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Effect of Pre-drying, Blanching and Citric Acid Treatments on the Quality of Fried Sweet Potato Chips

[1]G. Abdulla, [1]Gehan A. El-Shourbagy and [2]Mahmoud Z. Sitohy
[1]Department of Food Science, Faculty of Agriculture, Zagazig University, Zagazig, Egypt
[2]Department of Agriculture Biochemistry, Faculty of Agriculture, Zagazig University, Zagazig, Egypt

Corresponding Author: Galal Abdulla, Department of Food Science, Faculty of Agriculture, Zagazig University, Zagazig, Egypt Tel: 002 01095825947 Fax: 002 055 228 75 67

ABSTRACT
Frying of sweet potato slices is carried out to convert the roots to value added products. Frying method brings out unique flavor and texture to the products that improve their overall acceptability. The aim of this work was to determine the effect of some pretreatments on moisture, vitamin C content and color and oil absorption of fried sweet potato chips. Prior frying, sweet potato slices were pre-dried and blanched and pre-dried or treated with 0.1% citric acid solution and pre-dried. The pre-drying treatments were carried out at 70°C for 0, 30, 50 and 70 min. The mean of moisture content of the dried, blanched and citric acid treated chips were in the range of 1.38-1.91, 1.04-1.41 and 1.35-1.88%, respectively. While, the fat content in the same samples ranged between 12.57-14.23, 14.09-17.92 and 12.31-14.54%, respectively. Vitamin C content in fried sweet potato chips pre-dried only, blanched and pre-dried and citric acid treated and pre-dried ranged between 17.43-40.50, 9.23-29.23 and 19.87-44.93 mg 100 g^{-1}, respectively. The samples pre-dried only gave darker chips compared to that blanched and pre-dried or citric acid treated and pre-dried. Fried sweet potato chips treated with citric acid and pre-dried for 50 min had the best sensory scores for all sensory quality attributes.

Key words: Sweet potato chips, pretreatments, vitamin C, oil absorption, color

INTRODUCTION
Sweet potato (*Ipomoea batatas* L.) is native to tropical and subtropical regions of the world and ranked the seventh most important crop following rice, wheat, maize, potato, cassava and barley (Woolfe, 1992). China is the leading producer of sweet potatoes with production reaching 75 million metric tons in 2011, which accounts for approximately 73% of global production. The production of sweet potatoes in Egypt is 274 935 metric tons in 2011 (FAO, 2012).

Sweet potatoes tubers have good nutritional value, containing many vitamins, minerals, non fibrous complex carbohydrates and dietary fiber (Suda *et al.*, 2003). Orange flesh sweet potato is rich source of β-carotene (provitamin A), a very good source of vitamin C and a good source of copper, dietary fiber, vitamin B6, manganese, potassium and iron, while purple-fleshed varieties are rich source of anthocyanins (Baybutt *et al.*, 2000; Teow *et al.*, 2007; Yang and Gadi, 2008). Sweet potato serves as a stable food vegetable (fleshy roots and tender leaves), snack food, wearing food, animal feed, as well as a raw material for industrial starch and alcohol. It is processed into diverse products (Udensi, 2000; Ukom *et al.*, 2009).

Sweet potato can be roasted or baked, fried, steamed or microwaved. Each cooking methods lead to different changes in the quality attributes of sweet potato (Wang and Kays, 2001; Takenaka *et al*., 2006). Processed products include chips, purees, dehydrated flakes, canned sweet potatoes, patties, breads, beverages and especially products including candies and baby foods (Kays, 1985).

Antioxidants such as vitamin C have been shown to interact with and stabilize free radicals within the body. This action decreases the risk eye problems, like cataracts, many cancers and can help slow down the aging process. Vitamin C is also necessary for normal growth, absorption of iron, healing of wounds, formation of important protein used to make skin and stimulating the activity of the immune system. It is also needed for the maintenance of teeth and bones (Sweetman, 2007; Babalola *et al*., 2010; Everette and Islam, 2012).

One of the most important dietary compounds found in sweet potatoes is β-carotene, an important vitamin A source for human, which constitute 86 to 89% of orange and yellow fleshed sweet potatoes (Woolfe, 1992). Also, Burri (2011) suggested that orange-fleshed sweet potatoes are a nutritious and sustainable source for preventing vitamin A deficiency. Beta-carotene is most important as the precursor of vitamin A in human diet which maintains and protects eye tissues, but it has also been linked to enhanced immune response and suppressed cancer development. Carotenoids generally cannot be manufactured by humans so it must be added to their diet in appropriate amounts (Kopsell and Kopsell, 2006).

Taiwo and Baik (2007) found that the bulk density of fried sweet potato discs subjected to various pre-treatments (air drying, osmotic dehydration, blanching and freezing) decreased while porosity increased with frying time. Effect of pre-treatment though not significant on bulk density but was significant on product porosity.

The currant study focused on improves the quality of sweet potato chips to enhance the consumption of sweet potato in Egypt. Thus improving the aim of this paper is to investigate the effect of some pretreatments such as pre-drying time, blanching and citric acid treatments on the quality of fried sweet potato chips.

MATERIALS AND METHODS

Sample preparation: About 10 kg of orange flesh sweet potatoes were freshly purchased from a local market in Zagazig city, Egypt. Sweet potato tubers were soaked in tap water for 15 min and then cleaned by tap water to remove adhering soil particles and other foreign debris. The cleaned roots were wiped dry with clean tissues and sorted to remove small and injured roots. The sorted roots were cut into slices of 0.8 mm thick using an adjustable stainless steel hand slicer. Sweet potato slices were rinsed in distilled water immediately after cutting to eliminate the excess starch adhering on the surface and controlling the browning reactions.

Pre-drying, blanching and citric acid treatments: Sweet potato slices were divided into three groups, each group contained four portions of 200 g. The first group was pre-dried only at 70°C for 0, 30, 50 and 70 min. The second group was blanched at 65°C for 5 min, while the third group was immersed in 0.1% citric acid solution for 5 min and subjected to hot air drying at 70°C for 0, 30, 50 and 70 min. The moisture content of the slices was determined at the end of each drying time. The partially dehydrated chips were deep fried at 170±1°C. Figure 1 presents the schematic diagram of sweet potato chips processing.

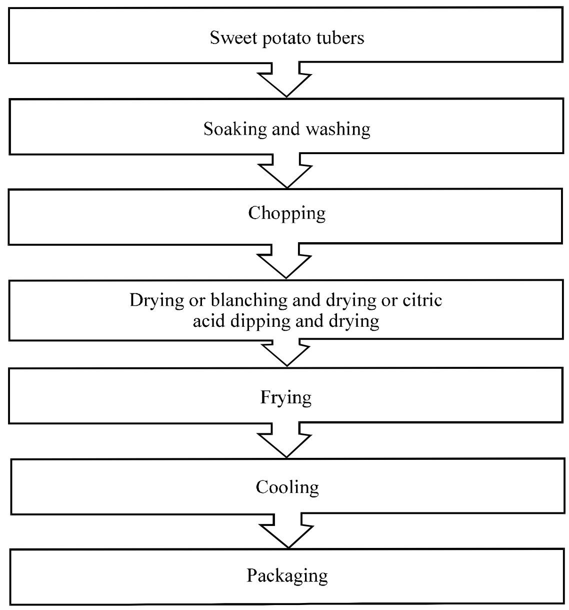

Fig. 1: Schematic diagram of sweet potato chips processing

Frying process: Home deep fat fryer (Deep Fryer, Moulinex, France) with temperature controller was used. The fryer was filled with 3 L refined pure sunflower oil. The fryer was equipped with a metal mesh basket in which the samples were immersed in the oil and fried. To determine optimal frying time, frying temperature was kept at 170±1°C (Taiwo and Baik, 2007; Baik and Mittal, 2003). The frying time was adjusted carefully to produce the bright color and crisp chips. After each frying process, the oil level was checked and replenished. The fried chips were gently blotted with tissue to remove surface oil and were put in sealed plastic bags wrapped with aluminum foil and kept at 5°C for objective analysis. Fried samples for panel test were introduced to the panelists immediately after frying.

Chemical analysis: The objective quality ratings consisted of analyzing moisture, fat, ascorbic acid and color values. For moisture, fat and ascorbic acid determination chips were ground in a blender with a cup of stainless steel cup. Ground samples were kept in plastic, bags at -18°C until analyzed.

Moisture determination: Approximately 5 g of sweet potato slices or ground chips were weighed and dried at 105°C to a constant mass in an oven. Moisture percentage was calculated from the deference of weight (AOAC, 2000). The test was performed in triplicates.

Fat determination: Fat content is determined by Soxhlet extraction (AOAC, 2000). The fried ground chips used for moisture determination were extracted with petroleum ether at room temperature for 4 h. Petroleum ether is removed under vacuum by a rotary evaporator (Buchi Waterbath B-480 with Buchi Rotavapor R-124) at 45°C. The recovered oil is left for 24 h in a vacuum oven at 70°C and weighted.

Ascorbic acid determination: About 10 g of each sample was weighed in a 50 mL volumetric flask and extracted with little glacial acetic acid and the extract was made up to the mark with distilled water. This was followed by filtration into a conical flask. The filtrate was run from a burette into a conical flask containing one drop dilute acetic acid and 1 mL of 2,6-dichlorophenol indophenol solution (0.001 mol L^{-1}). The volume required to decolorize the dye was recorded. The titration was repeated using standard ascorbic acid solution (1 mg pure vitamin per 100 mL) in place of the samples. Hence the amount of ascorbic acid per 100 g of the samples was determined (Sadasivam and Manickam, 1996).

Color determination: Color attributes of the fried sweet potato chips; lightness (L*), redness (a*) and yellowness (b*) were performed using Minolta color Reader C-10 (Minolta CO. Ltd., Osaka, Japan). Samples were placed vertically and measurements were made directly on the top (upper) surface, which was always steady, of cylindrical samples. The color intensity (C), the hue angle (h_{ab}) and total colour difference (ΔE) was calculated as, where h_{ab} = 0° for red hue and h_{ab} = 90° for a yellow hue (Rora and Einen, 2003; Shih *et al*., 2009) the results were expressed as:

$$C = (a^{*2}+b^{*2})^{0.5}$$

$$h_{ab} = \tan^{-1} (b^*/a^*)$$

$$\Delta E = [(L-L_0)^2+(a-a_0)^2+(b-b_0)^2]^{0.5}$$

where, L_0, a_0 and b_0 were the L, a and b values of the reference sample which here is the citric acid treated (dried for 50 min) sample.

Sensory evaluation: Subjective qualities of the chips were evaluated according to Silayo *et al*. (2003) by 10 panelists (Staff of Food Science, Depart. Faculty of Agricultural, Zagazig University, Egypt). The panelists were chosen randomly and the samples were subjected to sensory evaluation using a 5-point hedonic scale for color, flavor, texture and brittle, oil taste and overall acceptability.

Statistical analysis: The data of the present study were subjected to analysis of variance (ANOVA) using SAS software (SAS Institute, 1990). Differences between means were determined by the least significant difference test and significance was defined at $p<0.05$. All measurements were carried out in triplicate.

RESULTS AND DISCUSSION

Effect of pre-drying time on moisture content of sweet potato samples: Data in Table 1 show the effect of drying times on the moisture content of sweet potato samples. The initial moisture content of the sweet potato samples was 85.46%, while it was 95.65 and 92.70% after blanching (65°C for 5 min) and after dipping in 0.1% citric acid for 5 min, respectively. In order to evaluate the effect of the moisture content of the samples on the oil absorption during frying process, sweet potato samples were subjected to hot air drying at 70°C for different times (0, 30, 50, 70 min) before frying. It was noticed that, the longer the drying time, the lower the moisture content of sweet potato samples. At the end of each drying time the moisture content of the partially dried, blanched and citric acid treated samples was 60.90, 86.85 and 74.79%, respectively.

Table 1: Effect of pre-drying time on moisture content of sweet potato

	Moisture content		
Pre-drying time (min)	Pre-drying	Blanching and pre-drying	Citric acid and pre-drying
0	85.46	95.65	92.70
30	78.01	93.83	88.94
50	71.20	91.35	84.98
70	60.90	86.85	74.79

Table 2: Effect of pre-drying time on moisture and fat content of fried sweet potato chips

	Pre-drying		Blanching and pre-drying		Citric acid and pre-drying	
Pre-drying time (min)	Moisture content (%)	Fat content (%)	Moisture content (%)	Fat content (%)	Moisture content (%)	Fat content (%)
0	1.91±0.05	14.23±0.11	1.41±0.01	17.92±0.11	1.88±0.02	14.54±0.10
30	1.54±0.08	13.01±0.10	1.28±0.04	15.70±0.08	1.58±0.01	13.62±0.13
50	1.43±0.03	12.83±0.13	1.17±0.01	14.99±0.13	1.47±0.01	13.04±0.15
70	1.28±0.05	12.57±0.09	1.04±0.02	14.09±0.10	1.35±0.03	12.31±0.11

Mean value±Standard Deviation (SD)

Moisture and fat content of fried sweet potato chips: Table 2 shows the effect of pre-drying time on the moisture and fat content of fried sweet potato chips. Pre-drying treatment at 70°C reduced the moisture content and the oil absorption in all samples after frying. Generally, as the drying time increased the moisture and fat content of the chips decreased. The mean of moisture content of the dried, blanched and citric acid treated chips were in the range of 1.91-1.28, 1.41-1.04 and 1.88-1.35%, respectively. While, the fat content in the same samples ranged between 12.57-14.23, 14.09-17.92 and 12.31-14.54%, respectively. In this respect, Pedreschi and Moyano (2005) reported that pre-drying decreased the oil absorption and increased significantly the crispness of the blanched potato slices after frying. Blanched sweet potato chips were characterized by the lower moisture contents after frying. Krokida *et al.* (2001b) and Moyano *et al.* (2002) reported that pre-drying treatment of potatoes was a successful way to reduce oil uptake in fried potatoes as well. The reduction of moisture content in the blanched samples after frying may be due to the gelatinization of starch. In this respect, Gunaratne and Hoover (2002) reported that starch is hydrolyzed by thermal treatments in water enabling oil absorption by the samples during the frying process in all treated samples compared with the control. Blanched sweet potato had the highest oil content after frying, that may be due to the reduction in porosity after blanching treatment. Similar conclusions were reached by Kawas and Moreira (2001) and Taiwo and Baik (2007) who found that the porosity of blanched and air dried sweet potato were much lower than for the other pretreatments (freezing, osmotic dehydration and control).

Vitamin C in fried sweet potato chips: Effect of pre-drying time, blanching and citric acid dipping on vitamin C content of fried sweet potato chips is shown in Table 3. Vitamin C content in raw sweet potato slices was 63.38 mg 100 g^{-1}. Vitamin C content in fried sweet potato chips ranged between 9.23 to 44.93 mg 100 g^{-1}. Generally, ascorbic acid content decreased gradually with the increase in pre-drying time. Citric acid treatment had a good effect on vitamin C retention since the samples treated with citric acid before frying retained 31.35-70.89% of the original vitamin C content. While, blanching had the lowest affect on vitamin C retaining where, the samples blanched before frying retained only 14.56-46.12% of original vitamin.

Table 3: Vitamin C content of raw and fried sweet potato chips

	Vit. C content (mg 100 g^{-1})			
Pre-drying time (min)	Raw	Pre-drying	Blanching and pre-drying	Citric acid and pre-drying
0	63.38	40.50±0.30	29.23±0.15	44.93±0.40
30	-	28.53±0.23	19.80±0.17	32.70±0.35
50	-	23.53±0.40	13.60±0.26	27.70±0.36
70	-	17.43±0.42	9.23±0.15	19.87±0.35

Mean value±Standard deviation (SD)

Table 4: Effect of pre-drying, blanching and citric acid treatments on color values of fried sweet potato chips

		Color values					
Treatments	Pre-drying time (min)	L*	a*	b*	C	h_{ab}	ΔE
Pre-drying	0	50.60	11.45	21.25	24.14	49.42	6.89
	30	48.45	9.60	18.10	20.49	48.77	10.22
	50	52.60	9.30	23.65	25.41	37.47	3.35
	70	53.20	6.85	24.65	25.58	27.11	3.12
Blanching and pre-drying	0	51.10	8.75	20.20	22.01	40.88	6.92
	30	50.50	6.65	17.95	19.14	35.48	9.42
	50	51.60	6.60	19.30	20.40	32.95	7.79
	70	47.00	6.95	16.60	18.00	39.65	12.46
Citric acid and pre-drying	0	49.20	7.65	19.45	20.90	37.47	8.81
	30	50.10	10.25	17.60	20.37	52.74	9.71
	50	55.15	9.00	25.80	27.32	33.56	-
	70	51.30	5.85	22.25	23.01	25.71	6.11

*Mean of three reading

Babalola *et al.* (2010) studied the effect of some processing methods (cooking, frying and baking) on the Vitamin C content of sweet and Irish potatoes. Raw sweet and Irish potatoes contained 160 and 79.3 mg 100 g^{-1} of Vitamin C, respectively. The highest loss of 71.25% was observed when sweet potato was cooked followed by frying 61.93 while baking produced a loss of 51.50%. Akpapunam and Abiante (1991) reported that sweet potato slices dehydrated at 70°C for various times (0, 90, 105, 120, 135, 150, 165 min) before frying resulted in about 26 to 76% decrease in the ascorbic acid content of the chips.

Color values of sweet potato chips: Color is considered the most important attribute in the perception of sweet potato chip quality. The effect of pre-drying, blanching and citric acid treatments on color values of fried sweet potato chips are given in Table 4. Although there are different color spaces, the most commonly used in the color measuring of foods is the L*, a*, b* color space because of the uniform distribution of colors and because it is very close to human perception of color (Leon *et al.*, 2006). The L* value describes lightness and is equal to zero for black and 100 for white. This corresponds to the intensity of light recorded by the human eye. The values of L* changed slightly for all sweet potato samples and ranged between 47 to 55.15. Blanched and citric acid treated samples were lighter in color with higher L* values than samples pre-dried only before frying and control (darker chips).

The a values of fried sweet potato chips were low, indicating a tendency of the potato chips to have more of a greenish color rather than red. A red color is an indication of overcooked sweet potato chips. A higher L* value means that the fried sweet potato chips were lighter in color, while higher a* values indicate that more Maillard reactions are occurring (Garayo and Moreira, 2002). The samples which pre-dried only before frying had higher a* values than the samples blanched or citric acid treated before frying this may be due to the Maillard reaction.

The yellowness of food product is specified by the parameter b* in color measurement. The b* values increased gradually with increasing of pre-drying time for all samples. In general, higher b* parameter values give more yellow products, which is desirable for fried products (Krokida *et al.*, 2001a). These results are in agreement with those obtained by Shih *et al.* (2009).

Sensory evaluation: The effects of pre-drying, blanching and citric acid treatments on sensory characteristics (color, flavor, texture and brittle, oil taste and overall acceptability) of fried sweet potato chips are shown in Fig. 2. Generally, pre-drying at 70°C for various times had a good effect on texture and brittle and overall acceptability of sweet potato chips. Pre-drying for 30 min significantly ($p>0.05$) improved all sensory characteristics (Fig. 2a). Blanching and pre-drying improved the texture and brittle of the chips but increased the oil absorption by samples (Fig. 2b). Citric acid and pre-drying for 50 min improved significantly ($p>0.05$) the color, over all acceptability and the other quality characteristics (Fig. 2c). Santis *et al.* (2007) reported that color of the food surface is the first quality parameter evaluated by consumers and is critical in acceptance of the product, even before it enters the mouth. Images of fried sweet potato chips obtained under different processing conditions are shown in Fig. 3.

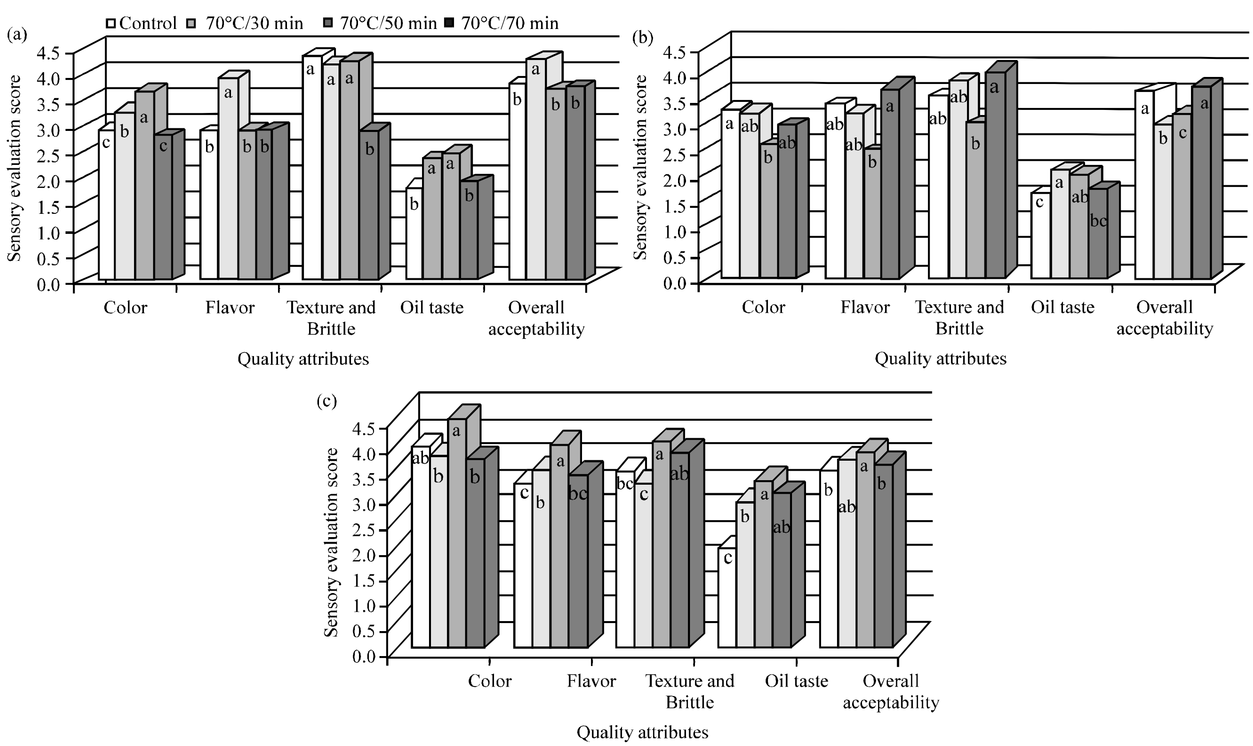

Fig. 2(a-c): Effect of Pre-drying, blanching and citric acid treatments on sensory evaluation of fried sweet potato chips, a: Pre-dried; b: Blanched and pre-dried; c: Citric acid treated and pre-dried, (a) *Control = fried sample after pre-drying treatment at 0 min, (b) *Control = fried sample after blanching treatment and pre-drying at 0 min, (c) *Control = fried sample after citric acid treatment and pre-drying at 0 min

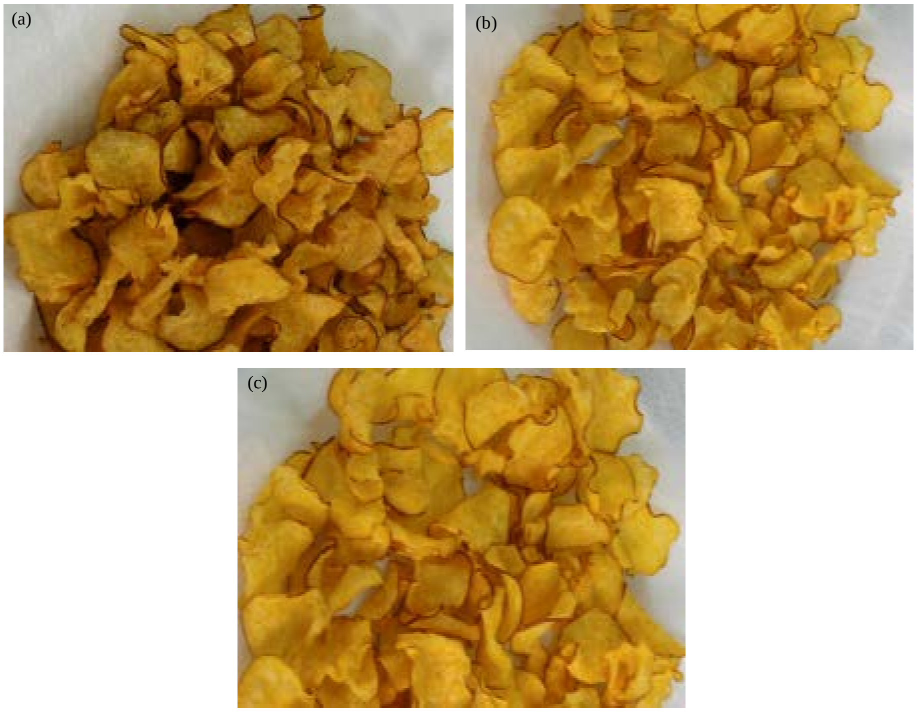

Fig. 3(a-c): Images of fried sweet potato chips, (a) Control and pre-dried for 50 min, (b) Blanched and pre-dried for 50 min, (c) Citric acid treated and pre-dried for 50 min

CONCLUSION

The effect of pre-drying, blanching and pre-drying and citric acid treatment and pre-drying on moisture, vitamin C content, color and oil absorption of fried sweet potato chips was determined. The pre-drying treatments carried out at 70°C for different periods. The results showed that as the drying time increased, the moisture and fat content of the chips decreased. Citric acid treatment was the best treatment in retaining vitamin C while, blanching had the lowest effect. Fried sweet potato treated with citric acid and pre-dried for 50 min was the best sample in all sensory characteristics.

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