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Research Article

Evaluation of the Microbiological, Sensory and Nutritional Quality of Chips Produced from Four Varieties of Potato (*Solanum tuberosum*) in Jos, Nigeria

Danladi Margaret Musa Atsen[1,2]*, Brains Ode Okechalu[1], Danahap Luka S[1]

[1]*Department of Plant Science and Biotechnology, University of Jos, Nigeria*

[2]*Department of Microbiology, Plateau State University, Bokkos, Nigeria*

***Corresponding Author:** Danladi Margaret Musa Atsen, Department of Plant Science and Biotechnology, University of Jos, Nigeria.

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Abstract

Potato is prone to deterioration and eaten fresh in most developing countries, therefore the need to process into its less perishable form. This study was aimed at assessing the quality of chips produced from potato. Representative tubers picked from each cultivar were processed into crispy (test) and striped (control) chips. Serial dilution was done and 0.1 ml was inoculated on Nutrient agar MacConkey agar and Potato Dextrose agar, then incubated for 24 to 72 hours, biochemical tests and fungal atlas were used to identify microbes. Proximate composition was determined using Association of Official Analytical Chemist method. Sensory evaluation was determined by nine point (9) hedonic scale. The chips colour were all cream. There was significant difference in the total fungal, bacterial and coliform counts in the chips at 5% of level of probability. The microbes isolated with their respective frequencies of occurrence were Cladosporium cladosporioides (62.5%), Aspergillus niger (75%), Aspergillus ochraceus (50%), Penicillium roquoforti (50%), Fusarium solani (37%), Rhizopus microsporus (50%), Bacillus (62.5%), Citrobacter (37.5%), Proteus (25%), Staphylococcus (37.5%) and Serratia (62.5%). Proximate composition values were significantly different ($P \leq 0.05$) with the following ranges for crispy and striped chips: Moisture (4.92 ± 0.03 to 2.45 ± 0.03%) (54.90 ± 0.07a to 53.72 ± 0.04), crude protein (8.28 ± 0.06 to 5.76 ± 0.03%) (2.40 ± 0.01 to 1.33 ± 0.01), crude fibre (11.75 ± 0.03 to 9.57 ± 0.02%) (1.56 ± 0.03 to 1.46 ± 0.03), lipid (26.51 ± 0.02 to 22.3 ± 0.20%) (20.79 ± 0.03 to 18.45 ± 0.03), ash (2.46 ± 0.06 to 1.55 ± 0.05%) (1.72 ± 0.02 to 1.59 ± 0.06) and carbohydrate (55.74 ± 0.02 to 48.28 ± 0.03%) (21.87 ± 0.01 to 19.71 ± 0.05) respectively. Sensory scores indicated Nicola variety being most accepted overall with a score of (8.55 ± 0.69), all the other sensory parameters of the chips fell between like moderately (7.0) and like very much (8.0). The study shows that chips from the commonly grown varieties in Jos are safe, nutritious and organoleptically acceptable.

Keywords: Potato; Microbes; Chips

Introduction

Potato is highly perishable because of its high moisture content, though a high yielding crop which needs to be processed to reduce post-harvest losses [1,2]. Microbes associated with potatoes in Jos and Bukuru towns of Plateau State, Nigeria have been reported by some researchers [3,4]. Many agricultural raw materials such as tubers, roots, fruits, pulses, pseudo cereals, animal products, cereals, vegetables, oilseeds are been processed to add value and to mitigate wastage [5]. In recent years snack consumption has formed a significant part of the nutritional requirements of many Nigerians which cuts across many strata in the society [6]. Flour, chips, French fries, boiled, mashed, bread, cakes, pancakes, potato crisp, potato sticks from other starchy tubers such as sweet potato, taro and yam have been produced and has enhanced the food industry [7-11]. Many developing countries are yet to have viable potato processing industries.

Microbial contamination has been reported in wheat grains, wheat flour, powdered pap, bread, and chips made from potato and wheat [12-15]. Sensory evaluation is a field, which integrates

techniques from diverse scientific disciplines [16] which depends on standard and unified protocols used to understand the human stimuli and their response to food and beverage products [17]. Novel processed food products are assessed for acceptability through sensory evaluation and colour which is a traditional method of assessing the quality of foods [18,19]. The food market is constantly stimulated towards the development of new products with good sensory acceptance and of high nutritional value [20], therefore there must be a balance between the physical, nutritional and sensory characteristics of food products [21].

Though many potato varieties are grown in Jos including Caruso, Nicola, Marabel [22], there is no viable potato chips processing industry in Jos, Nigeria. For any new product, a substantial assessment must be done for acceptability by consumers. Therefore, aim and objectives of the study are the production of chips, assessing the microbiological quality, proximate composition and sensory evaluation of potato chips produced from four varieties of potatoes.

Materials and Methods

Sample collection and preparation

Four varieties of non-deteriorated potato tubers, namely Caruso, Diamante, Nicola and Marael were obtained from National Root Crop Research Institute (NRCRI), Vom and taken to Spectra Holdings laboratory at the Technology and Incubation Center, Bukuru, Jos South in clean plastic crates. Potato tubers were washed with clean portable water to remove dirt and soil. Tubers with signs of spoilage were selected and discarded prior to washing.

Preparation of potato chips from four varieties of potato

450 g of representative tubers were randomly picked from each cultivar, washed and peeled using a stainless-steel kitchen knife. The whole potato tubers were cut transversely into about 1.75 mm for the crispy chips and 8 by 8 mm thick slices using a slicer (Kitchen ideas vege slicer, China) and a stainless-steel knife respectively. The slices were washed using portable water and blanched, drained and placed on paper towels. The slices were fried in 2 litres of oil at 180 °C for 1 minute 40 seconds and 5 minutes for crispy and striped chips respectively using grand pure soya oil in a deep fryer. The fried slices were drained to remove excess oil, placed on paper towels for 2 min and allowed to cool, then packaged in air tight zip lock bags as described by [23,24] with slight modification.

Microbiological quality of processed potato chips

One gram (1 g) of each sample was mixed in 9 ml of sterile peptone water to determine the microbiological quality of chips. Serial dilutions were made for each sample for 10^5 dilutions. Approximately 0.1 ml of aliquots were plated on appropriate media from 10^1 dilutions. PDA (Merck, Germany) for all fungi species, NA (Merck, Germany) for aerobic bacteria and MacConkey agar (Merck, Germany) for coliforms. All the plates were in triplicates and incubated at 25 °C for 3 to 5 days for fungi and 24 to 48 h for bacteria.

The discrete colonies were isolated and subcultured on the appropriate media. Pure isolates of bacteria were biochemically identified using methods such as Catalase, Coagulase, Indole, Methyl red, Voges Proskauer, Citrate, Urease, and Triple Iron Sugar Tests as described using modified methods by [25-27]. The fungal isolates were identified by carbohydrate utilization test, macroscopic and microscopic characteristics using standard taxonomic keys and atlas as described by [28].

Proximate composition of chips

The moisture (oven drying method), protein (kjeldahl's method), crude fibre (gravimetric method), fat/lipid (soxhlet method), ash (dry ashing method), as described by [29] while the carbohydrate was determined by difference method [30], calcium (titrimetry),Phosphorus (Colorimetry) for processed potato chips.

Sensory evaluation of prepared potato chips

Sensory evaluation was carried out on a nine point (9) hedonic scale with the following ratings 9 = Like extremely, 8 = Like very much, 7 = Like moderately, 6 = like slightly, 5 = neither like or dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much and 1 = dislike extremely based on colour, taste, texture, aroma and overall acceptability using a 20-member trained panellist as described by [31].

Results

Production of Crispy and Striped Chips from the four variety of potato

The result for the production of crispy (test) and striped (control) chips are represented in Table 1. The colour of both the crispy and striped chips were cream. However, there was a difference in the texture of both chips. The crispy chips were brittle or crispy while the striped chips were soft with a dry surface.

Microbial load in crispy and striped chips

There was significant difference at $p \leq 0.05$ in the microbial load in chips. The limit of fungal count was within 10^1 colony forming unit (cfu/g). The fungal load was highest in Marabel and Diamante crispy chips (MCC and DCC) with counts of 7.67 while Nicola crispy chips had the least fungal load with counts of 1.33 (Table 2). The limits of bacterial counts were within 10^2 colony forming unit per gram (cfu/g). The total bacterial load was highest in DCC with counts of 36.33 while the least bacterial load was observed in Nicola crispy chips (NCC) with counts of 30.33. The limits of coliform counts were within 10^2 colony forming unit per gram (cfu/g). The total coliform count was observed to be highest in Marabel crispy chips (MCC) with counts of 36.00 while the least was observed in Marabel striped chips (MC) with counts of 31.00. No coliform was detected in Caruso crispy chips (CCC). The microbes isolated with their varying percentage frequencies of occurrence were *Cladosporium cladosporioides* (62.5%), *Aspergillus niger* (75%), *Aspergillus ochraceus* (50%), *Penicillium roquoforti* (50%), *Fusarium solani* (37%), *Rhizopus microsporus* (50%), *Bacillus subtilis* (62.5%), *Citrobacter feundii* (37.5%), *Proteus mirabilis* (25%), *Staphylococcus aureus* (37.5%) *and Serratia marcescens* (62.5%).

Proximate composition of potato crispy chips

There was significant difference at $p \leq 0.05$ as observed in Table 3. The moisture content of the potato crispy chips ranged from 4.92 ± 0.03^a to 2.45 ± 0.03^b for the crispy chips. Crude protein values ranged from 8.28 ± 0.06^a to 5.76 ± 0.03^c for the crispy chips. Crude fibre values among the crispy chips range from 11.75 ± 0.03^a to 9.57 ± 0.02^c. The result for lipids ranged from 26.51 ± 0.02^a to 22.3 ± 0.20^c for the crispy chips. The ash content for the crispy chips ranged from 2.46 ± 0.03^a to 1.55 ± 0.05^b for the crispy chips. Carbohydrate content ranged from 55.74 ± 0.02^a to 48.28 ± 0.03^d for the crispy chips. The calcium content ranged from 1.01 ± 1.38^a to $0.15 \pm 0.0.02^b$ for the crispy chips. The phosphorus content ranged from 0.08 ± 0.00^a to 0.04 ± 0.00^a for the crispy chips. The energy content of crispy chips ranged from 466 to 455 Kcal.

Proximate composition of potato striped chips

The results of the potato striped chips are represented as the mean of triplicate readings ± standard deviation as presented in (Table 4). Results with the same superscript are not statistically different while results with different superscripts along the column are statistically different at $p \leq 0.05$. The moisture content of the potato the striped chips ranged from 54.90 ± 0.07^a to 53.72 ± 0.04^b. The crude protein ranged from 2.40 ± 0.01^a to 1.33 ± 0.01^b. The crude fibre values ranged from 1.56 ± 0.03^a to 1.46 ± 0.03^b. Lipid contents of striped chips were in the range 20.79 ± 0.03^a to 18.45 ± 0.03^c. The ash contents ranged from 1.72 ± 0.02^a to 1.59 ± 0.06^c. The carbohydrate content ranges from 21.87 ± 0.01^a to 19.71 ± 0.05^d. The calcium contents ranged from 0.32 ± 0.01^a to 0.14 ± 0.01^a for. The phosphorus content ranges from 0.04 ± 0.00^a to 0.02 ± 0.00^a. The energy content ranged from 274 to 263 Kcal.

Sensory evaluation of crispy and striped chips produced from the four varieties of non-deteriorated potato tubers

The result for the sensory evaluation for potato chips was determined on a 9-hedonic scale as shown in Table 5. The scores represented the mean of triplicate readings ± standard deviation which was ranked on a 9-hedonic scale. The colour ranged from 8.45 ± 0.51 to 6.35 ± 2.03. The taste parameter score showed that it ranged from 8.45 ± 0.51 to 6.30 ± 2.34. The score for the texture ranged from 8.35 ± 0.62 to 6.60 ± 2.09. The score for aroma ranged from 8.40 ± 0.60 to 6.95 ± 1.70. The score for overall acceptability ranged from 8.55 ± 0.69 to 6.80 ± 0.96. The scores fell within the like moderately and like very much.

Sample	Colour	Texture
DCC	Cream	Crispy/brittle
MCC	Cream	Crispy/brittle
NCC	Cream	Crispy/brittle
CCC	Cream	Crispy/brittle
DC	Cream	Soft/ dry surface
MC	Cream	Soft/dry surface
NC	Cream	Soft/dry surface
CC	Cream	Soft/dry surface

Table 1: Production of Crispy and Striped Potato Chips.

DCC = Diamante crispy chips, MCC = Marabel crispy chips, NCC = Nicola crispy chips, CCC = Caruso crispy chips, DC = Diamant chips (striped), MC = Marabel chips (striped), NC = Nicola chips (striped), CC = Caruso chips (striped).

Products	Total fungal Count($\times 10^1$)	Total bacterial count ($\times 10^2$)	Total coliform count ($\times 10^2$)
DC	5.33 ± 0.58 ^{b}	31.00 ± 1.00^d	31.33 ± 1.16^e
MC	4.00 ± 0.00^c	34.67 ± 0.58^b	31.00 ± 1.00^e
NC	3.00 ± 0.00^d	33.00 ± 0.00^c	32.67 ± 1.16^d
CC	1.67 ± 0.58^e	36.00 ± 1.00^a	33.00 ± 1.00^c
DCC	7.67 ± 0.58^a	36.33 ± 1.53^a	34.67 ± 0.58^b
MCC	7.67 ± 0.53^a	34.00 ± 1.00^b	36.00 ± 0.00^a
NCC	1.33 ± 0.58^e	30.33 ± 0.58^e	33.00 ± 0.00^c
CCC	4.33 ± 0.58^c	35.00 ± 0.00^a	ND
LSD	1.16		
Pvalue	0.0001		

Table 2: Microbial quality (Fungal, Total bacterial, and Coliform Counts) in Crispy and Striped Chips.

At P ≤ 0.05, there was significant difference in the total fungal, bacterial and coliform counts between the Crispy and striped chips. Values were presented as means of triplicate readings ± standard deviation. The ranking was done across the columns. Values with different superscript are significantly different. ND-Not Detected

Discussion

Production of crispy chips and striped chips from the four variety of potato

Crispy and striped chips (commonly known as French fries) were produced from the four varieties of non-deteriorated potato. The colour of both types of chips were cream in colour as presented in (Table 1). The crispy chips were brittle and dry while the striped chips were soft within with a dry surface, this is in agreement with reports of [32] who produced crunchy chips. The crispy and dry surface of chips indicates its quality. The dry nature of chips is as a result of the tissues having air cavities surrounded by brittle structural phase [33] and another reason for the dry surface is as a result of the moisture loss from the potato during frying [34]. The colour of chips is the first parameter judged by a consumer [35]. [36,37] reported the production of quality and healthy potato chips. The findings of the researchers are in agreement with the present study.

Microbiological quality (Total Fungal, bacterial, and Coliform Counts) distribution and percentage frequencies of occurrence in crispy and striped chips

Chips were produced from the four varieties of non-deteriorated potato. The fungal count ranged from 7.67 × 10^1 to 1.67 ×

Colony colour	Surface	Nature of hyphae	Fungal isolate
Grey	Smooth	Septate	*C. cladosporioides*
Black	Black Smooth walled	Septate	*A. niger*
Amber Green	flaky Smooth velvety green	Septate Septate	*A. ochraceus* *P. roquoforti*
Pinkish	Whitish pink cottony	Aseptate	*F. solani*
White with black tips	Cottony	Aseptate	*R.mircosporus*

Table 3: Fungal Macroscopy and Microscopy.

Catalase	Coagulase	Indole	MR	VP	Citrate	Urease	Triple Sugar Iron				Isolated bacteria	Gram reaction
							Slant	Butt	Gas	H_2S		
+	-	-	-	+	+	-	K	A	+	+	*Bacillus subtilis*	+
+	-	-	+	-	+	+-	K	A	+	+	*Citrobacter feundii*	-
+	-	-	+	+	+	+	K	A	+	+	*Proteus mirabilis*	-
+	-	-	-	+	+	-	K	A	+	-	*Serratia macescens*	-
+	+	-	-	+	+	+	A	A	-	-	*Staphylococcus aureus*	+

Table 4: Biochemical identification of bacteria.

K=Alkaline, A=Acid, +=Positive, -=Negative

Samples	Moisture	Crude Protein	Crude fibre	Lipid	Ash	Carbohydrate	Calcium	Phosphorus	Energy Kcal
CCC	2.45 ± 0.03^b	5.76 ± 0.03^c	10.35 ± 0.02^b	25.33 ± 0.05^b	2.38 ± 0.06^a	53.7 ± 0.03^b	0.36 ± 0.0^b	0.04 ± 0.00^a	466
DCC	4.11 ± 0.01^c	7.85 ± 0.03^b	11.75 ± 0.03^a	22.3 ± 0.20^c	2.46 ± 0.03^a	55.74 ± 0.02^a	0.39 ± 0.0^b	0.04 ± 0.00^a	455
NCC	4.74 ± 0.12^a	8.28 ± 0.06^a	10.27 ± 0.03^b	26.51 ± 0.02^a	1.88 ± 0.08^b	48.28 ± 0.03^d	1.01 ± 1.38^a	0.08 ± 0.00^a	465
MCC	4.92 ± 0.03^a	7.87 ± 0.05^b	9.57 ± 0.02^c	25.36 ± 0.02^b	1.55 ± 0.05^b	50.83 ± 0.03^c	0.15 ± 0.02^b	0.04 ± 0.00^a	463
LSD	0.40								
P value 0.0001									

Table 5: Proximate Composition of Potato Crispy Chips produced from the four varieties of potato in gram per 100g of sample.
At p ≤ 0.05, the results represent the mean of triplicate readings ± standard deviation. Means with the same superscripts are not significantly different and values with different superscript are significantly different as represented along the column. DCC = Diamante crispy chips, MCC = Marabel crispy chips, NCC = Nicola crispy chips, CCC = Caruso crispy chips.

Samples	Moisture	Crude Protein	Crude fibre	Lipid	Ash	Carbohydrate	Calcium	Phosphorus	Energy kcal
CC	54.90 ± 0.07^a	1.33 ± 0.01^b	1.56 ± 0.03^a	20.79 ± 0.03^a	1.72 ± 0.02^a	19.71 ± 0.05^d	0.32 ± 0.01^a	0.04 ± 0.00^a	271
DC	53.72 ± 0.04^b	1.33 ± 0.01^b	1.54 ± 0.01^a	20.44 ± 0.04^b	1.66 ± 0.02^a	21.27 ± 0.02^c	0.14 ± 0.01^b	0.02 ± 0.00^a	274
NC	54.29 ± 0.03^c	2.35 ± 0.03^a	1.46 ± 0.03^b	19.51 ± 0.05^d	1.59 ± 0.06^c	20.82 ± 0.01^b	0.14 ± 0.01^a	0.02 ± 0.00^a	268
MC	54.20 ± 0.05^d	2.40 ± 0.01^a	1.48 ± 0.02^b	18.45 ± 0.03^c	1.64 ± 0.02^b	21.87 ± 0.01^a	0.17 ± 0.02^b	0.03 ± 0.00^c	263
LSD	0.08								
P value 0.0001									

Table 6: Proximate Composition of Potato Striped Chips produced from the four varieties of potato in gram per 100g of sample.

At p ≤ 0.05, the results represent the mean of triplicate readings ± standard deviation. Means with the same superscripts are not significantly different and values with different superscript are significantly different as represented along the column. DC = Diamante striped chips, MC = Marabel striped chips, CC = Caruso striped chips, NC = Nicola striped chips.

Treatment	Colour	Taste	Texture	Aroma	Overall Acceptability
NCC	7.75 ± 0.97	8.30 ± 0.80	7.90 ± 0.79	7.95 ± 1.05	8.55 ± 0.69
NC	6.80 ± 1.51	7.45 ± 1.15	7.45 ± 0.89	7.65 ± 0.93	7.50 ± 1.40
DCC	8.15 ± 0.67	8.20 ± 0.70	8.20 ± 0.62	7.90 ± 0.91	8.05 ± 0.61
DC	7.65 ± 0.75	8.00 ± 0.92	7.60 ± 0.94	7.75 ± 0.91	7.75 ± 0.85
MCC	8.40 ± 0.50	8.45 ± 0.51	8.35 ± 0.59	8.40 ± 0.60	8.40 ± 0.60
MC	6.35 ± 2.03	6.60 ± 2.06	6.80 ± 1.67	6.95 ± 1.70	6.85 ± 1.69
CCC	8.45 ± 0.51	8.25 ± 0.72	8.30 ± 0.47	7.90 ± 0.85	8.20 ± 0.52
CC	6.35 ± 2.25	6.30 ± 2.34	6.60 ± 2.09	7.65 ± 0.93	6.80 ± 0.96

Table 7: Sensory evaluation of Chips produced from the Four varieties of Non-deteriorated Potato Tubers.

The table represents the mean ± standard deviation of the various parameters accessed by the tasters for both the control and test samples. The study was ranked on a 9-hedonic scale which include:9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like or dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much and 1 = dislike extremely, DC = Diamante striped chips, MC = Marabel striped chips, CC = Caruso striped chips, NC = Nicola striped chips, DCC = Diamante crispy chips, MCC = Marabel crispy chips, NCC = Nicola crispy chips, CCC = Caruso crispy chips.

10^1 cfu/g in the chip's samples. The total bacterial count ranged from 36.33 × 10^2 to 30.33 × 10^2 cfu/g in the chips samples while the coliform count ranged from 36.00 × 10^2 to 31.00 × 10^2 cfu/g among the striped and crispy chips. [38] has stated that aerobic plate counts of between 10^4 to 10^6 of cells per ml or gram in foods are permissible. The microbial counts in this study did not exceed the permissible limits and therefore safe for consumption. There was varying distribution of fungi, bacteria which showed their presence or absence. *Bacillus subtilis* was distributed more across the crispy chips samples while the least distributed were *Proteus mirabilis* and *Staphylococcus aureus.* The most contaminated with bacteria were Diamante crispy chips and Marabel crispy chips. The bacterial species isolated in both crispy and striped chips were *Bacillus subtilis, Citrobacter feundii, Proteus mirabilis, Staphylococcus aureus, Serratia marcescens.* Both fungi and bacteria were isolated from the products. *Cladosporium cladosporiodes, Aspergillus niger* were most distributed among the chips samples but the most contaminated was Caruso crispy chips. The fungi species isolated in the crispy and striped chips were *Cladosporium cladosporiodes, Aspergillus niger, Aspergillus ochraceus, Penicillium roquoforti, Fusarium solani and Rhizopus microsporus*. The most contaminatedchips was Marabel striped chips. *Serratia marcescens* occurred most across the chips samples while the least was distributed across the striped chips samples were *Citrobacter feundii* and *Proteus mirabilis*. The few fungal and bacterial species on the products may be as a result of the hygiene that was observed during the production process.

All the fungi species implicated in this study may be as a result of exposure of the product during the cooling process where spores must have settled on the striped and crispy chips. This is in agreement with reports of [6,39] who reported *Staphylococcus aureus, Bacillus* spp*, and Aspergillus* spp, *Penicillium* spp, and *Rhizopus* spp.

The presence of *Bacillus subtilis* is as a result of human handling since it is a skin microflora *Citrobacter feundii* was isolated from chips its presence indicates food contamination since it is an intestinal parasite in humans and animals and also from the environment [6,39] and a potential cause of food borne disease. Its occurrence may have been as a result of human handling.

Aba metropolis, Abia State, Nigeria and also isolated *Penicillium* species, *Rhizopus* species and *Aspergillus* species and bacteria associated with their work were the genera *Staphylococcus* and *Bacillus* sp. The work is also in consonance with the works of [6].

The distribution of microbes followed a certain pattern. *Bacillus subtilis*, *C. feundii*, *Proteus mirabilis*, *Staphylococcus aureus*, *Serratia marcescens*, *Bacillus cereus* was distributed differently in most in

striped chips. *Citrobacter feundii* occurred most in Marabel chips followed by Diamante striped chips. *S. aureus* was among the bacteria with the highest occurrence in Diamante then followed by Nicola and Caruso chips. *Serratia marcescens* occurred highest in both Nicola and Caruso striped chips. The works of [6] agrees with the present study because they also isolated some similar bacteria such as *Staphylococcus aureus* and *Bacillus* species. [40] also isolated *Staphylococcus aureus* from their work on ready to eat foods which is in consonance with the present study. *C. feundii* is associated with foods and it's found in human and animal gastrointestinal tract. Most foods are hardly protected from flies because they are found in almost everywhere and they are potential carriers of food borne pathogens [6]. Consumers who depend on snacks are not interested in the safety of such foods but their convenience and affordability [41]. The few microbes associated with this study indicate that food safety standards were adhered to.

Proximate composition of crispy and striped chips

There was significant difference ($p \leq 0.05$) in the moisture content which ranged from 4.92 ± 0.03^{a} to 2.45 ± 0.03^{b} for all the crispy chips. The low moisture content may be as a result of water loss during frying. The moisture content of simulated chips reported by [42] was within the range 4.42 ± 0.03^{a} to 3.22 ± 0.05^{c} and is within the range of the present study which supports the present study. There is a correlation between moisture and any food's perishability [43]. Crispiness is attributed to texture, firmness, freshness [44] (Tunick, 2011). The force required to bite, chew and the sound produced during chewing tells the crispiness of a food [45].

There was significant difference ($p \leq 0.05$) in the protein content. The protein content of crispy chips ranged from 8.28 ± 0.06^{a} to 5.76 ± 0.03^{c}. The values may be as a result of cultural practices during cultivation. [46] reported the protein of chips from six varieties of potato having the range of values 2.73 ± 0.4 to 1.00 ± 0.18. Their values do not support those of this present study. On the other hand, [47] reported 6.14 ± 0.26^{c} for one of the raw materials used in the preparation of healthy chips for children which is closely related to this present study.

The crude fibre ranged from 11.75 ± 0.03^{a} to 9.57 ± 0.02^{c} and was significantly different (At $p \leq 0.05$) across the crispy chips produced with four varieties of potato.

The lipid content ranged from 26.51 ± 0.02^{a} to 22.3 ± 0.20^{c} for all the crispy chips and values obtained were significantly different ($p \leq 0.05$). The high lipid content may have been as a result of the traditional frying method employed during processing. [48] reported $29.38^{b} \pm 0.28$ fat content in one of the chips produced from one clone of potato which is most closely related to the present study. [49] reported the lipid content of crispy chips which ranged from 37.0 to 21.0 which were fried in different cooking oil. Some of the values in their study were closely related to the present study, therefore supports this study.

The ash content was significantly different ($p \leq 0.05$) across all the crispy chips which ranged from 2.46 ± 0.03^{a} to 1.55 ± 0.05^{b}. [46] reported their ash content which ranged from 0.97 ± 0.56 to 0.85 ± 0.45 in chips. There was disparity in the values, therefore does not in agree with the present study. Varietal difference may be the reason for the values obtained.

There was significant difference ($p \leq 0.05$) in the carbohydrate content which ranged from 55.74 ± 0.02^{a} to 48.28 ± 0.03^{d} across all the crispy chips. [48] reported carbohydrate content of chips produced from cloned potatoes with values which ranged from $65.28^{b} \pm 0.26$ to $41.05^{c} \pm 0.29$ which are closely related to values reported in the present study.

There was significant difference ($p \leq 0.05$) in the calcium content of the variety of crispy chips which ranged from 1.01 ± 1.38^{a} to 0.15 ± 0.02^{b}. The calcium content was low in all the crispy chips. This may be as a result of genetic variation among the potato varieties. There was no significant difference ($p \leq 0.05$) in the phosphorus content which ranged from 0.08 ± 0.00^{a} to 0.04 ± 0.00^{a}. Mineral composition are usually low in gluten free foods [50]. The energy content of crispy chips ranged from 466 to 455 Kcal among the chip's products. [51] reported their energy value ranging from 453 to 410 Kcal per 100g in their gluten free cookies and their values are closely related to those obtained in this study. The energy content in any foods is obtained mainly from carbohydrate and can be used to combat protein energy deficiency [52].

There was significant difference in the moisture content among the chip's samples. The moisture content of striped chips ranged from 54.90 ± 0.07^{a} to 5.72 ± 0.04^{b}. The moisture content is much

higher than those of the crispy chips. This may be because of the thickness of the chips and the surface area exposed to frying which helps remove moisture.

The protein content of striped chips ranged from 2.35 ± 0.03[a] to 1.33 ± 0.01[b] which differed significantly ($p \leq 0.05$). [46] reported the protein of crisp chips having the value 2.73 ± 0.4 to 1.00 ± 0.18, a much lower value compared to the values obtained in this study.

There was significant difference ($p \leq 0.05$) in the crude fibre content. The crude fibre content for striped chips ranged from 1.56 ± 0.03[a] to 1.46 ± 0.03[b] across all the striped chips. The crude fibre content may be as a result of retention or reduction of nutrients as a result of cooking [53] (Jayanty., et al., 2019). [54] reported the crude fibre content of 3.89, 3.70 and 3.39 for chips fried at 180, 190 and 200 ˚C in hot oil. The reports of the present study disagree with their study. This may be as a result of the cooking method they employed or the nutrient composition of the varieties of potato [53]. [55] reported a crude fibre content which ranged from 2.6 to 1.5 which is closely related to values of the present study and is in agreement with the present study. At $p \leq 0.05$, there was significant difference in the lipid content. The lipid content for the stiped chip ranged from 20.79 ± 0.03[a] to 18.45 ± 0.03[c] across all the striped chips. The variation in the lipid content may be as a result of absorption of oil as water evaporated during frying and the chemical composition of the potato varieties and frying time. Abong., *et al*. (2009) [7] reported the lipid content of their French-fried potato from different variety of potato which ranged from 9.82 ± 0.420 to 6.40 ± 0.880. These values are lower than those obtained from this study and does not support the present study but the oil content of their frozen chips was 15.33 ± 0.620 to 10.38 ± 0.100 and closely related to those values obtained in this study and agrees with the present study.

There was significant difference ($p \leq 0.05$) between the ash content of striped chips. The ash content ranged from 1.72 ± 0.02[a] to 1.59 ± 0.06[c] for striped chips. [56] reported the ash content of their potato chips which ranged between 2.93 to 1.0. The values in the present study range within their values obtained in the present study. [57] reported ash content in their work ranging from 1.43 to 1.86. Their report supports the present study.

There was significant difference ($p \leq 0.05$) in the carbohydrate content between striped potato chips. The values ranged values for striped chips ranged from 21.87 ± 0.01[a] to 19.71 ± 0.05[d] across all the striped chips. The variation in the carbohydrate content may be as a result of excessive frying which increases the amount of carbohydrate [56]. [56] reported the sugar content of their work with values ranging from 51.79 to 19.80. The values of their study agree with some of the values in this present study fall within their study which this makes the present study agree with their study.

Calcium was significantly different for stiped potato chips at $p \leq 0.05$ while the phosphorus content had no significant difference at $p \leq 0.05$ for striped chips. The calcium levels ranged from values for striped chips ranged from 0.17 ± 0.02[b] to 0.14 ± 0.01[a] whereas the phosphorus values ranged from 0.04 ± 0.00[a] to 0.02 ± 0.00[a] for striped chips. The calcium and phosphorus content striped chips may be as a result of potato variety or physicochemical characteristics of the soil. [58] reported the presence of 15% phosphorus. Potassium rich diets must be used consumed alongside the potato product in this study. The energy content ranged from 274 to 263 Kcal among the chip's product. The energy content in an any foods are mainly obtained from carbohydrate, fat and in some cases protein and can as well be used to combat protein energy deficiency [52].

Sensory evaluation of chips produced from four varieties of potato

Chips were produced from the four varieties of potato. The colour of the chips produced was brown in colour which ranged from 8.45 ± 0.51 to 6.35 ± 2.25 which fell within the like scores. The taste parameter score showed that the scores ranged from 8.45 to 6.30 ± 2.34. The scores are observed along the column for taste which indicated that the taste was generally liked for all the chips samples. The score for texture ranged from 8.35 ± 0.59 to 6.60 ± 2.09 across all the chips samples. The scores indicated a general likeness for the chip's products by the tasters. The highest score for aroma ranged from 8.40 ± 0.60 to 6.95 ± 1.70 which indicated that the chips samples were generally liked by the panel of tasters. The score for the overall acceptability ranged from 8.40 ± 0.60 to 6.80 ± 0.96. The scores indicated that there was a general likeness for all the chips samples because of the high scores obtained. [59], also reported his findings on that the colour of chips as the first parameter that consumers analyse followed by other parameters such as safety, sensory qualities and nutrition. This is in agreement with this present study. The dependable parameters for the acceptability of chips by consumers correlates to the physical, chemical

and sensory quality of chips. The colour change is also as a result of changes that took place during frying. The crispy chips were dry from the surface to within while the striped chips were dry at the surface but soft on the inside. The crispy test sample and control sample is closely related to this study and in agreement with [32,60] who reported crispiness of their chips. Crispiness of chips is also as a result of the tissues having air cavities surrounded by a brittle structural phase [33]. [61] reported that the size of potato influenced its colour, overall acceptability, aroma, and texture all fell within the like score. Their report is closely related to the present study. [62] reported the potato cultivar influenced the sensory scores of colours, flavour, texture and overall acceptability of their potato chips. Their report is closely related to the present studies.

There was general acceptability of both the crispy and striped chips which is in consonance with [32] who stated that the light colour of chips attracted people. [63] reported a high score of above 8 of the crispiness, acceptability, colour, taste in their traditionally produced potato chips. Their work is closely related with the present study that also used traditional frying method in oil. The reason for the acceptability is that the lifestyle of adults and young adults is geared towards spicy, sweet and savoury fatty snacks. The differences in the scores obtained may be as a result of variety of potato.

Highlights

Potato chips were produced from four varieties of potato. The crispy and stiped chips were both cream while the texture for both chips ranged from brittle surface and dry surface as well as soft from the inside for crispy and striped chips respectively. The microbial counts were significantly different and ranged within safe limits for edible food products. The few microbial genera isolated and were *Cladosporium*, *Aspergillus*, *Penicillium*, *Fusarium*, *Rhizopus*, *Bacillus*, *Citrobacter*, *Proteus*, *Staphylococus* and Serratia indicated contamination but safe for consumption. The proximate composition of both the crispy and striped chips provides the nutritious benefit of consuming such food products. The chips produced were acceptable by the organoleptic assessment of consumers.

Conflict of Interest

There is no conflict of interest

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