Performance of Yam as an Alternative to Frozen Potato French Fries

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Abstract: Yam is produced in large quantities in Ghana. Although a highly perishable commodity, it has not been processed to any significant extent commercially like potato. Yam tubers were processed into frozen yam chips that can be used like frozen potato chips in baked or fried products. The effects of yam variety (*Dioscorea rotundata poir* (puna) and *Dioscorea rotundata* (white yam)), Blanching time (0, 2.5 and 5 minutes) and Blanching temperature (70ºC, 80ºC, 90ºC) on the sensory and physicochemical properties of frozen yam chips were studied using a 2X3X3 full factorial design. Yam variety, blanching time and temperature affected moisture content, oil absorption, hardness, chewiness and gumminess of the fried yam chips. Blanching at 90ºC for 2.5 minutes gave products which were more preferred by sensory panelists than commercial potato chips. The commercial success of this product will reduce the huge postharvest losses of yams and provide income to the farmers. [Nature and Science 2010;8(12):70-78] (ISSN: 1545-0740).

Key words: Yam; French fries; blanching; texture; fat content; peroxidase activity.

1. Introduction

Yam is a major staple food in Ghana and in many tropical countries, where many varieties are cultivated. Some varieties include *Dioscorea rotundata, Dioscorea alata, Dioscorea cayensis, Dioscorea bulbifera, Dioscorea dumetorum* and *Dioscorea esculenta* (Tetteh and Saakwa, 1994). Yam has been suggested to have nutritional superiority when compared with other tropical root crops (Wanasundera & Ravindran, 1994). The starches of yam have also been shown to have low glycemic index unlike potato which has a high glycemic index thus yam products will provide a more sustained form of energy and give better protection against obesity and diabetes (Brand-Miller et al, 2003). Researchers have shown that yam extracts can reduce blood sugar (Hikino et al., 1986; Undie and Akubue, 1986). However because of its high moisture content, large size and high respiration rates, yam is highly perishable. Post harvest losses of yam have been reported to range from 10-50% (Muck, 1974; Alhassan, 1994). Much of the yam cultivated is consumed fresh, and not much has been done to extend the shelf life by value addition or in new product development. It is traditionally consumed as boiled or pounded yam.

Yam tubers are usually stored under ambient tropical conditions, and changes in wholesomeness occur under such conditions. Diseases and pests infestations during storage also lead to spoilage. The effect of storage on the composition, appearance, and physical properties of yam has been investigated (Afoakwa and Sefa-Dedeh, 2001; Sefa-Dedeh and Afoakwa, 2002).

In recent years French fries have become popular in fast food restaurants in many tropical and, developing countries where yams are also produced in large quantities. Potatoes, which are used for French fries production, are not locally available in many of these countries thus making them an expensive food. The use of yam as a substitute for potato in French fries production, will not only make the fries more affordable, but will also help to reduce post harvest losses and enhance its distribution network. The quality of French fries depends on the properties of the raw materials as well as the processing conditions. Some attributes of French fries of much importance to the consumer is the color, texture and oil absorption. Good quality French fries must have crispy outer crust and moist and soft interior as cooked potato (Sanz et al, 2007).

This study aimed at determining the performance of yam as an alternative to potato in French fries production. The variety of yam, the blanching time and blanching temperature that will produce frozen yam chips that could be used to obtain fries of desirable appearance, color, texture, oil adsorption and overall acceptability was determined.

2 Materials and Methods

Frozen potato chips were obtained from a super market in Accra and transported to the Nutrition and Food science department of the University of Ghana in a portable ice chest. Two varieties of fresh yam: *Dioscorea rotundata poir* and *Dioscorea rotundata* were obtained from the Madina market in Accra.

2.1 Sample Preparation

The yam tubers were washed in clean water, peeled manually and sliced into strips of about 1×1cm in cross section and 6-7cm in length using a sharp knife. The yam strips were soaked in 0.5% ascorbic acid solution for 15 minutes (following the results of a preliminary determination of the efficacy of ascorbic acid to minimize enzymatic browning). The yam strips were blanched in hot water at varying temperatures (70ºC, 80 ºC and 90ºC) and times (0, 2.5 and 5 minutes). The blanched yam strips were cooled and dried for 3 minutes at 50ºC, packaged into polyethylene bags (120 µm thickness) and frozen at -21ºC.The frozen yam strips were deep fat fried in cooking oil at 160ºC for 4 minutes. The oil was drained and the fries used for physiochemical and sensory analysis.

2.1.1 Experimental Design

A 2×3×3 full factorial design was used for the study. The factors were yam variety (*D. rotundata poir* and *D. rotundata*), blanching time (0, 2.5 and 5 minutes) and blanching temperature (70ºC, 80 ºC and 90ºC) (Table 1)

Table1: Processing Conditions for the Yam Chips.

Sample	Yam Variety	Blanching Time (minutes)	Blanching Temperature (ºc)
1	*D. rotundata poir*	2.5	70
2	*D. rotundata poir*	2.5	80
3	*D. rotundata poir*	2.5	90
4	*D. rotundata poir*	5	70
5	D. rotundata poir	5	80
6	*D. rotundata poir*	5	90
7	*D. rotundata*	2.5	70
8	*D. rotundata*	2.5	80
9	*D. rotundata*	2.5	90
10	*D. rotundata*	5	70
11	*D. rotundata*	5	80
12	*D. rotundata*	5	90

2.2.1 Peroxidase Activity

The method described by Jacobs o) was followed with modifications. Approximately 20g of freshly cut yam was blended with 60ml of distilled water at moderate speed, filtered through whatman filter paper No 4. 2 ml of the filtrate was added to 20 ml of distilled water in a test tube. A blank sample was prepared by adding 2 ml of the filtrate to 22 ml of distilled water in another test tube, which was used as a color comparison tube without the addition of any guaiacol or peroxide. 1ml of 0.5% guaiacol solution was added to the first tube without mixing, followed by 1ml of 0.08% hydrogen peroxide solution without mixing. The content were then mixed thoroughly, and observed for any color development differing from the blank, regardless of hue, but of sufficient intensity to show an obvious contrast to blank. The color developed was measured for absorbance at 460nm against a blank using a Shimadzu spectrophotometer (UV 120-02, Tokyo, Japan). Similar procedure was carried out using the blanched yam chips.

2.2.2 Moisture Analysis

The moisture content of samples was determined in triplicate using the air-oven method, (AOAC, 1990). The yam was manually grated and about 2g of the yam grates was weighed into pre-conditioned moisture cans in triplicate and dried in a Shimadzu Air oven (Tokyo, Japan) at 105ºC for 6 hours. Moisture content was calculated as percent loss in weight.

2.2.3 Fat Analysis

Fresh and Fried yam chips were dried in the Shimadzu Air oven at 105ºC, and then ground using a laboratory mortar and pestle. Approximately 2g of the powdered yam was weighed into a cellulose extraction thimble, and the fat content determined using the Soxhlet method (AOAC, 1990) with petroleum ether (40-60ºC) as the extracting solvent.

2.2.4 Hardness of Yam Strips (Cutting Force)

The peak force required to cut through yam chips was determined using a TA-XT2 texture analyzer (stable micro systems, Halsmere surrey, England) equipped with a load cell of 25Kg and interfaced with an IBM computer. A Warner Bratzler blade was used at a test speed of 5mm/s. A yam chip of surface 1cm×1cm was placed on to the horizontal mounting plane. The peak force required to cut through the chips was measured.

2.2.5 Texture Profile Analysis (TPA)

Texture profile analyses for the fried yam chips were determined using the TA-XT2 texture analyzer (Stable Micro systems, Halsmere surrey, England) equipped with a load cell of 25Kg and interfaced with an IBM computer. A spherical glass probe of 20mm in diameter (smsp/0.25s) was used at a test speed of 5mm/s. Double compression cycle test was performed and 5s allowed to elapse between the two compression cycles. The following parameters were measured: springiness (degree to which the chips returns to its original shape once it has been compressed), cohesiveness (degree to which the substance is compressed between the teeth before it breaks), gumminess (energy required to disintegrate the chips to a state ready for swallowing) and chewiness (length of time required to masticate the chips to a state suitable for swallowing).

2.2.6 Sensory Analysis

Sensory evaluation was done using a panel size of 30 untrained panelists , to determine if there were detectable differences in the appearance, color, taste, oiliness, mealiness and overall acceptability of yam fries from the different treatments. Traditional French fries (using frozen potato chips) were used as the control.

Panelists were provided with (coded) samples on paper plates and were instructed to score them on a 7 point hedonic scale.

3. Results and Discussion

3.1 Peroxidase Activity of Blanched Yam Chips

The color of fries is an important quality attribute to consumers. The presence and activity of polyphenol oxidases (PPO) lead to enzymatic browning and darkening of yam tissues with consequent loss in product quality. Submerging the cut yam strips in ascorbic acid to minimize browning provided a temporary solution during processing and cutting of the fresh yams. Blanching was employed to inactivate the PPO, and to inhibit enzymatic browning during storage of the yam strips. Fresh *D. rotundata poir* had higher polyphenol oxidase activity than the *D. rotundata*. The most severe blanching conditions of 90°C for 5 minutes had a profound effect on lowering PPO activity, but did not completely destroy it in both varieties of yam (Figure 1).

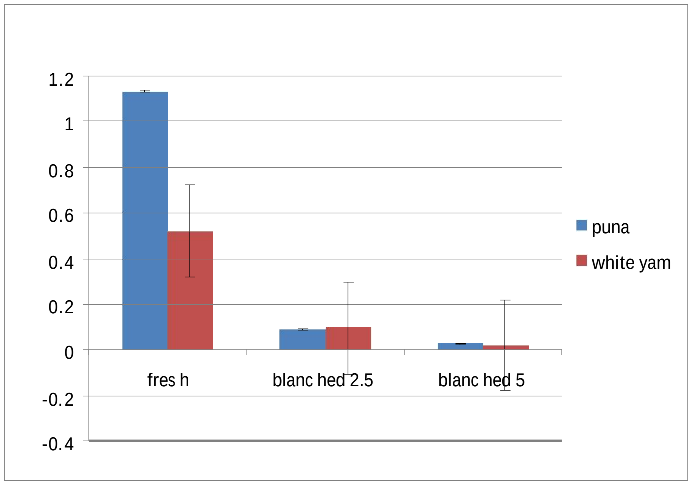

Figure 1: Effects of Blanching Time on Polyphenol Oxidase Activity in Yams

3.2 Moisture Content

The moisture content of fresh *D. rotundata poir* (puna) and *D. rotundata* (white yam)were 63.1% and 59.3% respectively (Table 2). As expected, blanching increased the moisture content of the yam chips (Table 2). Frying was both a cooking and a dehydration process, as the heat transferred by the hot oil into the yams during frying provided enough energy for vaporization of moisture from the yam chips. The data for moisture content of fried yam chips was fitted to a multiple regression model, with blanching time and temperature as the predictors (Table 3). The model was sufficiently adequate (R-squared 92.9%) and did not suffer lack of fit. The response plots generated from the model show that moisture content of blanched yam chips, and fries made from them were significantly influenced by blanching time and temperature (Figure 2a and 2b). Yam chips that were blanched at higher temperatures had higher moisture content even after frying.

Table 2: Moisture and Fat Content Of Yam Chips Under Different Processing Conditions.

Yam Variety	Blanching Time (minutes)	Blanching Temperature (^{o}C)	Moisture Content (blanched) (%)	Moisture Content (frozen) (%)	Moisture Content (fried) (%)	Fat Content (%)
D. rotundata poir	0	25	61.82±0.04	40.99±0.21	33.64±0.35	7.95±0.23
	2.5	70	62.19±0.32	42.82±0.06	35.35±0.40	9.36±0.14
	2.5	80	62.91±0.20	42.09±1.01	37.07±0.81	9.68±0.37
	2.5	90	63.33±0.67	41.97±0.26	38.11±0.44	12.56±0.72
	5	70	62.39±0.83	43.35±0.56	36.12±0.04	8.08±0.43
	5	80	64.13±0.20	41.54±0.45	37.94±0.11	10.34±0.18
	5	90	65.89±0.13	41.69±0.23	38.95±0.34	12.58±0.56
D. rotundata	0	25	59.31±0.02	38.87±0.66	32.52±1.05	6.31±0.37
	2.5	70	59.92±0.35	40.29±0.09	33.73±0.67	6.95±0.62
	2.5	80	61.13±0.07	39.41±0.26	35.04±0.21	8.07±0.13
	2.5	90	62.49±0.45	37.53±0.19	36.65±0.11	9.16±0.21
	5	70	60.31±0.90	39.10±0.54	34.13±0.42	7.17±0.27
	5	80	61.81±0.34	37.45±0.17	35.95±0.31	9.13±0.46
	5	90	63.62±1.03	38.73±0.21	37.40±0.52	10.59±0.61

Table 3: Regression Models for Moisture Content, Fat Content and Hardness of Blanched and Fried Yam

Regression term	Moisture content (blanched yam)	Moisture content (fried yam)	Fat content (%) (fried yam)	Hardness (blanched yam)	Hardness (fried yam)
Constant	58.79	31.78	5.00	11322.6	3031.80
X_1	-0.35	-2.53	-3.33	16664.0	-33.28
X_2	2.49	5.00	5.49	-19638.1	-636.89

X_1^2	0.25	2.82	2.88	-16865.9	563.26
X_2^2	1.21	-0.18	-1.37	10243.8	-398.89
R-squared	99.9%	98.7%	99.2%	99.9%	99.8%

Where X_1= Blanching time (minutes)
and X_2= Blanching temperature (°C)

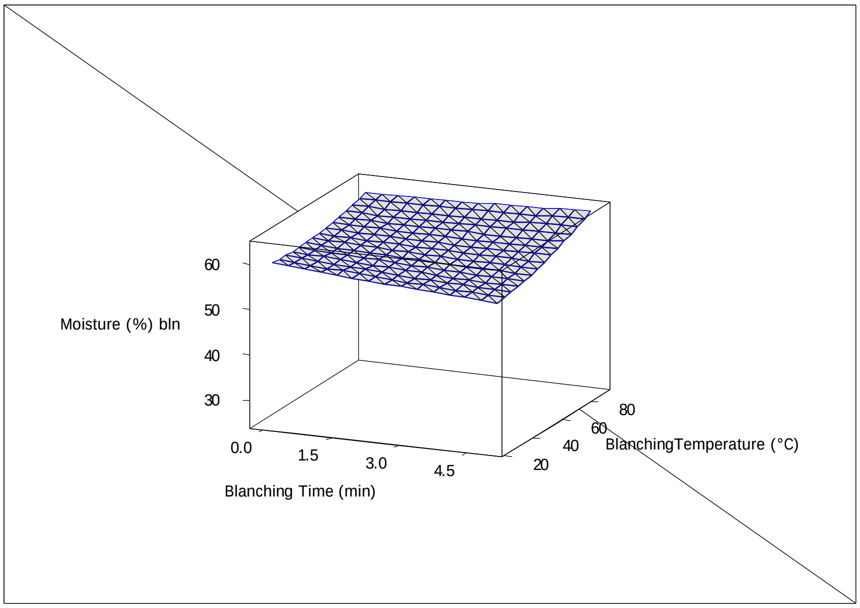

Figure 2a: Surface Plot of Moisture Content of Blanched Yam Chips as a Function of Blanching Temperature and Time.

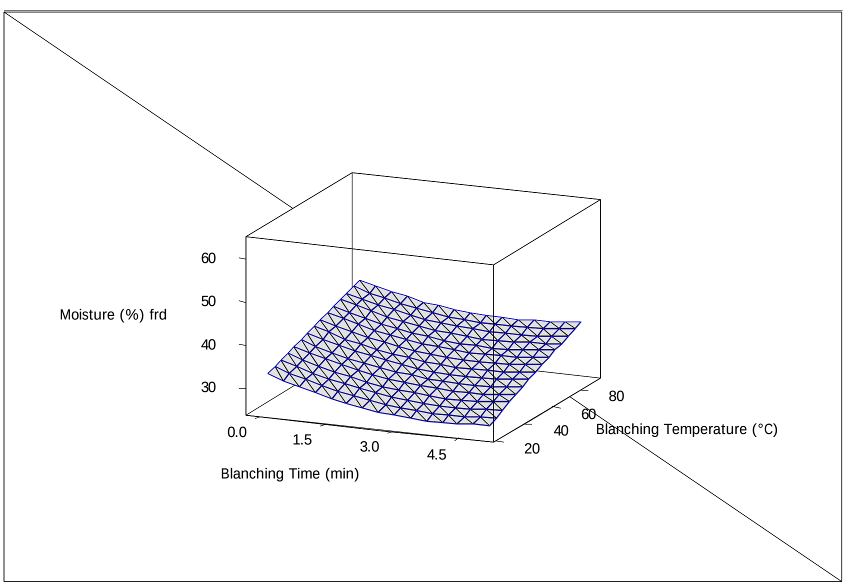

Figure 2b: Surface Plot of Moisture Content of Fried Yam Chips as a Function of Blanching Temperature and Time.

3.3 Fat Content

French fries are necessarily produced by frying, but modern trends indicate a conscious effort by consumers to cut out fat in the diet. Consequently a fried product with minimum oil content will be desirable for consumers. The data show that deep fat frying increased the fat content of the yam chips as would be expected (Table 2). Fat absorption by the fried chips was influenced by the blanching conditions of the yam. Multiple regression analysis and response surface plots (figure 3) show that yam chips obtained from high blanching temperatures and long blanching times absorbed more fat when fried. This was probably due to the uptake of oil to replace the water (absorbed during blanching) which was removed during the process of frying. The data (Table 4) show a high and significant correlation between the moisture of blanched yam strips and the oil content after frying (r=0.893, p= 0.003).

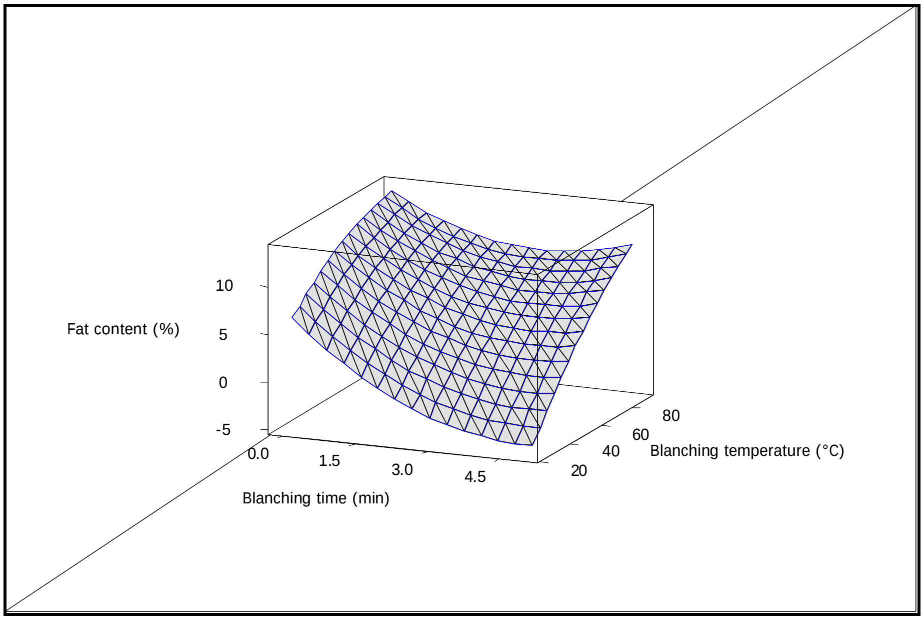

Figure 3: Surface plot of fat content of fried yam chips as a function of blanching temperature and time.

Table 4: Correlations Between Some Physiochemical And TPA Attributes Of The Fried Yam Chips

Correlation	Moisture Content (blanched)	Fat Content
Moisture (blanched)	1	.893*
Fat content	.893*	1
Springiness	-.179	-.068
Cohesiveness	-.544	-.295
Chewiness	-.791*	-.701
Gumminess	-.811*	-.723*

Where
* significance at the 0.05 level B-tailed).

3.4 Hardness

For all treatment conditions, *D. rotundata* chips were significantly harder than *D. rotundata poir* chips (Table 5). This may be related to the relatively high solids content of white yam. The hardness of the yam chips depended on the blanching conditions before freezing storage. High blanching temperatures significantly decreased the hardness of the yam chips (Table 5) probably due to softening of the yam tissues and partial pasting of starch during blanching (Lisinska and Golubowska, 2005).

Table 5: Multiple Range Analysis on the Hardness (Cutting Force) of the Yam Chips

	Hardness (blanched)	Hardness (frozen)	Hardness (fried)
Yam variety			
D. rotundata poir	3071.33 ^{a}	1612.18 ^{a}	2318.82 ^{a}
D. rotundata	3199.89 ^{a}	2889.57 ^{b}	2577.02 ^{b}
Blanching temperature (ºc)			
70	4979.98^{c}	3501.66^{c}	3059.19 ^{c}
80	2723.4^{b}	2044.11^{b}	2379.01 ^{b}
90	1703.46^{a}	1207.36^{a}	1905.55 ^{a}
Blanching time (minutes)			
2.5	3528.66^{b}	2496.43^{b}	2541.67^{a}
5	2742.57^{a}	2005.63^{a}	2354.17^{a}

Parameter values with same super script letters (a, b) are not different at p_0.05

3.5 Texture Profile Analysis

A typical force-time texture profile analysis on yam chips obtained from the TA-XT2 Texture Analyzer is shown in figure 4.

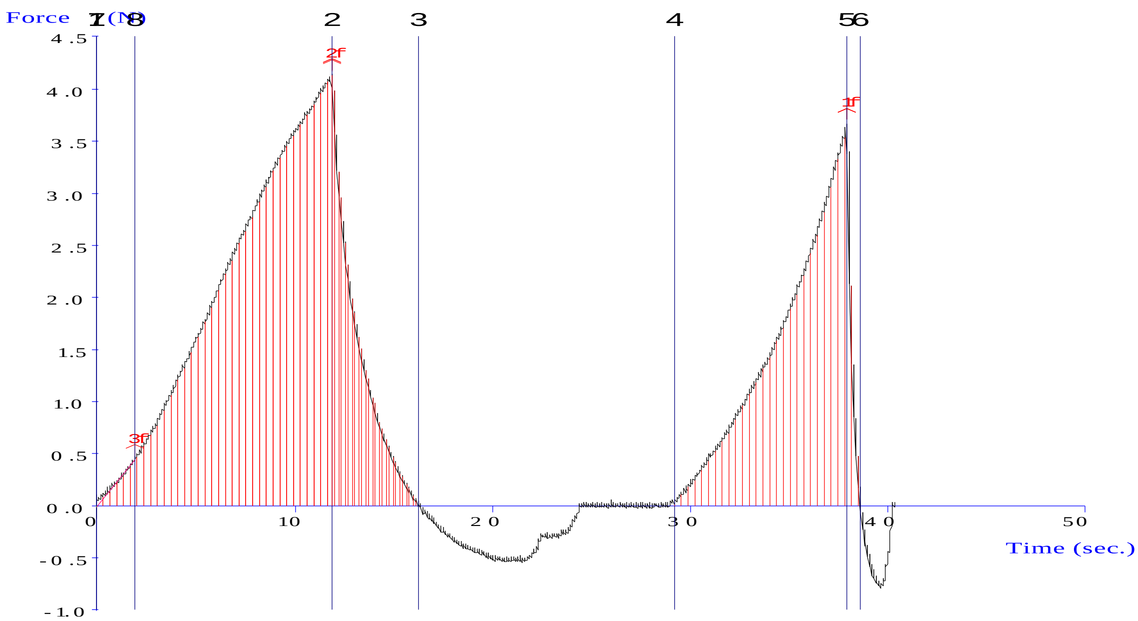

Figure 4: A Typical Texture Profile Analysis Force-Time Obtained From the TA XT2 Texture Analyser

Blanching temperature and blanching time had significant effects on the texture profile parameters. There were also significant differences between the yam varieties in the TPA parameters. D. rotundata showed significantly high springiness, cohesiveness, chewiness and gumminess than the *D. rotundata poir* probably due to its higher solids content (Table 6). Thus fries made using the *D. rotundata* will be firmer and mealier than those made from *D. rotundata poir.* The moisture of the blanched yams was also significantly, but inversely correlated with TPA parameters such as chewiness and gumminess of the yam after frying.

Table 6: Multiple Range Analysis for Parameters of TPA on Yam Chips

	Hardness	Chewiness	Cohesiveness	Gumminess	Springiness
Yam variety					
D. rotundata poir	2318.82 [a]	151.499 [a]	0.28133 [a]	210.859 [a]	0.71140 [a]
D. rotundata	2577.02 [b]	386.159 [b]	0.28542 [a]	509.244 [b]	0.74460 [b]
Blanching time (minutes)					
2.5	2541.67 [a]	335.65 [b]	0.293467 [b]	437.182 [b]	0.74750 [b]
5	2354.17 [a]	203.009 [a]	0.273267 [a]	282.921 [a]	0.70850 [a]
Blanching temperature (ºc)					
70	3059.19 [c]	452.682 [c]	0.29955 [b]	606.400 [c]	0.73100 [ab]
80	2379.01 [b]	231.859 [b]	0.27825 [ab]	312.067 [b]	0.70135 [a]
90	1905.55 [a]	123.447 [a]	0.27230 [a]	161.687 [a]	0.75165 [b]

Parameter values with same super script letters (a, b) are not different at p_0.05

3.7 Sensory Analysis

Some treatments produced yam chips with more preferred sensory attributes than others. Blanching conditions influenced many sensory attributes of the fried yams. Blanching (*D. rotundata poir*) at 90°C for 5 minutes gave the best chips in terms of appearance. Blanching (*D. rotundata poir)* at 90°C for 2.5 minutes gave the best taste and blanching (*D. rotundata* at 90°C for 2.5 minutes gave the least oily chips. Potato fries gave the oiliest product, which is not desirable. Based on the preference ranking (Table 7) using Friedman's test, the most preferred fried yam chips was made from *D. rotundata poir* blanched at 90°C for 2.5 minutes, indicating that hot water blanching of yam chips at 90°C for 2.5 minutes produce yam fries of desired acceptability.

Table 7: Preference Ranking of Fried Yam Chips

Yam variety	French Fries Samples: Blanching Time (minutes)	Blanching Temperature (ºc)	Sum of Ranks	Order of Ranks
D. rotundata poir	2.5	70	16.43	4th
D. rotundata poir	2.5	90	14.83	1st
D. rotundata poir	5	70	17.84	6th
D. rotundata poir	5	90	15.45	2nd
D. rotundata	2.5	70	19.76	9th
D. rotundata	2.5	90	16.33	3rd
D. rotundata	5	70	17.68	5th
D. rotundata	5	90	18.59	8th
Potato	-	-	18.29	7th

D. rotundata poir was the preferred yam species for yam fries production because it scored better for appearance, taste, mouth feel and overall acceptability. The traditional French fries (from frozen potato chips) only scored the highest for color.

4. Conclusion

Yam, like potato could be used for processing and distributing frozen yam strips for French fries production. Ascorbic acid treatment and hot water blanching at 90°C were effective in minimizing PPO activity and preventing enzymatic browning. Blanching time and blanching temperature are critical pre-process parameters for frozen yam chips. They affect quality parameters of the fries as determined by hardness, chewiness, springiness, cohesiveness and gumminess. *Dioscorea rotundata poir* (puna) was the preferred yam variety for fries production, especially when blanched for 2.5 minutes at 90°C.

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