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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(7): 2066-2070

www.thepharmajournal.com
Received: 12-05-2022
Accepted: 22-06-2022

Suman Soni
Ph.D. Dairy Chemistry, Department of Food Science and Technology, Chaudhary Devi Lal University, Sirsa, Haryana, India

Ritika B Yadav
Ph.D. Food Technology Department of Food Science and Technology, Chaudhary Devi Lal University, Sirsa, Haryana, India

Corresponding Author:
Suman Soni
Ph.D. Dairy Chemistry, Department of Food Science and Technology, Chaudhary Devi Lal University, Sirsa, Haryana, India

Effect of pre-treatments and drying methods on the quality attributes of sweet potato chips

Suman Soni and Ritika B Yadav

Abstract
The study was done to see the effects of pre-treatments and drying methods on sweet potato chips and to develop a method for the preparation of sweet potato chips with high consumer acceptability. The sweet potato slices of uniform thickness were subjected to different pre-treatments such as blanching in boiling water and brine solution followed by soaking in potassium metabisulphite (KMS) solution. The pre-treated slices were dried by different methods of drying (hot air oven, sun, microwave oven). The dried chips were fried in refined soyabean oil at 165-185 ^{0}C for 25-30 sec. The dried and fried sweet potato chips were analyzed for their physicochemical properties i.e. moisture content, β-carotene, non-enzymatic browning (NEB), and ash content. The fried chips were also analyzed for moisture content, oil uptake, NEB, and sensory characteristics. It was observed that slices given pre-treatment of blanching in boiling 2.0% brine solution showed the highest drying rate whereas blanching in boiling water showed the lowest drying rate. Out of all pre-treatments, the β-carotene retention was found to be highest in the hot air oven-dried samples of slices given blanching pretreatment in boiling water followed by soaking in 0.2% KMS solution (sample (0.374µg/100g); whereas, the Sun Dried sample (0.034µg/100g), showed the lowest value. The moisture content of Dried & fried sweet potato chips varied from 4.17 to 6.95% & 1.06 to 1.85%, respectively. Out of four pre-treatments, KMS (0.2%) treated sample showed the lowest NEB both in dried and fried chips. Brine blanched KMS (0.2%) treated samples showed maximum overall acceptability.

Keywords: Sweet potato, blanching, sweet potato chips, chips, pre-treatments, drying methods

Introduction
Sweet potato (Ipomea batata) is regarded as a nutritionally rich food (Achuleta, 2003) [1]. It is an excellent source of dry matter and calories along with this a good source of minerals, carotene, and ascorbic acid (Akpapunam and Abiate, 1991) [2]. Sweet potato is a tuber and an important food crop for the future and much needed greater attention from both consumers and agricultural scientists all over the world.

Processed products, such as Chips, from sweet potatoes, will increase awareness among the consumer as well as expands the use of the products from sweet potato. The preparation of sweet potato products is not an easy task due to their high sugar content. Sweet Potato is grown in monsoon rains and harvested in the early winter season. In peak season, these tubers can be converted into different types of products. Sweet potatoes are a rich source of carbohydrates and other bioactive principles. The yellow flesh of sweet potatoes is a rich source of carotene pigment and this carotene is converted into two molecules of Vitamin A (Potter and Hotchkiss, 1997) [12].

Chips like Potato chips, Sweet Potato chips, Banana Chips, etc are thin slices that are either deep fried or baked until crunchy and served as snacks, appetizers, and side dishes. The Children are much fond of Chips. Sweet potato chips can give a nutritional benefit to people due to having a high source of Vitamin A.

Fig 1: Sweet Potato

The brown color is a major problem in the production of quality products from Sweet potatoes and arises from two different reasons. The first is the formation of brown discoloration caused action of the polyphenol oxidase enzyme on polyphenols present in sweet potatoes in presence of oxygen; the second is the non-enzymatic browning products (at high temperatures) that are produced when reducing sugars condense with amino groups of protein (Kokrida *et al.*, 2001) [8]. The brown-colored sweet potato products are undesirable for consumer acceptability. Several methodologies have been developed to eliminate this type of discoloration. Several enzymes are inactivated by balancing (heat treatment in water). Nowadays, blanching is becoming a necessary pre-treatment method in fruit and Vegetables to inactivate enzymes.

Traditionally, a 2% salt solution is generally used for blanching commercially and in small-scale production of potato chips. Miller, (1975) [9] used sodium acid pyrophosphate in blanching treatment and successfully eliminated browning in sweet potato chips. Olurunda *et al.* (1977) [10] reduced discoloration in chips made from white fleshy potatoes by dipping them in sodium sulphite solution. Sweet potato can be incorporated into different types of products, such as cookies, biscuits, muffins, noodles, cake, breakfast foods, and pies, with sweetness and longer shelf-life, and improved quality attributes.

The drying or dehydration of food is a multiplex process and needed a step by step monitoring to foresee the drying behavior and to amend parameters for the drying process for special products. Simulation models are used for the design and operation of dryers. Some researchers have standardized and developed methods similar to natural and forced convection drying systems (Darvishi *et al.*, 2013) [7].

Material and Methods

Material

Sweet potatoes (*Ipomoea batatas*) and refined soybean oil were purchased from local market of Sirsa (Haryana)**.**

Chemicals

1. **0.2% potassium metabisulphite (KMS) solution:** Potassium hydrogen phthalate (>99.95% pure) purchased from merk.
2. **2% Sodium Chloride Solution:** Sodium Chloride (>99.0% pure) purchased from merk.
3. **Water:** Vtec Distilled water was purchased from Sigma Aldrich
4. **Acetone:** (> 99.5 pure), purchased from Pallav
5. **Anhydrous Sodium Sulphate:** (>98% pure) purchased from Sisco laboratory Pvt Ltd
6. **Petroleum Ether:** (40-60 °C) purchased from merk

Method

Pre-treatment

Sweet potato is washed thoroughly and peeled and sliced in uniform thickness by the slicer. The sweet potato slices of uniform thickness were subjected to different pre-treatments *i.e.*

(i) Blanching in boiling water for 2 min (T_1)
(ii) Blanching in boiling water for 2 min followed by 10 min soaking in 0.2% potassium metabisulphite (KMS) solution (T_2)
(iii) Blanching in boiling 2.0% brine solution for 2 min (T_3)
(iv) Blanching in boiling 0.2% brine solution for 2 min followed by 10 min soaking in 0.2% KMS solution (T_4).

Drying

1. **Sun Drying:** The pre-treated sample was dried in direct sunlight at a natural temperature ranging between 39-43^{0}C and relative humidity (RH) 36-52% for 6-8 hrs. followed by overnight drying at room temperature (26-35^{0}C) and relative humidity (RH) 52-72%.
2. **Hot-Air Drying:** The pre-treated slices were dried by hot air oven drying at 75-80^{0}C for 4 hours.
3. **Microwave oven Drying:** The pre-treated samples were dried in a microwave oven at a selected 100% microwave power for 18 min.

Analysis of dried % fried chips

The dried and fried sweet potato chips were analyzed for their physicochemical characteristics i.e. moisture percentage, ash percentage, β-carotene & non-enzymatic browning (NEB). The fried chips were also analyzed for percent yield, β-carotene & non-enzymatic browning (NEB) oil uptake, and sensory characteristics.

Moisture content

Moisture content was determined using a hot air oven taking 5 g of the sample at 100^{0}C for 5 hrs. Ash content was determined by taking 5g of sample in a muffle furnace at 550^{0}C temperature for 5 to 6 hours (AOAC, 1975) [3].

Ash content

Ash content was determined by taking 5g of sample in a crucible and placing a muffle furnace at 550^{0}C temperature for 5 to 6 hours (AOAC, 1975) [3].

β-carotene analysis

β-carotene content was analyzed by the method of Srivastava and Kumar (2001) [18]. Briefly, a 5 g sample was crushed in a mortar pestle with 10-15 ml acetone with the addition of a few crystals of anhydrous sodium sulphate, with the help of a pestle and mortar. The supernatant was separately taken in a beaker. The process was repeated twice and the combined supernatant was transferred to a separatory funnel, then 10-15 ml petroleum ether was added in a separate funnel and mixed vigorously, two-layer separated on standing. The lower layer was discarded and an upper layer (petroleum ether) was collected in a 100 ml volumetric flask, the volume was made up to 100 ml with petroleum ether and OD was recorded at 452 nm. Taken reading of sample, petroleum ether kept as a blank.

Calculations

$$\beta - \text{Carotene}\ (\mu g/100g) = \frac{\text{O.D.} \times\ 13.9\ \times\ 10^4\ \times\ 100}{\text{Wt. of sample}\ \times 560\ \times 1000}$$

$$\text{Vitamin A (I.U.)} = \frac{\beta - \text{carotene}\ (\mu g/100)}{0.6}$$

Non-enzymatic browning

Non-enzymatic browning was recorded by the method of Berwal *et al*. (2004). 0.5g sample was accurately weighed and 5ml of 60% alcohol was mixed with it. The sample was dissolved and kept overnight. The next day sample was filtered to get a clear solution. Then the intensity of color at 440 nm was measured with a spectrophotometer keeping 60% alcohol blank. Optical density was noted.

Calculations

Non-enzymatic browning = S-B

S = Optical density of the sample

B = Optical density of the blank

Percent yield calculation

The percent yield of chips was calculated after frying the slices and recording the final weight. The percent yield was calculated as follows:

$$\% \, yield = \frac{w_f}{w_i} \times 100\%$$

w_f = total weight of fried chips

w_i = initial weight of sweet potatoes

Oil uptake (%)

Oil uptake of sweet potato chips was estimated, by soxhlet apparatus and used hexane as solvent AOAC (1975) [3].

Sensory quality Evaluation

Evaluation of sensory quality of fried chips for appearance, texture, taste, flavor, and overall acceptability was done, by a semi-trained panel of 8 members with 9 points Hedonic scale with scores of 9 for very desirable and 1 for very undesirable.

Statistical Analysis

Statistical analysis of dried and fried chips was done to find out the effect of different pretreatments and drying methods used. The data were examined statistically in a completely randomized design (CRD) using one factor and two-factor analysis of variance (ANOVA) with the help of OPSTAT.

Result and discussion

Moisture and Ash Content

The effects of pre-treatments and drying methods on the moisture content (%) and ash content (%) of dried chips are given in Table 1. Out of four pre-treatments (T_1, T_2, T_3, and T_4), the blanching in 2% brine solution, for 2 min showed a higher drying rate. This is due osmotic effect of salt. Ash content does not significantly affect by any treatment.

Table 1: Effect of pre-treatments and drying methods on moisture content (%) and ash content (%) of dried chips

Drying method	Pre-treatments	Moisture Content	Ash Content
Sun Drying	T1	6.56 ±0.07	4.07±0.02
Hot- air Drying	T2	4.88±0.02	4.19±0.02
Microwave oven Drying	T3	4.22±0.02	3.60±0.02
	T4	6.19±0.02	3.92±0.02
	T1	6.95±0.02	3.50±0.02
	T2	6.52±0.04	3.62±0.02
	T3	4.87±0.02	4.07±0.02
	T4	5.92±0.02	4.33±0.02
	T1	6.43±0.01	4.19±0.02
	T2	4.86±0.02	4.03±0.02
	T3	4.17±0.02	3.84±0.02
	T4	4.52±0.03	3.78±0.02

Non-enzymatic browning

It was found that blanching in boiling 2% brine solution for 3 min (T_3 and T_4) followed by dipping in 0.2% solution of potassium meta-bisulfite for 10 min was the best pre-treatment to reduce the non-enzymatic browning in Dried and fried Sweet potato chips as revealed in Table 2 and Table 6. Picha (2006) [11] also used sodium metabisulfitea long with water in blanching and found that NEB decreased significantly in potato chips. Coffin *et al.* (1998) [6] found that frying at higher temperatures causes hydrolysis of sucrose into monomer unit glucose and fructose which participate in Maillard reactions. Browning during frying at normal temperature has been attributed to Maillard reaction but browning at higher frying temperature (≥ 220^{0}C) is caused by caramelization of sugar (Prang *et al.*, 1998) [13]. Sandhu and Parhawk (2002) also recommended that dipping in 0.2% KMS solution for 10 min of potato slices, lowers the value of NEB. Out of four pre-treatments, KMS (0.2%) treated sample (T_2-T_4) showed the lowest NEB because KMS is an anti-browning agent.

Table 2: Effect of Pre-Treatments and Drying Methods on non-enzymatic browning (OD_{440}) of Dried Chips

Methods	Pre- Treatments				Mean for A
	T1	T2	T3	T4	
Sun Drying	0.662	0.283	0.793	0.472	0.472
Hot- air Drying	0.323	0.215	0.972	0.264	0.443
Microwave oven Drying	1.731	0.151	1.725	0.092	0.934
Mean for B	0.905	0.211	1.725	0.164	
Effect	C.D.	SEM±			
Drying method(A)	0.002	0.001			
Pre-Treatments (B)	0.002	0.001			
A X B	0.004	0.001			

β-carotene content

Pre-treatment effects on β-carotene content of dried sweet potato chips are also presented in Table 3. Out of all pre-treatments, the β -carotene retention was found to be highest in the T_2 sample (0.374µg/100g) dried in a hot air oven. The β-carotene content of chips was found to be significantly (p< 0.05) higher in the T_2 sample. Sungpuag *et al.* (1999) [19] also demonstrated that boiling sweet potato roots had a loss of the β –carotene (43%). The sweet potato roots showed an abundant amount of β –carotene, but the content decreased with time and the processing method used (Van Hal, 2000) [20].

Table 3: Effect of Pre-treatments and drying methods on β- carotene content (µg/100g) of dried sweet potato chips

Methods	Pre- Treatments				Mean for A
	T1	T2	T3	T4	
Sun Drying	0.193	0.091	0.075	0.034	0.098
Hot- air Drying	0.043	0.374	0.036	0.051	0.125
Microwave oven Drying	0.072	0.045	0.046	0.092	0.063
Mean for B	0.102	0.211	1.725	0.621	
Effect	C.D.	SEM±			
Drying method(A)	0.004	0.001			
Pre-Treatments (B)	0.004	0.001			
A X B	0.007	0.002			

Oil uptake (%) in fried sweet potato chips

Pretreatments and drying methods also change the oil uptake behavior of fried sweet potato chips as given in Table 7. Out of three drying methods, the sun-dried, T_3 sample showed the highest oil uptake (15.77%) whereas, microwave oven-dried, T_4 samples showed the lowest oil uptake (8.25%). Rice (1993) [15] recommended the use of microwave drying to produce low-fat potato chips, by first giving high heat treatment to potato slices to remove surface moisture, then cooking in a high-intensity microwave which quickly evaporates most of the moisture and causes the slices to puff into chips. Oil content at any time is found to be independent of oil temperature and thickness of the slice, but it depends on moisture content and condition of oil. Oil uptake also increased with rancid oil with low flash point temperature (Reddy and Das, 1993) [14]. During deep fat-frying heat transfer is accompanied by heat and mass transfer, which is characterized by the penetration of hot oil into the product and the exit of vapor from the product (Bhumenthal, 1991) [5].

Table 4: Percent yield of fried of fried

Methods	Pre-treatment			
	T1	T2	T3	T4
Sun Drying	37.40	38.01	37.59	38.10
Hot- air Drying	35.42	36.02	35.55	36.10
Microwave oven Drying	40.95	41.30	40.40	42.02

Percent yield

The percent yield of fried sweet potato chips is shown in Table 4. Microwave oven dried, T_4 sample showed the highest yield of 42.02%, whereas the hot air oven-dried T_1 sample showed the lowest value for yield (35.42%). The yield of chips is largely determined by the dry matter (DM) of tubers and high DM is positively correlated with crispness, rigidity, and less oil uptake by chips (Santerre *et al.*, 1986) [16]. Out of three drying methods in a microwave oven, dried chips showed the highest yield. Moisture content plays important role in the frying and shelf life of the processed agricultural product (Simpson, 1969) [17].

Table 5: Effect of Pre-Treatment & Drying methods on moisture content (%) of fried chips

Methods	Pre-treatment			
	T1	T2	T3	T4
Sun Drying	1.84	1.85±0.02	1.06±0.01	1.28±0.01
Hot- air Drying	1.53	1.44±0.02	1.40±0.02	1.21±0.02
Microwave oven Drying	1.19	1.23±0.02	1.24±0.02	1.24±0.009

Table 6: Effect of pre-treatments and drying methods on non-enzymatic browning (od_{440}) of fried sweet potato chips

Methods	Pre- Treatments				Mean for A
	T1	T2	T3	T4	
Sun Drying	0.695	0.289	0.795	0.479	0.564
Hot- air Drying	0.329	0.217	1.003	0.265	0.453
Microwave oven Drying	1.802	0.155	1.794	0.096	0.961
Mean for B	0.942	0.220	1.197	0.840	
Effect	C.D.	SEM±			
Drying method(A)	0.002	0.001			
Pre-Treatments (B)	0.002	0.001			
A X B	0.004	0.001			

Sensory Evaluation

Out of three drying methods, microwave oven dried, T_4 sample showed a maximum overall acceptability score (8.7) and was very desirable whereas, hot air oven dried, T_3 sample showed minimum overall acceptability as shown in table 8. The samples which are brine blanched, KMS (0.2%) treated and microwave oven dried samples showed maximum acceptability. Out of three methods of drying, microwave oven-dried chips (T_2 and T_4) showed maximum acceptability and are desirable due to their crispness and bright yellow color. Hot air oven-dried chips were moderately desirable, having good crispness. Sun-dried chips are slightly desirable because of their dull color and hard texture.

Table 7: Effect of Pre-Treatments and Drying Methods on Oil uptake (%) of Fried Chips

Methods	Pre- Treatments				Mean for A
	T1	T2	T3	T4	
Sun Drying	14.60	12.89	15.77	12.55	13.95
Hot- air Drying	14.22	12.93	14.38	12.06	13.40
Microwave oven Drying	11.22	9.84	9.96	8.25	9.82
Mean for B	13.35	11.88	13.37	10.95	
Effect	C.D.	SEM±			
Drying method(A)	0.06	0.019			
Pre-Treatments (B)	0.07	0.022			
A X B	0.12	0.039			

Table 8: Effect of Pre-Treatments and Drying Methods on Sensory Characteristics of Fried sweet potato Chips

Drying method	Pre-treatments	Appearance	Texture	Taste	Flavour	Overall Acceptability
Sun Drying	T1	2.8	2.5	2.2	2.5	2.4
	T2	7.6	5.4	5.2	7.4	6.5
	T3	2.2	2.4	1.8	1.8	2.0
	T4	8.0	7.5	7.4	7.8	7.6
Hot- air Drying	T1	6.6	5.4	5.6	6.4	6.0
	T2	7.0	6.8	6.6	7.4	7.0
	T3	1.4	1.4	1.2	1.4	3.1
	T4	7.6	6.6	6.6	7.2	7.1
Microwave oven Drying	T1	3.2	3.8	3.0	3.0	3.1
	T2	8.6	7.8	8.6	8.2	8.2
	T3	2.6	3.6	3.0	2.8	3.2
	T4	8.6	8.8	8.8	8.4	8.7

Conclusion

Out of four pretreatments, the T_4 sample showed a maximum overall acceptability score (8.7) and was very desirable whereas, the T_3 sample showed minimum overall acceptability. The interaction effect between pre-treatment and drying methods was also significant ($p < 0.05$). The samples which are brine blanched, KMS (0.2%) treated and microwave oven dried samples showed maximum acceptability. Out of three methods of drying, microwave oven-dried chips showed maximum acceptability and are very desirable due to their crispness and bright yellow color. Hot air oven-dried chips were moderately desirable, having good crispness. Sun-dried chips are slightly desirable because of their dull color and hard texture. From the present study, it was concluded that blanching in boiling 2% brine solution for 2 min followed by 10 min soaking in 0.2% KMS solution (T_4) was the best pre-treatment for sweet potato chips. Microwave drying for 18 min was the best drying method to produce sweet potato chips of high overall acceptability.

Sweet potato Chips are more valuable than Potato chips due to their high β-carotene. Sweet potato chips can be used as a snack, appetizer, and side dish.

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