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Research Article

Quality attributes of gluten free fried products from defatted peanut flour and starches of selected tropical roots and tubers

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Abstract

The aim of this study was to develop and evaluate gluten free fried products from defatted peanut flour and starches of common tropical roots. The result of the analysis showed that moisture content ranged from 3.52% to 5.89%; fat content ranged from 11.22% to 13.84%; crude fibre content ranged from 5.54% to 7.50%; colour (lightness) ranged from 22.21% to 69.88%; colour (redness) ranged from 9.95% to 26.54%;colour (yellowness) ranged from 10.15% to 43.17% and shrinkage ranged from 1.32% to 8.75%. The sample which was a composite of 90% sweet potato starch and 10% defatted peanut fried at 170 °C for 1 min had the lowest fat content. This study is very significant in meeting the demand in the management of celiac disease and gluten-related disorders, since gluten free diet is the only medically accepted treatment in resolving the challenge attributed to the consumption of foods containing gluten.

Introduction

Roots and tubers have been a key parts of food choices and modern diet due to the fact that they proffer therapeutic, nutritional and health benefits based on their abundant antioxidant phytochemicals; they are good antioxidative, anti-cancer, antimicrobial, anti-inflammatory agents [1-3]. Roots and tubers are excellent functional foods and nutraceutical agents to treat many ailments and to ensure general wellness. Many studies have reported the antioxidant activities of several roots and tuber crops [4-6]. Globally, people have become very conscious of the quality attributes of their diets especially with the aim of consuming foods that will nourish their bodies and also keep them in good health, most especially food with good antioxidant properties [7-11]. The mitigative potential of natural food substances rich in antioxidant phytochemicals are used as a means of detoxification of poisonous agents in human and animals [12,13]. Several fried snack products are based on wheat flour dough (mainly composed of gluten, starch, and water) since it is suitable to be sheeted and fried [14-18]. Foods rich in gluten constitutes health hazard for people with celiac disease and also lead to wheat allergy which affect immune system [19,20]. Celiac disease is autoimmune disease that attacks the small intestine due to the presence of gluten, for which a gluten-free diet is the only medically accepted treatment [21-23]. Researchers are of the view that flour from a rich protein source and starches of common tropical roots such as cassava, sweet potato, potato etc. should therefore be capable of producing fried snack products [4,24-29]. Food scientists and nutritionists have gained interest in development of nutritionally balanced protein foods to feed growing populations [4,30]. The defatted peanut flour has potential to be used in food system as low fat peanut concentrate for extending comminuted meat products, production of beverages, fermented products, composite flours and protein supplementation of bakery products and weaning foods [25,31]. Despite the fact that defatted peanut flour has an excellent potential in food formulations because of the high protein content, its uses remain limited. Its functional properties such as whipping properties, emulsification, bulk density, viscosity, and water and oil absorption are also important in food processing and food product formulation [25,32,33]. Starch on the other hand, is the most abundant food component whose crystalline structure is disrupted when heated in excess of water causing an increase in granule swelling and solubility. This gelatinization process is of great importance since it defines crust development and oil adsorption during frying [34-38].

The aim of this study was to develop gluten free fried products from defatted peanut flour and starches of common tropical roots and tubers (cassava and sweet potato), evaluate the quality of the developed gluten free fried products in terms of moisture, oil absorption, crude fibre, colour and shrinkage and to study the effect of frying temperature and time on some quality attributes of the fried products.

Materials and methods

Collection and preparation of samples

The raw materials used in the production of the fried snack products are defatted peanut flour, lecithin (as binder), starches (cassava / sweet potato starch), high linoleic sunflower oil (as frying medium). The lecithin was used as a binder, to effectively bind the ingredients of the matrix dough together and the sunflower oil is the frying medium for the matrices. It was chosen because it is long chain fatty acid linoleic oil with 9-12 carbon chains; it has only one double bond between carbon 9-10. It is stable and does not undergo rancidity easily. The peanut seeds, cassava and sweet potato roots were collected from Ota market in Ota, Ogun State. Soya lecithin was sourced from Nestle Nigeria Plc. Sun flower oil was purchased from Justrite Supermarket in Ota, Ogun state.

Production of defatted peanut flour

The peanut seeds were sorted, cleaned and dried in cabinet dryer at 60 °C for 24 hrs.The dried seeds were skinned and winnowed to remove the coats. The seeds were then defatted using Piteba during which oil and defatted cake are separated into different containers. The defatted cake was dried in the cabinet dryer at 60°C for 4 hrs, milled into fine flour and packaged to be used for the formulation of the matrices with starches [25].

Production of cassava starch

The cassava roots were peeled, washed and grated. The grated pulp was mixed with water and filtered using muslin cloth during which fibrous materials were removed. The filtered slurry was allowed to settle and then decanted. It was further washed with water to obtain a white starch paste. The starch paste was dried in cabinet dryer at 60 °C for 5 h and then milled in a hammer mill to obtain a fine powder and packaged to be used for the formulation of the matrices with starches [39-41].

Production of sweet potato starch

The sweet potato roots were peeled, washed and grated. The grated pulp was mixed with water and filtered using muslin cloth during which fibrous materials were removed. The filtered slurry was allowed to settle and then decanted. It was further washed with water to obtain a white starch paste. The starch paste was dried in cabinet dryer at 60 °C for 5 hrs and then milled in a hammer mill to obtain a fine powder and packaged to be used for the formulation of the matrices with starches [39,42,43].

Production of the fried products

The Defatted peanut flour was added at 10%, 15% and 20% levels to the starches of common tropical roots (i.e. cassava and sweet Potato) in various proportions to produce a formulation of the matrices as shown in Table 1. Same level of addition of Lecithin (0.5%) was added to the different formulations. The matrices were prepared ensuring the same final moisture content in the dough (40 g water/100 g dough). The amount of water added to the dry ingredients was a function of the moisture content of the dry ingredients and was adjusted in order to ensure that all samples contained the specified amount. Ingredients moisture was determined by drying in an oven at 105 °C for 24 hrs (to constant weight). Dry ingredients were first mixed thoroughly with hand for 2 min using. Then half of the water required was added at 15 °C while mixing for 2 minutes, after mixing for another 2 min, the remaining amount of water was added at 90 °C while mixing for 2 min, after mixing for another 2 min, the final mixture (the dough) was allowed to rest for 1 hr in a plastic film. Thereafter, the dough was sheeted and cut into 3.8 cm diameter discs, ensuring a constant weight (2.4 ± 0.1 g). Discs were maintained in plastic film to prevent dehydration before frying. The frying was done at the temperature of 170 °C (± 2 °C) in a stainless steel fryer using deep frying method for different period of time (1min., 3 min., 5 min., 7min., 9 min. and 11 min.) after which the product was allowed to stand for 8-10 min to cool at room temperature and drainage of the surface oil, after which it was stored in a desiccator for further analysis [14].

Table 1: Different formulations of composite flour for the fried products.

Sample	Cassava Starch (%)	Defatted Peanut Flour (%)	Sweet Potato Starch (%)
A	80	20	0
B	85	15	0
C	90	10	0
D	0	20	80
E	0	15	85
F	0	10	90

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Sample analysis

Determination of moisture content: Moisture content of the fried products' samples was determined using the oven drying method [44]. This involves oven drying 5 g duplicate samples at 105 °C for 4 hr and cooling in desiccator for 1 h. The moisture content was calculated from reduction in weight and expressed as:

$$\%\ \text{moisture content} = \frac{W_1 - W_2}{W_1 - W_0} \times 100$$

Where:

W_0= weight of empty dish

W_1= weight of dish + sample before drying

W_2= weight of dish + sample after drying

Determination of fat content

The fat content of the fried products' samples was determined using Soxhlet extraction method. The extraction flask was dried in an oven to a constant weight and fixed up with the reflux condenser and the flask, then connected to water supply. Then 5 g of the duplicate samples was weighed into a moisture dish and dried in the oven for 5 hrs at 100 °C to remove moisture. 3 g of the dried sample was then weighed into a filter paper wrapped properly, placed in the thimble and then transferred into the extractor barrel. Petroleum ether was added through the barrel into the extraction flask placed directly below it. More Petroleum ether was added until the volume is enough to run through the period of extraction (i.e. about ¾ the volume of the flask). The water inlet was then opened and the flask heated on the regulated water bath for 6 hr at a condensation rate of 5 drops per second. After extraction, the thimble was removed from the extractor barrel and dried in the oven. The flask was removed from the oven, cooled in a desiccator and the weight of the flask and also that of the content were taken [45].

$$\%\ \text{fat content} = \frac{W_2 - W_3}{W_1} \times 100$$

Where:

W_1= weight of sample (g)

W_2= weight of flask + sample before extraction (g)

W_3= weight of flask + sample after extraction (g)

Determination of crude fibre content

The crude fibre content was determined using Kassegn, [46] method. 2 g of the duplicate samples was refluxed in 100 ml digestion with mixture of 450 ml glacial acetic acid, 20 g trichloro acetic acid, 50 ml citric acid and 500 ml distilled water. The extracted mixture was filtered through ash less filter paper, washed with 100 ml boiling water which was followed by 50 ml ethanol, after which it was dried to a constant weight, the residue was then washed by incineration at 750 °C for 6 hrs. The crude fibre content was calculated as difference in weight between the residues.

Calculations:

$$\%\ \text{crude fibre} = \frac{W_3 - W_4}{W_1} \times 100$$

Where

W_1= weight of sample (g)

W_2= weight of crucible (g)

W_3= weight of crucible + sample after drying (g)

W_4= weight of crucible + sample after ashing (g)

Determination of colour

Colour analysis of the fried products' samples was performed using colorimeter [47]. The colour flex Colorimeter was tuned on and allowed to stay for 30 min for it to warm up and in Read mode. The colorimeter was then calibrated prior to analysis for the purpose of accuracy. The disposable petri dish was filled with the sample and centered over the sample port and covered, ''Read sample'' button was pressed on the menu to obtain the first two colour readings, the sample dish was rotated 120 -180° and ''Read sample'' button was pressed again to obtain the second two colour readings .The average of the two readings were displaced on the colorimeter and recorded. This procedure was replicated for all other samples and colour values recorded.

Determination of shrinkage

The shrinkage of the fried products was determined according to Mohammadi, et al.; Cruz, et al. [48,49]. The initial diameter of the sheeted dough prior to frying and the final diameter after frying were determined.

The shrinkage was calculated from reduction in diameter and expressed as:

$$\%\, \textit{shrinkage} = \frac{\boldsymbol{M}1 - \boldsymbol{M}2}{\boldsymbol{M}1} \times 100$$

Where:

M1 = Diameter before frying (mm)

M2 = Diameter after frying (mm)

Statistical analysis

Data obtained from the different parameters of this study were statistically analysed using SPSS version 20.0. Analysis was calculated at $P < 0.05$ using Analysis of Variance (ANOVA). Duncan's Multiple Range Test (DMRT) was used to separate the means.

Results and discussions

Moisture content of the fried products

The moisture content followed a decreasing trend for all

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the samples. Table 2 indicates the results obtained for the moisture content of the fried products. This is as a result of the release of moisture from the matrices following heat transfer from the hot oil as the frying time increases. Samples with lowest amount of the starches have the least moisture values and samples with sweet potato starches have lesser moisture contents when compared with the corresponding samples having cassava starches. At 1 min frying duration, the moisture content ranged from 4.33-5.89%, with sample C having the highest moisture content. This might be a result of the addition of highest proportion of cassava starch. After 11 min of frying, the moisture content ranged from 3.52% - 5.06%, still with sample C having the highest moisture content which could also be attributed to the proportion of the cassava starch in the flour composite. Sample D had the least moisture content (3.52%) even lower than that of sample A (4.02 %) with the same proportion of the defatted peanut flour. However, the variation in the result might be due to the fact that sweet potato starch was used in the former while cassava starch was used in the latter (Table 2). The samples are significantly different from each other at $P < 0.05$. These results were in agreement with those reported by [50], that cassava starch generally has higher moisture content when compared with sweet potato starch although their oil absorption capacities were in the same range.

Fat content of the fried products

Table 3 indicates the results obtained for the fat content of the fried products. The fat content followed an increasing trend for all the samples. This is a result of the release of moisture from the matrices following heat transfer from the hot oil and absorption of oil into the matrices as the frying time increases. Samples with the highest amount of the defatted peanut flour have the highest fat content and samples with sweet potato starch have lesser fat contents when compared with the corresponding samples having cassava starch. At 1minute frying duration, the fat content ranged from 11.22-11.91%, with sample A having the highest fat content. This might be a result of the addition of highest proportion of defatted peanut flour since rate of oil absorption is very high in foods with high protein content. This is because protein composed both hydrophilic and hydrophobic parts which made them to bind more to the hydrocarbon side chains of the oil [51,52]. At 3 minutes frying duration, there is no significance difference between samples B and D i.e. samples containing 85% cassava starch + 15% defatted peanut flour and 80% sweet Potato starch + 20% defatted peanut flour respectively. The fat contents of samples C and F (i.e. samples having 90% of the starches and 10% defatted peanut flour) are not significantly different from each other at 3 and 5 minutes frying durations. This might be due to the fact that the quantity of the starches and defatted peanut flour used in the formulation were the same. The fat contents samples A and D (i.e. samples having 80% of the starches and 20% defatted peanut flour) are not significantly different from each other at 3, 5 and 7 minutes frying durations. After 11 minutes of frying, the fat content ranged from 12.93 - 13.84%, with sample A having the highest fat content which could also be attributed to the proportion of the defatted peanut flour in the flour composite which increased the oil absorption. Sample F had the least fat content (12.93%) which is less than that of

Table 2: Moisture content of the fried products.

Sample	Moisture content (%) at different frying time					
	1 min	3 min	5 min	7 min	9 min	11 min
A	5.05 ± 0.01^{e}	4.84 ± 0.02^{e}	4.64 ± 0.04^{e}	4.44 ± 0.02^{d}	4.22 ± 0.01^{e}	4.02 ± 0.01^{e}
B	5.60 ± 0.03^{c}	5.33 ± 0.01^{c}	5.17 ± 0.02^{c}	5.03 ± 0.04^{c}	4.82 ± 0.01^{c}	4.59 ± 0.02^{c}
C	5.60 ± 0.03^{c}	5.33 ± 0.01^{c}	5.17 ± 0.02^{c}	5.03 ± 0.04^{c}	4.82 ± 0.01^{c}	4.59 ± 0.02^{c}
D	4.33 ± 0.02^{f}	4.35 ± 0.03^{f}	4.04 ± 0.04^{f}	3.83 ± 0.03^{f}	3.65 ± 0.03^{f}	3.52 ± 0.01^{f}
E	5.39 ± 0.03^{d}	5.14 ± 0.03^{d}	4.84 ± 0.04^{d}	4.70 ± 0.01^{e}	4.42 ± 0.01d	4.09 ± 0.05^{d}
F	5.80 ± 0.01^{b}	5.59 ± 0.02^{b}	5.39 ± 0.01^{b}	5.25 ± 0.01^{a}	5.02 ± 0.01^{b}	4.89 ± 0.01^{b}

Mean values in the same column with different superscript are significantly different at $p < 0.05$.
A: 80% cassava starch + 20% defatted peanut flour; B: 85% cassava starch + 15% defatted peanut flour; C: 90% cassava starch + 10% defatted peanut flour; D: 80% sweet Potato starch + 20% defatted peanut flour; E: 85% sweet Potato starch + 15% defatted peanut flour; F: 90% sweet Potato starch + 10% defatted peanut flour

Table 3: Fat content of the fried products.

Sample	Fat content (%) at different frying time					
	1 min	3 min	5 min	7 min	9 min	11 min
A	11.91 ± 0.04^{a}	12.04 ± 0.04^{a}	12.53 ± 0.02^{a}	12.9 ± 0.01^{a}	13.03 ± 0.03^{a}	13.84 ± 0.04^{a}
B	11.91 ± 0.04^{a}	12.04 ± 0.04^{a}	12.53 ± 0.02^{a}	12.9 ± 0.01^{a}	13.03 ± 0.03^{a}	13.84 ± 0.04^{a}
C	11.42 ± 0.03^{d}	11.61 ± 0.02^{d}	11.94 ± 0.01^{c}	12.56 ± 0.04^{c}	12.86 ± 0.03^{b}	13.04 ± 0.04^{e}
D	11.79 ± 0.08^{ab}	11.94 ± 0.04^{b}	12.47 ± 0.04^{a}	12.85 ± 0.06^{a}	12.98 ± 0.04^{a}	13.65 ± 0.04^{b}
E	11.79 ± 0.08^{ab}	11.94 ± 0.04^{b}	12.47 ± 0.04^{a}	12.85 ± 0.06^{a}	12.98 ± 0.04^{a}	13.65 ± 0.04^{b}
F	11.22 ± 0.03^{e}	11.64 ± 0.04^{d}	11.93 ± 0.05^{c}	12.29 ± 0.02^{e}	12.69 ± 0.02^{c}	12.93 ± 0.28^{f}

Mean values in the same column with different superscript are significantly different at $p < 0.05$.
A: 80% cassava starch + 20% defatted peanut flour; B: 85% cassava starch + 15% defatted peanut flour; C: 90% cassava starch + 10% defatted peanut flour; D: 80% sweet Potato starch + 20% defatted peanut flour; E: 85% sweet Potato starch + 15% defatted peanut flour; F: 90% sweet Potato starch + 10% defatted peanut flour

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sample C (13.04%) although both contained same proportion of the defatted peanut flour but variation in the result might be due to the fact that sweet potato starch was used in the former while cassava starch was used in the latter. The fat contents of the samples are significantly different from one another after 11 min frying duration.

Crude fibre content of the fried products

Table 4 indicates the results obtained for the crude fibre content of the fried products. The crude fibre content ranged from 5.54 - 7.50%. At each of the frying periods, there was no significant difference between sample A (80% cassava starch + 20% defatted peanut flour) and sample E (85% sweet Potato starch + 15% defatted peanut flour). However, the crude fibre contents of all other samples (i.e. B, C, D and F) are significantly different from one another for all the frying durations. It can also be observed that the crude fibre of the fried matrices increases with the addition of defatted peanut flour as the one with the highest proportion (20%) have the highest values. Also, fried matrices having sweet potato starches have higher crude fibre content when compare with ones with corresponding fried matrices having cassava starch in the formulation. The crude fibre content of the fried products increases as the frying time increases. This might be due to decrease in the amount of digestible starch in the food matrix as frying time increased. As a matter of fact, this is a positive effect of the frying process as dietary fibre plays an important role in the prevention of diseases such as colonic cancer, cardiovascular disease and diabetes. The trend of these results is in agreement with those reported by [52,53].

Colour determination of the fried products

It is noteworthy that formulation affected the lightness, redness and yellowness aspects of the colour of the fried matrices. Tables 5-7 show the colour parameters of the fried products in terms of lightness, redness and yellowness respectively at different frying time. Colour is an important parameter for selection of a food product. The colour of the fried matrices signifies its freshness. The colour development is contributed by non enzymatic browning (maillard and caramelization) that produces brown coloured compounds that are accumulated during frying [24,54]. Heat and mass transfer phenomena take place during frying cause physicochemical changes, which affect the colour and surface of the fried products. The lightness values of fried matrices decreased as the frying time increased for all the samples. The trend of this report agrees with those reported by [55-57]. The redness values of the fried matrices increased as frying time increased for all the samples except for the samples with 80% of cassava starch. Redness is an undesirable quality factor in fried products as increase in redness shows increased crust development, resulting in lower acceptability [58,59]. Consumer acceptability of the different fried products' samples needs to be determined through sensory evaluation. The yellowness values of the fried matrices decreased as frying time increased for samples A and C but increased as frying time increased for samples B, D, E.

Shrinkage determination of the fried products

Table 8 indicates the results obtained for the shrinkage of the fried products. At the end of 1minute frying duration,

Table 4: Crude fibre content of the fried products.

Sample	Crude Fibre Content (%) at different frying time					
	1 min	3 min	5 min	7 min	9 min	11 min
A	6.32 ± 0.02^b	6.41 ± 0.04^b	6.55 ± 0.04^b	6.72 ± 0.01^b	6.87 ± 0.03^b	6.96 ± 0.04^b
B	5.93 ± 0.03^c	6.06 ± 0.02^c	6.24 ± 0.03^c	6.35 ± 0.04^c	6.43 ± 0.03^c	6.59 ± 0.04^c
C	5.54 ± 0.03^e	5.59 ± 0.02^e	5.75 ± 0.01^e	5.80 ± 0.03^e	5.86 ± 0.02^e	6.05 ± 0.01^e
D	6.93 ± 0.03^a	6.99 ± 0.02^a	7.16 ± 0.02^a	7.28 ± 0.03^a	7.39 ± 0.03^a	7.50 ± 0.04^a
E	6.34 ± 0.03^b	6.44 ± 0.01^b	6.59 ± 0.01^b	6.74 ± 0.04^b	6.93 ± 0.04^b	7.05 ± 0.04^b
F	5.77 ± 0.03^d	5.85 ± 0.04^d	5.94 ± 0.03^d	6.10 ± 0.02^d	6.23 ± 0.02^d	6.41 ± 0.28^d

Mean values in the same column with different superscript are significantly different at $p < 0.05$.
A: 80% cassava starch + 20% defatted peanut flour; B: 85% cassava starch + 15% defatted peanut flour; C: 90% cassava starch + 10% defatted peanut flour; D: 80% sweet Potato starch + 20% defatted peanut flour; E: 85% sweet Potato starch + 15% defatted peanut flour; F: 90% sweet Potato starch + 10% defatted peanut flour

Table 5: Colour (Lightness) of the fried products.

Sample	Colour (Lightness) (%) at different frying time					
	1 min	3 min	5 min	7 min	9 min	11 min
A	69.88 ± 0.57^a	62.21 ± 0.01^a	56.49 ± 0.18^a	49.94 ± 0.65^a	42.51 ± 0.01^a	36.91 ± 0.75^a
B	69.17 ± 0.28^a	57.92 ± 0.9^b	51.00 ± 1.11^b	44.78 ± 0.14^b	40.17 ± 0.08^a	36.03 ± 0.21^b
C	64.70 ± 2.09^b	57.75 ± 0.74^b	39.69 ± 0.99^{cd}	38.20 ± 0.12^d	27.19 ± 0.27^b	22.26 ± 0.11^d
D	58.87 ± 0.16^c	48.55 ± 0.08^c	42.28 ± 0.13^c	36.54 ± 0.24^c	27.02 ± 8.71^b	18.39 ± 0.15^e
E	52.74 ± 0.04^d	46.75 ± 0.21^d	42.48 ± 0.28^c	33.27 ± 0.70^c	27.64 ± 0.04^b	24.36 ± 0.23^c
F	48.63 ± 0.35^e	40.41 ± 0.09^e	37.81 ± 3.41^d	32.12 ± 2.21^d	29.88 ± 0.01^b	22.21 ± 0.07^d

Mean values in the same column with different superscript are significantly different at $p < 0.05$.
A: 80% cassava starch + 20% defatted peanut flour; B: 85% cassava starch + 15% defatted peanut flour; C: 90% cassava starch + 10% defatted peanut flour; D: 80% sweet Potato starch + 20% defatted peanut flour; E: 85% sweet Potato starch + 15% defatted peanut flour; F: 90% sweet Potato starch + 10% defatted peanut flour

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Table 6: Colour (Redness) content of the fried products.

Sample	Colour (Redness) (%) at different frying time					
	1 min	3 min	5 min	7 min	9 min	11 min
A	14.35 ± 0.13^{d}	11.49 ± 0.52^{e}	12.81 ± 0.02^{d}	10.22 ± 0.01^{e}	10.06 ± 0.06^{e}	9.95.06 ± 0.08^{e}
B	14.91 ± 0.04^{cd}	15.05 ± 0.50^{d}	18.40 ± 0.25^{c}	19.79 ± 0.65^{c}	22.27 ± 0.11^{c}	25.28 ± 0.21^{d}
C	12.70 ± 0.01^{e}	15.64 ± 0.25^{d}	19.62 ± 0.06^{a}	23.13 ± 0.11^{a}	29.31 ± 0.02^{a}	33.49 ± 0.12^{a}
D	21.69 ± 0.19^{a}	22.04 ± 0.22^{a}	18.42 ± 0.42^{c}	15.54 ± 0.49^{d}	17.21 ± 0.08^{d}	25.68 ± 0.02^{c}
E	23.67 ± 0.25^{a}	18.48 ± 0.05^{b}	19.60 ± 0.08^{a}	22.22 ± 0.05^{b}	23.57 ± 0.06^{e}	26.33 ± 0.19^{b}
F	15.42 ± 0.53^{c}	16.78 ± 0.09^{c}	18.97 ± 0.01^{b}	20.41 ± 0.36^{c}	22.23 ± 0.01^{c}	26.54 ± 0.01^{b}

Mean values in the same column with different superscript are significantly different at $p < 0.05$.

A: 80% cassava starch + 20% defatted peanut flour; B: 85% cassava starch + 15% defatted peanut flour; C: 90% cassava starch + 10% defatted peanut flour; D: 80% sweet Potato starch + 20% defatted peanut flour; E: 85% sweet Potato starch + 15% defatted peanut flour; F: 90% sweet Potato starch + 10% defatted peanut flour

Table 7: Colour (Yellowness) content of the fried products.

Sample	Colour (Yellowness) (%) at different frying time					
	1 min	3 min	5 min	7 min	9 min	11 min
A	30.48 ± 0.16^{b}	28.81 ± 0.25^{c}	22.25 ± 0.12^{e}	18.75 ± 0.23^{e}	12.85 ± 0.05^{e}	11.61 ± 0.28^{d}
B	30.56 ± 0.08^{b}	34.36 ± 0.19^{a}	35.69 ± 0.81^{b}	37.41 ± 0.04^{b}	38.52 ± 0.01^{b}	43.17 ± 0.08^{b}
C	18.66 ± 0.32^{d}	22.22 ± 0.56^{e}	17.42 ± 0.28^{f}	15.54 ± 0.04^{f}	12.22 ± 0.06^{f}	10.15 ± 1.31^{e}
D	25.23 ± 0.06^{c}	25.45 ± 0.05^{d}	27.25 ± 0.09^{d}	22.35 ± 0.13^{d}	28.20 ± 0.03^{d}	33.29 ± 0.13^{c}
E	31.57 ± 0.74^{b}	33.46 ± 0.29^{b}	34.07 ± 0.22^{c}	36.24 ± 0.07^{c}	37.26 ± 0.11^{c}	38.47 ± 0.08^{b}
F	41.89 ± 4.22^{a}	33.53 ± 0.13^{b}	38.43 ± 0.02^{a}	40.42 ± 0.24^{a}	41.28 ± 0.07a	42.24 ± 0.08^{b}

Mean values in the same column with different superscript are significantly different at $p < 0.05$.

A: 80% cassava starch + 20% defatted peanut flour; B: 85% cassava starch + 15% defatted peanut flour; C: 90% cassava starch + 10% defatted peanut flour; D: 80% sweet Potato starch + 20% defatted peanut flour; E: 85% sweet Potato starch + 15% defatted peanut flour; F: 90% sweet Potato starch + 10% defatted peanut flour

Table 8: Shrinkage of the fried products.

Sample	Shrinkage (%) at different frying time					
	1 min	3 min	5 min	7 min	9 min	11 min
A	2.50 ± 0.00^{a}	2.50 ± 0.00^{a}	3.75 ± 0.00^{b}	3.75 ± 0.00^{b}	5.00 ± 0.01^{a}	6.25 ± 0.00^{c}
B	2.50 ± 0.00^{a}	2.50 ± 0.00^{a}	3.75 ± 0.00^{b}	5.00 ± 0.00^{b}	6.26 ± 0.00^{b}	7.50 ± 0.00^{b}
C	2.50 ± 0.00^{a}	3.75 ± 0.02^{ab}	3.75 ± 0.00^{b}	5.00 ± 0.00^{b}	7.50 ± 0.00^{d}	8.75 ± 0.01^{d}
D	1.32 ± 0.01^{c}	2.63 ± 0.00^{a}	2.63 ± 0.01^{a}	3.95 ± 0.01^{a}	3.95 ± 0.01^{c}	5.26 ± 0.00^{a}
E	1.32 ± 0.00^{c}	2.63 ± 0.00^{a}	3.95 ± 0.00^{d}	5.26 ± 0.00^{c}	5.26 ± 0.01^{a}	6.58 ± 0.00^{c}
F	2.63 ± 0.00^{a}	3.95 ± 0.00^{b}	5.26 ± 0.00^{c}	5.26 ± 0.00^{c}	6.58 ± 0.00^{b}	7.90 ± 0.00^{b}

Mean values in the same column with different superscript are significantly different at $p < 0.05$.

A: 80% cassava starch + 20% defatted peanut flour; B: 85% cassava starch + 15% defatted peanut flour; C: 90% cassava starch + 10% defatted peanut flour; D: 80% sweet Potato starch + 20% defatted peanut flour; E: 85% sweet Potato starch + 15% defatted peanut flour; F: 90% sweet Potato starch + 10% defatted peanut flour

there is no significant different among all the samples having cassava starch (i.e. samples A, B and C) and sample F (90% sweet Potato starch + 10% defatted peanut flour). Also, there is no significant difference between samples D and E i.e. samples having 80% sweet Potato starch + 20% defatted peanut flour and 85% sweet Potato starch + 15% defatted peanut flour respectively. As the frying time increases, the shrinkage follows an increasing trend. There is a strong relation between moisture and shrinkage during frying of foods. As the frying proceeds, the cells shrink in size as a result of the removal of water and the circumferential surfaces are drawn in as the interior section looses moisture. From the results, the shrinkage is more pronounced in samples having cassava starch in the formulation of the matrices when compared with ones with sweet potato starch and highest shrinkage value is observed with sample C (90% cassava starch + 10% defatted peanut flour). This might be due to the fact that cassava starch is of lower water absorption capacity when compared with sweet potato starch as water absorption capacity is important in bulking and consistency of products made through dough formation [40,50].

Conclusion

From this study, low fat gluten free fried products were developed from defatted peanut flour and starches of common tropical roots.This serves as an alternative to wheat flour from which most fried snacks are made from. As a matter of fact, the increasing prevalence of celiac disease and gluten-related disorders has led to increasing consumer demand for gluten-free products. Furthermore, the quality attributes of the fried

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products such as moisture, fat, crude fibre, colour and shrinkage were influenced by the formulation of the defatted peanut flour and the starches used. The effect of frying temperature and time on the quality attributes of the fried products were also investigated. The outcome of this study is therefore very significant to meet the demand in the management of celiac disease and gluten-related disorders, gluten free diet is the only medically accepted treatment in resolving the challenge attributed to the consumption of foods containing gluten. Sensory evaluation of the various fried products will be done in the next phase of this research work during which comparison with gluten containing products will be done.

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