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Effect of Baking Temperature on the Quality of Baked Sweet Potato Crisps

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Authors' contributions

This work was carried out in collaboration between all authors. Authors OBO, GNE and SBK conceived and designed the research, authors AAJ and GOA managed the literature searches. Author SBK performed the statistical analysis. Authors SOO, SOAO and OAO carried, managed and oversee the experimental analyses of the research study. Authors SBK and OBO wrote the first draft of the manuscript. Authors GNE and OBO read and approved the final manuscript.

Original Research Article

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ABSTRACT

Aim: To investigate the effect of baking temperature on the quality characteristics of baked sweet potato crisp samples.
Place and Duration of Study: Department of Food Technology, Federal Institute of Industrial Research, Oshodi, Lagos Nigeria, from February to October, 2013.
Methodology: Yellow fleshed sweet potato were mashed upon cooking to form dough; and mixed with other baking ingredients. The developed dough was shaped and baked using five baking temperature levels (110ºC, 120ºC, 130ºC, 140ºC and 150ºC). The following analysis were carried out on the baked sweet potato crisp namely –proximate, textural and sensory analysis. The results obtained were statistically analyzed using Analysis of Variance and the means separated using Duncan Multiple Range Test (DMRT).
Results: The result of the proximate analysis shows that moisture content ranged

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between 3.31 to 5.76 %, crude protein 2.61 to 3.22 %, fat 8.93 to 14.01%, crude fibre 2.59 to 4.79 %, ash 2.56 to 3.59 % and carbohydrate 71.56 to 78.15%. The result of the textural properties of the circular baked sweet potato crisps (dough thickness of 3.3mm and 30mm diameter) showed that the force at peak of the baked crisp samples ranged between 5.83 to 20.30 N, deformation at peak ranged between 1.33 and 2.22mm, while deformation at break ranged between 1.88 and 3.69mm. Sensory evaluation of the baked sweet potato crisps showed that crisp sample baked at 120ºC had the highest sensory rating of all the samples in terms of overall acceptability.

Conclusion: The study revealed the possibility of producing crunchy baked sweet potato crisps using a baking temperature range not exceeding 140ºC. There is however need to strike a balance between the desirable sensory qualities and the textural properties to ensure product that would be acceptable to consumers.

Keywords: Sweet potato; baked crisps; proximate; textural; sensory.

1. INTRODUCTION

Sweet potato (*Ipomoea batatas (L)*) originated in the tropical America where it is grown extensively and is now one of the major root crops in the developing world, where over 90% of the production is found [1,2]. The crop is now cultivated throughout the tropics and subtropics and ranked among the most important crops worldwide [3]. It is considered to be a nutritionally rich crop; and as well rich in vitamins (B_1, B_2, C, E), minerals (calcium, magnesium, potassium and zinc), dietary fiber and non-fibrous carbohydrates [4-7].

According to FAO [8], about 35 to 95% of the 3318000 MT annual sweet potato productions in Nigeria are being wasted and value addition offers good potential for income generation, employment creation and enhance increase utilization of the crops. This provides a means to reduce poverty, improve food security and nutrition which is in line with the current Millennium Development Goals (MDGs).

Value addition and processing of crops which generally entails transformation of raw outputs into other forms of products with higher value and diversified utilities helps in providing an array of products, reduces post harvest losses, enhances the taste of the products and eliminates anti-nutritional factors in crops [5,9,10]. This with the present campaign of increasing food production, utilization and consumption of tradition food as a means of effectively combating the problem of food and nutrition insecurity makes the concept of product development as well as value addition necessary among other things [11]. However, proper value addition entails detailed research [12], especially when developing a new product in other to optimize the production parameters as well as come out with an acceptable product.

Snacks foods comprises a very large array of food items among which are crisps, chips, crackers, nuts, extruded snacks among others [13]; which may be produced through the application of heat in an oven (baking). Snacks and baked foods has been playing a very vital role in the diet of the modern day consumers [14-16]; supplying their daily nutrient and calories intake [17,18].

Currently, there are increasing demands for low-fat or fat-free snack products [19] which make the demand for baked products to increase as against fried products. However the properties of baked products are naturally influenced by process parameters such as baking temperature, thus carrying out research on the effect of baking temperature is necessary to obtain a final product with desirable characteristics. Therefore, this study aims at investigating the effect of different baking temperatures on the utilization of sweet potato in the production of baked snacks.

2. MATERIALS AND METHODS

2.1 Materials

Yellow fleshed sweet potato was purchased from a local market in Lagos State, Nigeria. Other materials used include vegetable fat, portable water, spices (ground pepper) and seasoning.

2.2 Methods

2.2.1 Production and product formulation of baked sweet potato crisps

Table 1 shows the formulation used in the development of the baked sweet potato crisps

Table 1. Formulation/recipes for the production of baked sweet potato snacks

S/N	Ingredient	Weight (gms)	% by weight
1	Sweet potato dough	882	95.25
2	Binder (Xanthan gum)	18	1.94
3	Vegetable fat	20	2.16
4	Seasoning (Curry powder, Maggi cube)	3.2	0.35
5	White pepper (dry)	1.8	0.19
6	Salt	1	0.11
	Total	**926**	**100**

2.2.2 Crisps snacks preparation

The production flow chart is as shown in Fig. 1. Upon careful weighing and sorting, the raw sweet potatoes were peeled and washed after which they were cut into smaller sizes. The potato slices were cooked with distilled water for about 30 – 35 min till well cooked sweet potato was obtained which was subsequently mashed. Thereafter, the mashed sweet potatoes along with other ingredients were transferred into a mixer (Hobart) and the content mixed thoroughly for about 30min to obtain dough of desired texture.

The mixed dough was manually sheeted using a rolling pin on a stainless steel tray of a height 3.3mm giving the sheet the thickness of 3.3mm and cut into shape using a 15mm radius (30mm diameter) circular biscuit cutter. Aluminium foil was used to prevent dough sticking to the rolling pin. The cut dough pieces were later transferred to a baking tray lined with aluminium foil [20]. The snacks were baked in a pre-heated air circulation oven (Memmert, Typ: UM 400) at prescribed different temperatures for a period of 40 ± 5min and allowed to cool for 30 min at room temperatures. Each batch of the baked snacks samples were properly packed in high density polyethylene bag prior to analysis.

Raw Sweet Potato
↓
Sorting and Weighing
↓
Peeling and Washing
↓
Size Reduction
↓
Cooking and Mashing
↓
Mixing ← Other ingredients (Spices, vegetable fat, etc)
↓
Sheeting and Cutting
↓
Baking (110-150ºC)
↓
Cooling and Packaging
↓
Baked Sweet Potato Crisps

Fig. 1. Production of baked sweet potato crisps

2.2.3 Baking temperature

The sample was baked at five different temperatures of 110ºC, 120ºC, 130ºC, 140ºC and 150ºC for a period of 40 ± 5min each

Where;

Sample A = Baking temperature of 110ºC. B = Baking temperature of 120ºC.
C = Baking temperature of 130ºC. D = Baking temperature of 140ºC.
E = Baking temperature of 150ºC.

2.3 Analyses

2.3.1 Proximate analysis

The quantitative evaluation of moisture content, crude fibre, crude protein, fat and ash of the sample were determined using the method of AOAC [21]. Carbohydrate was obtained by difference:

$$\text{Carbohydrate} = (100 - (\text{moisture} + \text{crude protein} + \text{crude fibre} + \text{fat} + \text{ash}))\ \%$$

2.3.2 Textural analysis

The baked samples were subjected to textural analysis using Testometric Universal Testing Machine (Serial No. 500 – 689; Capacity – 25KN). They were fractured to complete failure in the three-point bending as described by Vincent [22]. Specifically, parameters such as force at peak, energy at peak, deformation at peak and deformation at break were determined.

2.3.3 Sensory evaluation

The baked sweet potato crisp samples were organoleptically evaluated (using 18 panellists) for different sensory quality attributes and overall acceptability as described by Ihekoronye and Ngoddy [23], using a 9-point hedonic rating method where 1 represents “extremely unacceptable” and 9 represent “extremely acceptable”. The mean of sensory scores for attributes - colour, taste, after-taste, flavour, crispiness, mouth-feel and overall acceptability of the developed products were recorded and analyzed.

2.3.4 Statistical analysis

The results of the proximate, textural and sensory analysis were compared using one-way analysis of variance (ANOVA) and the significant differences between baked mean values of the baked sweet potato crisps samples carried out using Duncan’s multiple range test (DMRT). Also, Pearson’s correlation matrix between the proximate and textural parameters was done using SPSS version 17.

3. RESULTS AND DISCUSSION

3.1 Proximate Composition

Table 2 shows the proximate composition (%) of baked sweet potato crisp samples. Moisture content ranged between 3.31 to 5.76%, ash 2.42 to 3.59%, crude fibre 2.59 to 4.79%, crude protein 2.61 to 3.22%, fat 8.93 to 14.01% and carbohydrate 70.86 to78.15%. It revealed a significant difference ($p<0.05$) of baking temperature on the proximate compositions of the samples. The reason for this may be attributed to the reduction in the moisture content of the samples as the baking temperature increases [24] and this reduction might have subsequently caused the concentration of some of the other proximate parameters.

Table 2. Proximate composition of baked sweet potato crisp samples

Proximate composition (%)	Baked sweet potato crisp samples				
	A	B	C	D	E
Moisture	$5.67^{a}\pm0.26$	$5.41^{ab}\pm0.17$	$5.06^{bc}\pm0.14$	$4.63^{c}\pm0.09$	$3.31^{d}\pm0.11$
Crude protein	$2.88^{ab}\pm0.08$	$2.99^{a}\pm0.12$	$2.90^{ab}\pm0.06$	$2.61^{b}\pm0.13$	$3.22^{a}\pm0.09$
Fat	$10.00^{d}\pm0.14$	$10.72^{c}\pm0.09$	$14.01^{a}\pm0.15$	$13.46^{b}\pm0.17$	$8.93^{e}\pm0.10$
Crude fibre	$2.59^{c}\pm0.14$	$4.79^{a}\pm0.08$	$2.88^{c}\pm0.11$	$2.90^{c}\pm0.05$	$3.83^{b}\pm0.12$
Ash	$2.87^{b}\pm0.16$	$2.42^{b}\pm0.13$	$3.59^{a}\pm0.15$	$2.59^{b}\pm0.07$	$2.56^{b}\pm0.13$
Carbohydrate	$75.90^{b}\pm0.12$	$73.67^{c}\pm0.13$	$71.56^{d}\pm0.07$	$73.81^{c}\pm0.14$	$78.15^{a}\pm0.15$

Values are mean +/- the standard deviation of 3determinations.
Mean values having different superscript in the same row are significantly different (p<0.05)

3.2 Textural Properties

The result of the textural properties (Table 3) of the developed baked sweet potato crisps samples showed significant difference ($p<0.05$) in the effect of baking temperature on the some of the textural properties determined. Generally, textural properties are mostly related to physical (especially mechanical) characteristics of foods products; and most dry crispy/crunchy food products have porous structure consisting of beams and films of solid materials surrounding air cells; thus variation in the water activity of the product would have effect on the force-deformation characteristics, as well as the number of sound peaks due to softening or otherwise of the air cell [25,26].

Table 3. Textural properties of developed baked sweet potato crisp samples

Baked sweet potato crisp samples	Textural properties		
	Force @ Peak (N)	Deformation @ peak (mm)	Deformation @ break (mm)
A	5.83^{e}±0.60	2.22^{a}±0.40	2.24^{bc}±0.24
B	6.45^{d}±0.30	2.08^{a}±0.16	2.59^{b}±0.57
C	11.77^{c}±0.54	1.33^{b}±0.06	1.88^{c}±0.04
D	18.63^{b}±0.16	2.09^{a}±0.18	2.43^{bc}±0.12
E	20.30^{a}±0.10	1.59^{b}±0.12	3.69^{a}±0.08

Values are mean +/- the standard deviation of 3determinations.
Mean values having different superscript in the same column are significantly different ($p<0.05$)

The force at peak value was used to represent the hardness of the baked sweet potato crisp samples [27,28] and products with higher force at peak may be considered to have higher hardness [29]; the higher the value of force at peak the higher the hardness of the sample to fracture. The result shows that as the baking temperature increases, the force at peak increases. This can be directly attributed to loss of moisture with increase in temperature.

The maximum value for deformation at peak was recorded for sample baked at 110ºC while sample baked at 130ºC recorded the minimum value. The deformation at peak value of the samples first decreases with increase in baking temperature till 130ºC after which there is an increase in the value at 140ºC and decreases again at 150ºC.

The deformation at break value of the samples revealed that sample baked at 150ºC recorded the maximum value with sample baked at 130ºC recording the minimum value. There was an increase in the value after which it decreases at a baking temperature of 130ºC before increasing again.

3.3 Sensory Attributes

Table 4 reveals the sensory attributes of baked sweet potato crisp samples. The result of the colour from the sensory analysis of the baked sweet potato crisps revealed that most of the panellists preferred samples baked using the lower baking temperatures of 110ºC and 120ºC as samples baked with these two temperatures received higher sensory ratings. The preference of the panellists for the colour of these samples may be due to the fact that the colours of the samples produce from these two temperatures were lighter when compared with that of higher temperature.

Table 4. Sensory attributes of baked sweet potato crisps samples

Sensory attribute	Baked sweet potato crisp samples				
	A	**B**	**C**	**D**	**E**
Colour	7.75^{a}±0.26	7.42^{ab}±0.14	7.16^{bc}±0.12	7.16^{bc}±0.20	7.00^{bc}±0.43
Taste	7.33^{a}±0.11	7.42^{a}±0.14	7.25^{ab}±0.10	7.08^{bc}±0.16	7.00^{c}±0.10
Flavour	7.00^{a}±0.08	6.80^{a}±0.20	6.80^{a}±0.20	7.20^{a}±0.40	6.30^{b}±0.30
Crispiness	6.90^{c}±0.20	7.60^{a}±0.40	7.00^{bc}±0.12	7.42^{ab}±0.24	6.83^{c}±0.06
Mouthfeel	7.08^{a}±0.10	7.25^{a} ±0.20	7.00^{a} ± 0.06	7.33^{a} ± 0.20	6.75^{b} ± 0.22

Values are mean +/- the standard deviation of 18determinations.
Mean values having different superscript in the same row are significantly different ($p<0.05$)

Color as being recognized as an important sensory attribute known to strongly influence the acceptability of a food product [30,31] because oftentimes, it is the only attribute that consumer can base their purchasing decisions on [32]. The increase darkness of the colour of product with increase in baking temperature can be directly linked to the effect of non-enzymatic browning reactions such as Maillard reaction [33] which is a reaction of a reducing sugars (glucose and fructose) and an amino group of protein at elevated temperature. This trend was also observed by Shyu and Hwang [34] in their work on chips.

In terms of taste, sample baked at 120ºC received the highest rating but does not differs significantly ($p>0.05$) from samples baked at 110ºC and 130ºC. Sample baked at 150ºC recorded the least score though did not significantly differ ($p>0.05$) from sample baked at 140ºC. Sample baked at 140ºC recorded the highest score in terms of flavour, it does not differ significantly ($p>0.05$) from samples baked with 110ºC, 120ºC and 130ºC while sample baked at 150ºC recorded the least score.

Crispiness represents the key textural attributes of dry snacks products; denoting freshness and high quality, generally a crisp should be firm and snaps easily when bent, emitting a crunchy sound [35,36]. Its loss can be caused by increased moistness of the product which can be a major cause of consumer rejection. If the moisture of products increases due to water sorption from the atmosphere or by mass transportation from neighbouring components, it results in a soggy and soft texture [37]. The panellists rated samples baked at 120ºC highest followed by sample baked at 140ºC however it does not show any significant different ($p>0.05$) with sample baked at 120ºC while sample baked at 150ºC was scored the least. The reason for this might as a result of over dryness of the product at the baking temperature of 150ºC which makes it very hard. This same reason was put forward by Vickers and Bourne [35], noting that crisp products, while relatively firm, should not be overly hard and should snap easily.

Based on the mouthfeel, sample baked at 140ºC was rated highest by the panellists; however, it did not differ significantly ($p>0.05$) with sample baked at 120ºC. Similarly, sample baked at 150ºC recorded the least sensory rating.

With respect to the overall acceptability of the baked sweet potato crisp samples (Fig. 2.), the most preferred sample by the panellists was sample baked at 120ºC followed by sample baked with 110ºC, 140ºC, 130ºC and 150ºC. Though, there was no significant difference ($p>0.05$) in the overall acceptability rating between sample baked at 120ºC and samples baked at 110ºC and 140ºC, there was a significant difference ($p<0.05$) between this sample and samples baked at 130ºC and 150ºC, while samples baked at 110ºC and 140ºC also showed a significant difference ($p<0.05$) between sample baked at 150ºC. According to the rating/assessment of Sharma et al. [38] who put 7 as the cut-off score for perceptible change on a 9 point sensory scale, it can be concluded that sample baked at 150ºC did not meet the overall acceptability sensory criteria.

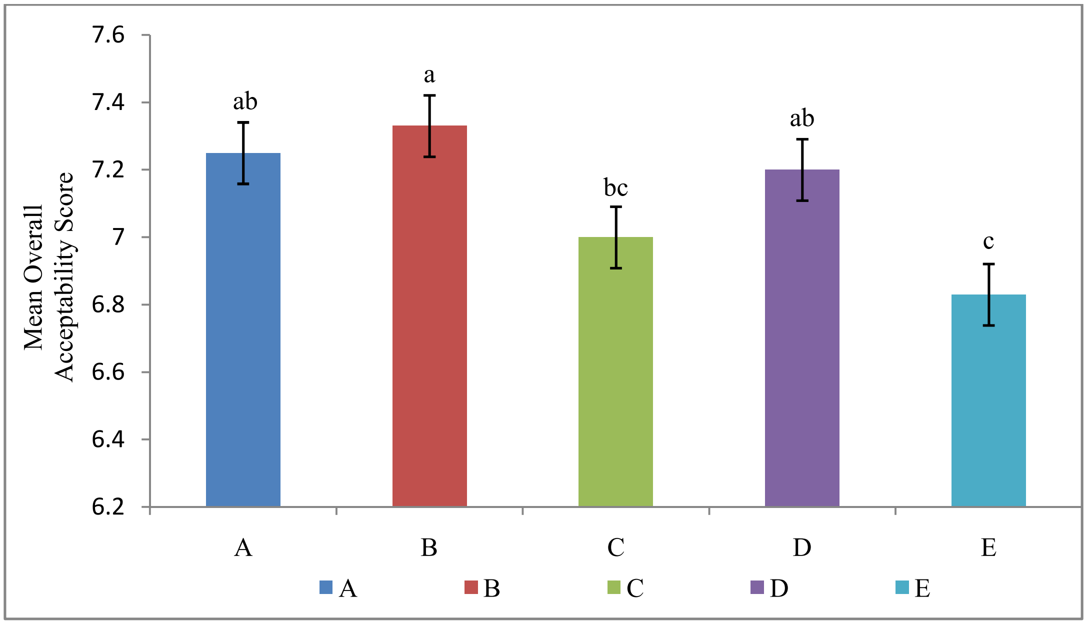

Fig. 2. Mean overall acceptability of baked sweet potato crisps samples

3.4 Correlation Matrix

The correlation matrix (Table 5) revealed a strong negative correlation ($p<0.01$) between moisture content and textural properties of both force and deformation at peak. The negative correlation between moisture content and force was also corroborated by Tabibloghmany et al. [39] in their work on potato chips. Fat also showing a negative correlation ($p<0.05$) deformation at peak; conversely, both crude protein and carbohydrate showed a positive correlation ($p<0.05$) with deformation at peak.

Table 5. Pearson's correlation matrix between proximate parameters and textural properties of baked sweet potato crisp samples

	M C	CP	Fat	CF	Ash	C	F@P	D@B	D@P
Moisture Content (MC)	1								
Crude Protein (CP)	-.479	1							
Fat	.290	-.680*	1						
Crude Fibre (CF)	-.173	.520	-.410	1					
Ash	.242	-.142	.555	-.571	1				
Carbohydrate (C)	-.564	.513	-.880**	.127	-.527	1			
Force @ peak (F@P)	-.873**	.023	.086	-.103	-.130	.327	1		
Deformation @ break (D@B)	.484	-.516	-.190	-.025	-.443	.164	-.304	1	
Deformation @ peak (D@P)	-.799**	.700*	-.677*	.473	-.621	.751*	.501	-.225	1

*** Correlation is significant at the 0.01 level (2-tailed)*
** Correlation is significant at the 0.05 level (2-tailed)*

4. CONCLUSION

The study has revealed the possibility of producing crunchy baked sweet potato crisps using a baking temperature range not exceeding 140ºC; this is because temperature is an important factor in baking as it controls non-enzymic browning (Millard reaction) and choosing within this range will give product with desirable qualities. There is however need to strike a balance between the desirable sensory qualities and the textural properties to ensure product that would be acceptable to consumers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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