicators in the final product, along with color, aroma and flavor which contributed to the choice of deep-fried and oven baked samples by the panelist. The sun dried samples have produced hard texture whereas the freeze-dried samples shown very soft texture which is not preferred by the panelist..

Table 4. Shows the comparison of sensory evaluation score results of orange and purple fleshed sweet potatoes based on different processing methods for the control sample without seasoning.

	Deep Fried	Freeze Dried	Air Fried	Oven Baked	Sun Dried
			Orange Fleshed Sweet Potatoes		
Color	$6.5^{c} \pm 0.99$	$2.3^{a} \pm 1.43$	$4.3^{b} \pm 1.46$	$6.1^{c} \pm 0.84$	$2.4^{a} \pm 1.33$
Aroma	$5.9^{c} \pm 1.39$	$2.7^{a} \pm 1.17$	$4.6^{b} \pm 1.17$	$5.4^{c} \pm 0.90$	$3.1^{a} \pm 1.36$
Texture	$6.5^{d} \pm 0.71$	$2.1^{a} \pm 0.97$	$4.7^{b} \pm 1.39$	$5.8^{c} \pm 1.00$	$2.3^{a} \pm 1.20$
Taste	$5.9^{c} \pm 1.63$	$2.1^{a} \pm 1.03$	$4.7^{b} \pm 1.28$	$5.9^{c} \pm 1.14$	$2.2^{a} \pm 1.31$
Acceptability	$6.2^{c} \pm 1.10$	$2.2^{a} \pm 1.06$	$4.8^{b} \pm 0.96$	$5.8^{c} \pm 0.99$	$2.4^{a} \pm 1.31$
			Purple Fleshed Sweet Potatoes		
Color	$6.5^{d} \pm 1.00$	$2.3^{a} \pm 1.42$	$4.2^{b} \pm 1.42$	$5.9^{c} \pm 0.83$	$2.3^{a} \pm 1.35$
Aroma	$6.0^{d} \pm 1.35$	$2.6^{a} \pm 1.18$	$4.5^{b} \pm 1.13$	$5.4^{c} \pm 0.90$	$2.9^{a} \pm 1.33$
Texture	$6.5^{d} \pm 0.73$	$2.0^{a} \pm 0.98$	$4.6^{b} \pm 1.37$	$5.6^{c} \pm 0.94$	$2.2^{a} \pm 1.15$
Taste	$6.0^{c} \pm 1.60$	$2.0^{a} \pm 1.04$	$4.6^{b} \pm 1.25$	$5.6^{c} \pm 1.08$	$2.3^{a} \pm 1.26$
Acceptability	$6.3^{d} \pm 1.10$	$2.1^{a} \pm 1.10$	$4.7^{b} \pm 0.96$	$5.6^{c} \pm 0.92$	$2.3^{a} \pm 1.26$

Values (a-d) with different superscript are statistically significant from each other ($p<0.05$).
Presented data are mean value for 65 panels with ± standard deviation.

CONCLUSION

In a nut shell, overall the physicochemical analysis which shows the nutrition value of two types of sweet potatoes based on different processing methods produced results where the freeze-dried samples tend to have the highest values of ash (OFSP: 1.77 g/100 g, PFSP: 2.00 g/100 g), crude protein (OFSP: 5.65 g/100 g, PFSP: 4.98 g/100 g) and crude fiber content (OFSP: 3.56 g/100 g, PFSP: 5.83 g/100 g). Adversely, freeze-dried samples provided small amount of fat content for both type of sweet potato which are 1.51 g/100 g compared to other samples. However for the sensory acceptance, deep-fried and oven baked samples was most acceptable by the panelist with the score of range 5 to 6 in the 7 hedonic scale test. Whereas, the deep-fried sample showed lowest value for the chemical analysis where for ash both type of sweet potatoes (1.19 g/100 g), crude protein (OFSP: 3.74 g/100 g, PFSP: 2.83 g/100 g) and crude fiber content (OFSP: 1.62 g/100 g, PFSP: 3.74 g/100 g). However, the deep-fried samples had highest fat content for both type of sweet potatoes which are 45.85g/100g. Concerning the physical attributes, the sun dried samples had the highest hardness value whereas the freeze-dried samples had the lowest fracturability value which made it least sensory acceptance. Color analysis indicated most OFSP retained color where the PFSP leached it color. Overall the oven baked samples had moderate amount of ash, crude fiber and crude protein. However, it consist lower fat content compared to deep-fried samples. Moreover, oven baked samples obtained similar sensory attributes score of range 5 to 6 as deep-fried samples. Further research are recommended to conduct experiment on oven baked potato chips with much lower fat content and higher nutrient retention.

ACKNOWLEDGMENTS

The first author gratefully acknowledge the science officers from Faculty of Bioresources and Food Industry, Universiti Sultan Zainal Abidin, Besut Campus for their technical support.

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How to cite this paper:
Sugumaran, K., Rois Anwar, N.Z. & Abd. Ghani, A. (2019). Effect of different processing methods on the physicochemical properties and sensory evaluations of sweet potatoes chips. Journal of Agrobiotechnology*,* *10*(2), 51-63