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Effect of Processing on Nutritional Value and Microbial Characteristics of Okra (*Abelmoschus esculentus*)

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Okra is consumed for its nutrients for healthy growth and development. Quality okra is essential for consumption and maximizing profits for okra producers and marketers. However, okra is perishable and limited in supply during the dry seasons. The stakeholders such as farmers, traders and consumers processed okra fruits to make them available all year round. Therefore, the objective of the study is to explore the effect of processing on nutritional value and microbial characteristics of okra fruits. The study involved both field survey and laboratory work among five okra producing communities within Sunyani Municipality Ghana, namely; Abesim, Atronie, Benu Nkwanta, Ayakomasu and Wawasua. Stratified sampling technique was used to select 50 farmers while purposive sampling technique was used to select 35 traders and 25 consumers, making a total of one hundred and ten respondents. Questionnaires were instruments used for the survey. Randomized Complete Block Design (RCBD) with four treatments was used and blocked five times to obtain data for laboratory analyses. Results from the study indicated that, variety of okra fruits

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most cultivated, sold and consumed was Asutem, July to September were identified to be the months of bumper harvest for farmers, declined in prices of okra fruits for traders and low purchasing prices of okra fruits for consumers. The processing methods identified for processing okra fruits were slicing, pounding/ milling and roasting. Nutritional analyses on techniques used for processing okra fruits in the study area, revealed that, fiber, ash and calcium contents (18.47 %, 9.7 % and 0.43 %) were higher in sliced okra fruits and carbohydrate content (48.34 %) was higher in roasted okra fruits. Microbial contamination analyses on techniques used for processing okra fruits, showed that, there were lower (1.24, 0.83, 1.73 and 0.66 log10 CFU/g of *Aspergillus flavus, Aspergillus niger, Penicillium digitatum* and *Penicillium* spp, respectively) in roasted okra fruits.

Keywords: Okra fruit; okra processing; nutritional qualities; microbial contamination.

1. INTRODUCTION

Okra (*Abelmoschus esculentus*) is a vegetable belonging to the family of *Malvaceae* [1]. Okra is a repository of valuable nutrients [2]. It is less of a staple than diet food [3]. Okra is consumed in immature stage to provide health benefits such as prevention of constipation because pods contain mucilaginous substances and high dietary fiber which serve as natural laxatives. It has high antioxidants, which fights against diseases in human body such as stroke and cardiac-related diseases. Okra also prevents cataract and helps with good vision. Again, it is used by diabetics to stabilize their blood sugar by slowing absorption from the intestine. Okra is also rich in protein, carbohydrates, folic acid, vitamins, potassium, calcium, iron and glycan [4]. Okra seed oil is important for human nutrition since is a rich source of polyunsaturated fatty acid and linoleic acid [5]. Because of the dietary fiber, robust nature and different seed protein balance of both tryptophan amino acids and lysine (unlike the proteins of cereals and pulses) okra has been called “a perfect villager’s vegetable” [6]. The composition of the amino acids of okra seed protein is similar to that of soybean [7] which makes it a suitable complement to cereal-based diets [8]. Okra plays an important role in human diet [9,10] since it also contains vitamins and carbohydrates [11-13]. Carbohydrates are mostly in the form of mucilage [14,15]. The young fruits of okra contain about 170,000 molecular weight long chain molecules made up of amino acids and sugar units. The main components are galacturonic acid (27%), galactose (25%), rhamnose (22%) and amino acids (11%). The solubility of mucilage in water is very high with an intrinsic viscosity value of 30%. The primary elements in pods are potassium, sodium, magnesium and calcium which contain about 17% seeds. The presence of manganese, iron, zinc and nickel has also been reported [16]. Practically, fresh pods contain no fat, low in calories (20 per 100 g), are high in fiber, and have numerous important nutrients, including recommended levels of about 5% of vitamin A, 10 to 20% of folate (46 to 88 mg) and 30% of the of vitamin C (16 to 29 mg). Both seeds and pod skin (mesocarp) are very good sources of zinc (80 mg/g) [16]. In Ghana, okra is consumed in diverse ways. They are used to prepare different varieties of dishes such as stews and soups [17].

Okra is cultivated all over the world, with leading producers including India, Nigeria, Iraq, Cameroon and Pakistan. India is the largest producer with quantity of production in terms of tonnage per year of 6,350,000 tons and Nigeria, the largest producer in Africa with total production per year of 1,100,000 tons [18]. In Ghana, total annual production of okra is about 63,860 tons. The largest producing regions include Brong Ahafo, Western, Ashanti, Greater Accra, Northern and Volta [19]. Okra thrives in warm weather which requires evenly distributed annual rainfall of 1000mm and temperature of 25 – 35^0 C. They are cultivated in sand to clay soils with well-drained soils. Again, a well-manure loamy soils with pH of 6.0 – 6.8 (slightly acidic) are recommended for cultivation. Planting is mostly done in the rainy season between April and August [19]. This is where okra is abundant and cheap which affect product pricing and discourage farmers from expanding their farms [20].

Processing is a set of procedures used to produce a product. Food processing is the transformation of raw ingredients, by physical or chemical means into food, or into other forms. Vegetables are rarely processed, presumably due to the general lack of basic preservation facilities for freezing, canning or dehydration. Okra is highly perishable because of its high moisture content and respiratory activities, therefore, it is necessary to preserve the commodity. In Africa, processing of okra is still

traditional and under-utilized. In Nigeria, particularly the Tiv people, Okra is processed by boiling in water to make raw soup. It is also sliced or dried whole to produce “Gyande” (sliced) or “Gbodi” (powdered) [21]. During the lean season, okra fruits are produced in low quantities, thus, they are scarce and expensive. In the peak seasons, they are produced in large quantities much more than what the local populace can consume leading to wastage. Proper processing and utilization of okra are necessary in order to harness the economic, nutritional and health benefits of the commodity [22]. Studies on effect of processing methods on selected physical and chemical properties of okra revealed that, the moisture content of fresh, boiled and dried okra ranged from 10.21 – 82.61 % and it was observed that fresh okra had a moisture content of 42.75%, boiled okra had the highest moisture content of 82.61% and dried okra had the least moisture content of 10.21%. Carbohydrate for fresh, boiled and dried okra value ranged from 7.87 – 22.29 (%). It was observed that, fresh okra had the highest value of 22.29 %, boiled okra had the least value of 7.87% while dried okra had value of 20.66 % and concluded that, it could be simply due to concentration of the nutrient as the moisture is highly reduced. Crude protein for fresh, boiled and dried okra ranged from 2.72 – 14.67 (%) and it was observed that fresh okra had the value of 10.24 %, boiled okra had 2.72 % which was the least while dried okra had the highest crude protein of 14.67 %. They explained that, the result could be, because of excessive heat involved in the boiling process, destroyed the protein cells. While that of the dried processed okra could be, because the heat involved could only remove the water content leaving the protein cells. They also noted that, crude protein depends on the processing method at 95% confidence level. Crude fat for fresh, boiled and dried okra ranged from 0.11 – 9.68 (%) and it was observed that fresh okra had the value of 6.21 %, boiled okra had the least value of 0.11% while dried okra had the highest value of 9.68 %. Ash content for fresh, boiled and dried okra ranged from 3.31 – 9.16 (%) and it was observed that fresh okra had the highest value of 9.16 %, boiled okra had 3.31% value which was the least while dried okra had 8.16 % value. This is because, the heat involved in the boiling process destroys the ash contents of okra. It was also observed that, the processing method had a significant effect ($p<0.05$) on porosity. The fiber for fresh, boiled and dried okra measured ranged from 3.44 – 36.62 (%) and it was observed that, fresh okra had value of 9.25%, boiled okra had the least value of 3.44% while dried okra had the highest value of 36.62%. For all the parameters measured, it was found that, the physico-chemical properties of okra were significantly affected by processing methods ($P<0.05$) [23]. A studies on the effect of drying methods on the physico-chemical properties of okra also showed that, moisture content was reduced by drying which corresponded with an increased protein, dry matter content, minerals (Zn, Ca, Mg and Fe) and ash in okra [24].

As other green vegetables with short shelf - life, the commonly conservative method used is drying. This process allows people to make okra more durable and preserve them for food insecure periods [25]. In Ghana, dried powdered okra is commonly called “nkrumasam”. The young tender fruits (2-3 days old) are sundried whole until becoming brittle, but, the old fruits are sliced in thin disks, dried and powdered [26]. However, in practice, the drying is mainly handmade where okra is either put on a mat or metal sheet laying on the ground and sundried for 3 or 4 days [27]. In these conditions, dried okra is exposed to microbiological contamination [28]. The incriminated germs (eg. yeasts and moulds) may be already present on fresh okra or could appear during the drying process under unhygienic conditions. Moreover, many microbes, especially fungi, can grow and secrete toxic substances which can induce hazardous risks to human health [29]. In fact, mycotoxins and fungal contamination in dried vegetables have been investigated by some authors. Among different studies concluded that, there were presence of moulds and their toxins in sundried okra on markets after 22 weeks of conservation [28]. Similarly, the load of moulds was very high in dried okra and dried hot chili [30]. But other investigations also indicated decrease in microbial load in fresh okra after the drying process and explanation been attributed to the decrease in mould loads to be due to the water activity declining which results from the loss of humidity in samples, causing the inhibition of microbial growth [31, 32].

Over the past 40 years, 40 to 50% of horticultural crops produced in developing countries are lost in quality and quantity terms long before they can be consumed, mainly because of high rates of bruising, water loss and subsequent decay during postharvest handling. Climatic factors such as sunshine, rainfall, humidity and temperature, influence condition and may have a

direct or indirect effect on the food rendering a decline in numbers or volume and its nutritional qualities. These changes, however, do not necessarily render the food unfit for human consumption, but they make it less palatable and sometimes unacceptable to consumers [33]. During postharvest handling, the product is susceptible to physical damage and deterioration. Horticultural produce losses are as high as 50% due to inefficient postharvest procedures [33]. Depending on the crop, losses are estimated at 20 - 40% in developing countries and 10 - 15% in developed countries. About half of the losses are due to physical injuries and improper handling and distribution [34]. Percentage loss of vegetable crops in Ghana was estimated at 20% with most losses occurring during harvesting, transportation and grading and sorting [35]. Quality is one characteristic that consumers associate each commodity with and which is dependent upon the particular end-use, such as sweetness, tenderness and crispness. Although, consumers do not consider quality loss in chemical and nutrients in food products because it is not an index for buying at the point of sales. Quality also refers to freedom from defects such as blemishes, mechanical injury, physiological disorders, water loss and decay. It is imperative to understand that, quality loss in fresh vegetables is cumulative, each incident of mishandling reduces the ultimate physical, chemical and nutritional qualities which are then presented to the consumer. Again, many pre - harvest and postharvest factors such as genetics, cultural practices, planting period, planting density, irrigation, fertilization, crop protection, maturity at harvest and postharvest handling techniques influence composition and quality of produce by the time it reaches the consumer. Postharvest losses had great impact on reducing profitability and efficiency of the supply chain [36]. In addition, vegetables are susceptible to nutritional loss, especially vitamins after harvest and during processing and cooking. The vitamins specifically ascorbic acid and vitamin A are soluble in water and sensitive to heat, light and oxygen [37]. Traditional sun drying is the cheapest and most accessible vegetable preservation in developing countries, causing considerable destruction of nutrients and bioactive compounds of dried product. Again, mould and other spoilage organisms can grow on partly dried processed okra fruits which affect the quality of the commodity which is dangerous for human health, causing allergic reactions, respiratory problems and produces “mycotoxins” poisonous substances that cause sickness in humans such as aflatoxins which is toxigenic strain and is potent natural carcinogen [38]. Processing of okra may cause substantial nutritional loss and influence mould growth by exposing the tender crop to relative heat and destroying bioactive compounds, which the stakeholders presume to be the effective ways of preserving and retaining nutrients or health benefits of the commodity. In addition, majority of stakeholders of okra in rural areas, think the processing methods of okra fruits used cannot influence microbial infections in processed okra fruits [39].

Therefore, it is paramount to explore the effect of processing on nutritional value and microbial characteristics of okra fruits to improve health benefits of consuming okra fruits, increase profitability of production and sales of okra fruits.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted in the Sunyani Municipality. Sunyani lies within the middle belt of Ghana, with latitudes 70 20’N and 70 05’N and longitudes 20 30’W and 20 10’W with altitudes of 229 – 376m above sea level [23]. The main rainy season is between March and September, with minor rainy seasons between October and December. This offers the Municipality two (2) farming seasons in a year to support agricultural production in the Municipality [40].

2.2 Methodology Used for the Field Survey

Strategies adopted to gather relevant information to address the objective of the study were; Consultation with the Regional Town and Country Planning, District Directorate of Ministry of Food and Agriculture (MoFA) on which communities were involved in okra cultivation and processing of okra. Five (5) communities (Abesim, Atronie, Benu Nkwanta, Ayakomasu and Wawasua) were selected for the study. Stratified sampling was used to select fifty (50) farmers, purposive sampling was used to select thirty – five (35) traders who bought their produce from farmers directly and twenty-five (25) consumers who ate okra at least thrice a week . Semi – structured questionnaires were used to obtain information from respondents. In order to ensure accuracy in their responses, respondents

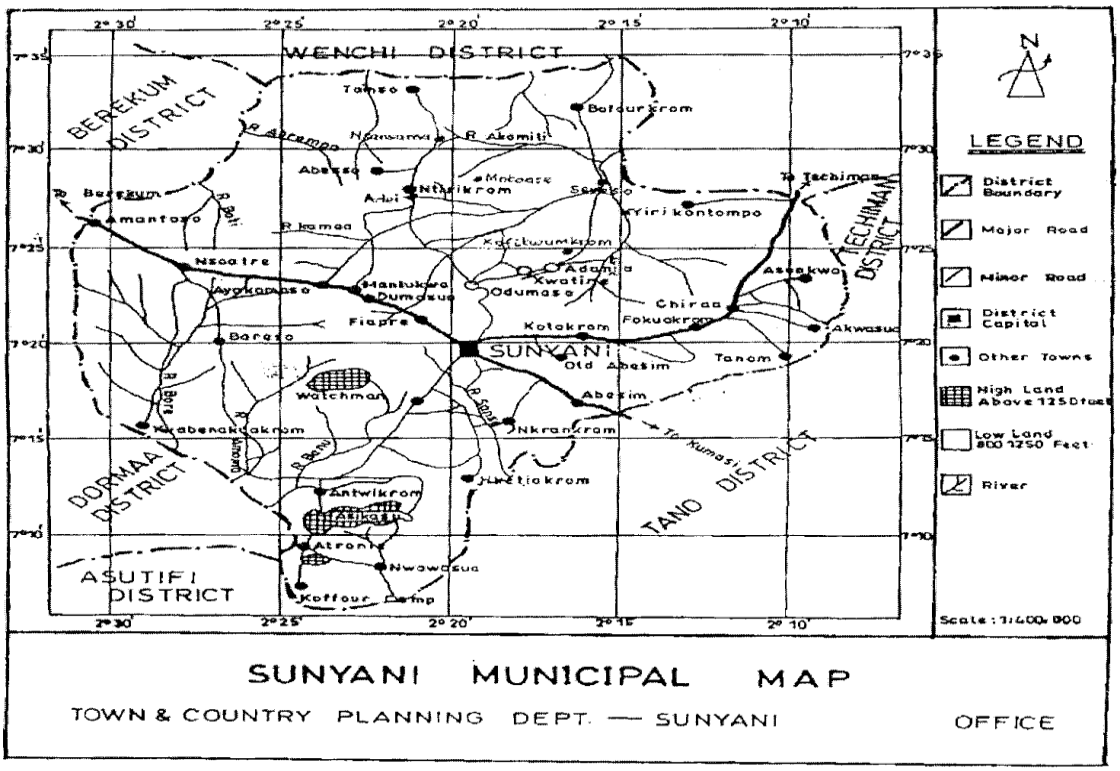

Fig. 1. Map of Sunyani Municipality

were given some guidance to administer their questionnaires. In the case of illiterate respondents, the questionnaires were read in their native dialects and responses were taken.

2.3 Methods Used in Processing Okra Fruits

2.3.1 Okra samples collection

One (1) bag of most preferred okra was bought at their major markets in each five (5) selected communities (Abesim, Atronie, Benu Nkwanta, Ayakomasu and Wawasua). They were transported to selected farmers, traders and consumers' houses in their respective communities.

2.3.2 Processing of fresh okra fruits into sliced, pounded and roasted okra fruits

Healthy fresh okra fruits were selected and washed using cold water from the tap. The one (1) bag of fresh okra fruits bought from each communities was divided into four (4) groups. Each group was processed into sliced, pounded and roasted okra but the remaining group of fresh okra fruits was used as control samples. For slicing, fresh okra fruits were cut into pieces (2cm) using kitchen knife, spread on black polythene sheet and allowed to sundry the cut fresh okra fruits for two (2) weeks in each respective communities. In case of pounding, the whole fresh okra fruits were spread on black polythene sheet and allowed to sundry for two (2) weeks in each respective communities. After sun drying, they were placed in wooden mortar and pounded with a wooden pestle until the dried okra fruits turned into powder. Furthermore, roasting was done by sun drying whole fresh okra fruits on black polythene sheet for two (2) weeks, pounded dried okra fruits into flour and put the okra powder into metal container (aluminium), then put it on fire (coal pot) and stirred the okra flour for five (5) minutes using aluminium ladle.

2.4 Methodology Used for Collection of Okra Samples for Laboratory Procedures

The processed okra fruits were carried - out by selected farmers, traders and consumers in each selected communities. Randomized Complete Block Design (RCBD) with four (4) treatments (control, sliced, pounded and roasted) was used to collect okra samples for laboratory analyses.

The experiment was blocked five (5) times. Okra samples were put in zip bags, labeled and placed in ice chest and transported within three (3) hours to Crops and Soil Science Department, Kwame Nkrumah University of Science and Technology, Ghana to determine nutritional and microbial characteristics of okra samples.

2.4.1 Nutritional parameters procedures

Nutritional parameters (moisture, fiber, ash, crude protein, fats, carbohydrate and calcium) were determined using standard protocols of [41].

2.4.2 Microbial parameters determination

The mould growth contamination was determined using counting of colonies (Cfu/g) as described by [42].

2.5 Data Analyses

Survey data obtained from farmers, traders and consumers using the questionnaires were coded and analyzed using the Statistical Package for Social Sciences (SPSS) version 21 and results were expressed using tables, frequencies, percentages and chart. Data collected from the laboratory analyses were subjected to Analysis of Variance (ANOVA) using Statistix 8.1. Where treatment means were significant, they were separated by Turkey's Highest Significant Difference (HSD) at 5 % probability level.

3. RESULTS AND DISCUSSION

3.1 Okra Varieties Cultivated, Sold and Consumed by Respondents

Fig. 2 revealed that, most of the farmers (68%) cultivated Asutem variety followed by Ladyfinger (12%) whilst Quim Bombo was the least cultivated (4%). The most traded variety was Asutem (71.4%) followed by Ladyfinger (14.3%). The most consumed variety was Asutem (60%) followed by Ladyfinger (16%). The results suggested that, most cultivated, traded and consumed varieties of okra fruits was Asutem. Therefore, plant breeders could investigate to improve Asutem variety of okra for easy cultivation such as reduce the long period of maturation of Asutem, drought tolerant Asutem, diseases and pests resistance Asutem in order to reduce difficulties in producing Asutem and encourage more Ghanaians to engage in the production of Asutem to reduce high unemployment rate in the country. Early maturation, drought tolerant crops, disease and pest resistance crops influence more cultivation of agricultural crops [43] Again, more education needed to be intensified by Ministry of Food and Agriculture (MoFA) to encourage more Ghanaians to venture into the business of Asutem since there is ready market for the sales of Asutem to improve their livelihood. Unemployment rate in Ghana is about 13.4 percent (1.74 million of Ghanaians are out of jobs) [44]. Furthermore, industries and consumers that use okra to manufacture various products and those that use as food could also consider Asutem variety since it is the popular and reliable variety of okra which could be easily obtained from farmers and marketers. Okra is used in pharmaceutical and food industries. Okra is used to manufacture nasal gel. Again, some application of okra in the food industries include salad dressing where it serves as preservative, in cheese okra gum is spread to act as emulsifier and in confectionery is used in the formulation of fondants, frosting, sauces etc and used to prepare stews and soups [45].

3.2 Months of Bumper Harvest, Decline in Prices and Purchasing of Cheap Okra Fruits by Respondents

Table 1 revealed that, majority of the farmers (50%) had bumper harvest from July to September while 30% had theirs from April to June. Majority of the traders (37.1%) experienced decline in prices of their produce from July to September and 34.3% of traders had their decline in prices of okra from April to June. Majority of the Consumers (44%) bought okra fruits at cheaper prices from July to September and 28% of consumers also enjoyed low prices of okra fruits from April to June. The results from farmers indicated that, okra was mostly abundant around July to September, hence, government of Ghana should intensify its policy implementation of One District One Factory (1D1F) to benefit the study area to reduce postharvest losses of okra in the study area. One District One Factory (1D1F) is a new policy implemented by government of Ghana in 2017 with the aim of transforming raw materials into finished products and exported to foreign countries to change the nature of Ghana's economy, which is, import driven economy [46]. Again, traders experienced low prices of okra fruits, mostly in the months of July – September. This suggested that, traders lose money or income to take care of their

children, pay taxes, utility bills (electricity and water). Therefore, Ministry of Food and Agriculture (MoFA) and research institutions could investigate the best techniques to preserve okra fruits for longer period of time for traders to sell the okra fruits, when they are scarce and more appealing to consumers to improve their profit margins in okra business and not to lose more money or income from July to September. Ministry of Food and Agriculture (MoFA) is mandated to improve the growth of income [47]. Again, most consumers bought cheap okra mostly from July to September which is an indication of sufficiency or availability and easy accessibility of okra fruits in the study area. Okra is rich in protein, carbohydrate, fiber, magnesium, folate, vitamins A, C, K and B6 as well as antioxidants that reduce health conditions such as cancer, diabetes, stroke and heart diseases [48].

3.3 Post-harvest Processing Techniques Used by Respondents for Processing Okra Fruits

From Table 2, 40% of farmers processed okra fruits by pounding/ milling the dried okra fruits, 36% of farmers used slicing method of processing okra fruits, and 24% farmers processed okra fruits by roasting. Majority of traders (40%) processed okra fruits by slicing while 25.7% traders used roasting. Majority of consumers (40%) used roasting to process their okra fruits but 28% of consumers used pounding/ milling to process their okra fruits. This showed that, majority of farmers used pounding or milling technique (wooden pestle and mortar) to transform okra fruits which is less expensive for use. However, since it involves physical activities, small quantity of okra could be processed. Most of harvested products could not

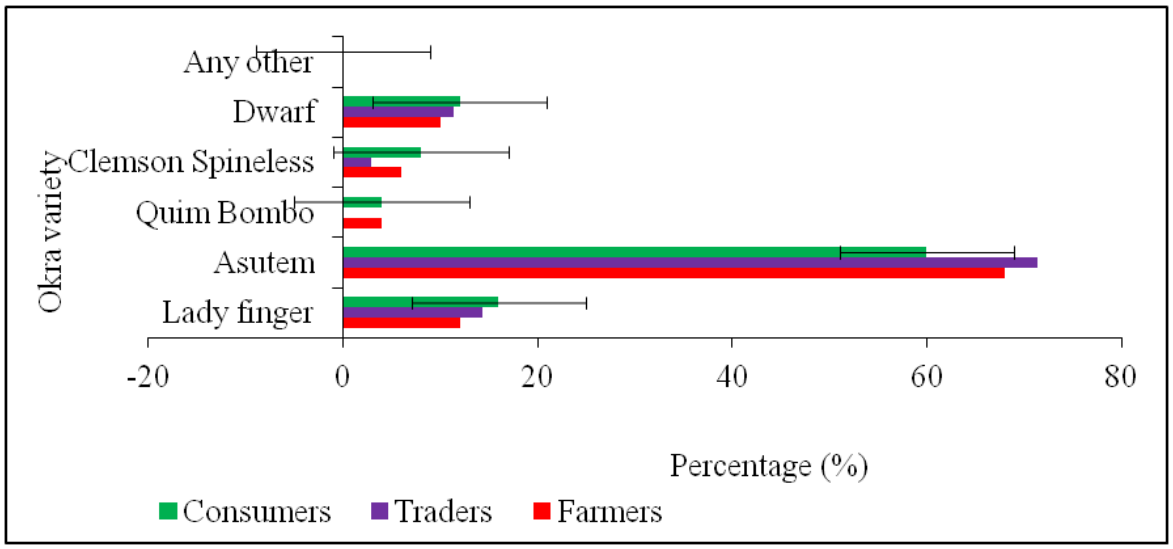

Fig. 2. Okra varieties cultivated, sold and consumed by respondents

Table 1. Months of bumper harvest, decline in sales and purchasing of cheap okra fruits by respondents

Month	Farmers		Traders		Consumers	
	Frequency	%	Frequency	%	Frequency	%
Jan. - Mar.	2	4	1	2.9	3	12
Apr. - Jun.	15	30	12	34.3	7	28
Jul. - Sept.	25	50	13	37.1	11	44
Oct. - Dec.	8	16	9	25.7	4	16
Total	50	100	35	100	25	100

Table 2. Post-harvest processing techniques used by respondents for processing okra fruits

Processing method	Farmers		Traders		Consumers	
	Frequency	%	Frequency	%	Frequency	%
Cooking	0	0	0	0	0	0
Slicing	18	36	14	40	8	32
Pounding/milling	20	40	12	34.3	7	28
Roasting	12	24	9	25.7	10	40
Any other	0	0	0	0	0	0
Total	50	100	35	100	25	100

be processed and go waste [49]. Majority of traders used slicing method which reduced the size of okra fruits for more okra fruits to be preserved. However, the slicing technique of processing okra fruits, exposes okra fruits to pathogenic infections. Slicing technique pre – disposes okra fruits to contamination by micro – organisms [50]. Majority of consumers of okra fruits used roasting. This indicated that, roasting improves the flavour of okra [51] but the use of charcoal would increase deforestation and degradation of the forest to cause adverse effect on the environment like global warming [52].

3.4 Effect of Processing Techniques on Nutritional Qualities of Okra Fruits

Nutritional analyses were conducted to determine the effect of processing methods on the nutritional qualities of okra fruits and the results were presented in Table 3. There were significant ($P < 0.05$) differences in nutritional value among the processing methods.

a. Moisture content

There were significant ($P < 0.05$) differences in moisture content among the processing methods. Controlled recorded the highest moisture content (12.62 %) among the processing methods followed by the sliced (12.05 %). The least moisture content was recorded by roasted (9.8 %). Moisture regulates the body temperature through perspiration, helps to prevent constipation, lubricates and cushions the joints, protects spinal cord and gets rid of waste through urination [53].

b. Fat content

Fat content was significantly ($P < 0.05$) highest in the controlled (1.75 %) which was higher among the processing methods while roasted recorded least fat content (1.35 %). Fat gives energy to the body, protects organs, supports cell growth, keeps cholesterol and blood pressure under control, keeps brain healthy and helps the body to absorb vital nutrients [54].

c. Fiber content

Sliced significantly ($P < 0.05$) produced the highest (18.47 %) fiber content among the processing methods which was followed by the controlled (16.71 %) while the roasted recorded the least (14.3 %). Fiber prevents or relieves constipation, helps to maintain healthy weight, lowering risk of diabetes, heart diseases and some types of cancers [55].

d. Ash content

The ash content followed a similar trend as the fiber content with the sliced significantly ($P < 0.05$) recorded the highest (9.7 %) with the least (7.31%) recorded in roasted. Ash reduces grout, fever, arthritis, bladder problems, constipation and increases urine production to relieve water retention (as a diuretic) [56].

e. Protein content

The controlled significantly ($P < 0.05$) recorded the highest protein content (16.94 %) among the processing methods followed by roasted (15.49 %). A similar no significant difference ($P > 0.05$) content of protein was produced by sliced and pounded methods (14.99 % and 14.98 %, respectively). Least significant difference ($P < 0.05$) was recorded in roasted (15.49%). Protein helps the body to repair worn - out cells or tissues and makes new ones. It helps in growth and development in children, teeth and pregnant woman [57].

f. Carbohydrate content

Roasted significantly ($P < 0.05$) recorded the highest (48.34 %) carbohydrate content among the processing methods which was followed by sliced (47.43 %), controlled (44.49 %) and pounded recorded the least (44.12 %). Carbohydrate is the primary source of energy for the body and the brain [58].

Table 3. Effect of processing methods on nutritional qualities of okra fruits

Processing method	Moisture	Fat	Fiber	Ash	Protein	Carbohydrate	Calcium
	(%)						
Controlled	12.62 a	1.75 a	16.71 b	9.3 b	16.94 a	44.49 c	0.35 c
Sliced	12.05 b	1.4 c	18.47 a	9.7 a	14 99 c	47.43 b	0.43 a
Pounded	11.65 c	1.45 b	16.21 c	7.9 c	14.98 c	44.12 d	0.34 c
Roasted	9.8 d	1.35 d	14.3 d	7.31 d	15.49 b	48.34 a	0.39 b
HSD (0.05)	0.03	0.02	0.10	0.03	0.07	0.14	0.01
CV	0.23	1.16	0.44	0.3	0.34	0.24	2.01

Means with the same letter(s) in the column are not significantly different from each other (P > 0.05, according to Tukey's HSD)

Table 4. Effect of processing techniques on microbial characteristics of okra fruits

Processing method	*A. flavus*	*A. niger*	*P. digitatum*	*Penicillium spp*
	(log10 CFU/g)			
Controlled	3.73 c	2.50 c	2.26 c	3.51 c
Sliced	4.90 a	2.58 b	5.41 a	4.36 a
Pounded	4.12 b	2.71 a	3.96 b	4.09 b
Roasted	1.24 d	0.83 d	1.73 d	0.66 d
HSD (0.05)	0.017	0.008	0.006	0.006
CV	0.37	0.29	0.14	0.14

Means with the same letter(s) in the column are not significantly different from each other (P > 0.05, according to Tukey's HSD

g. Calcium

Sliced significantly (P < 0.05) recorded the highest calcium content (0.43 %) among the processing methods followed by the roasted (0.39 %). There was no significant difference (P > 0.05) between controlled and pounded (Table 3) which also happen to be the least calcium content recorded. Calcium is associated with healthy bones and teeth formation. It helps in blood clotting, helps in muscles contraction and regulates normal heart rhythms and nerve functions [59].

3.5 Effect of Processing Techniques on Microbial Characteristics of Okra Fruits

Four different species of fungi were identified, namely; *Aspergillus niger, Aspergillus flavus, Penicillium digitatum* and *Penicillium spp*. With the exception of *Aspergillus niger*, sliced, significantly (P < 0.05) recorded the largest fungi contamination among all the processing methods (4.90, 5.41 and 4.36 log10 CFU/g for *Aspergillus flavus*, *Penicillium digitatum* and *Penicillium spp*, respectively). However, roasted recorded the least contamination in all the four (4) fungi species identified which were significantly (P < 0.05) lower than contaminations observed in the controlled which were presented in Table 4. The data suggested that, roasted okra fruits recorded lowest fungi contamination. This could be the application of heat during roasting of okra fruits. Most yeast and moulds are heat sensitive and are destroyed by heat treatment at temperature of 60 – 71^0 C [60].

4. CONCLUSION

The most cultivated, sold and consumed varieties of okra was Asutem, hence, plant breeders can further study Asutem variety of okra to improve difficulty in cultivating Asutem variety of okra such as reducing long period of maturation of Asutem (3 – 4 months), drought tolerant Asutem, disease and pest resistance Asutem to encourage more Ghanaians to engage in Asutem production to reduce high unemployment rate in the country. Also, Ministry of Agriculture (MoFA) should intensify education for unemployed Ghanaians to venture into the trade of Asutem variety since there is ready market for Asutem. Again, industrial users and consumers can consider the use of Asutem, because, it is the variety that is most available and accessible for use.

Bumper harvesting of okra fruits by farmers in the study area was mostly done from July to September, so government of Ghana should intensify its policy implementation of One District One Factory (1D1F) to benefit the study area to reduce postharvest losses of okra fruits in the

study area, in order to achieve the aim of One District One Factory (1D1F) policy of reducing import dependency economy of Ghana. Furthermore, traders experienced decline in prices of okra fruits, mostly from July to September. Therefore, Ministry of Agriculture (MoFA) and research institutions could investigate to identify the best preservative methods to extend the shelf – life of okra fruits to make okra fruits available in the lean seasons and attractive to consumers to enhance profit margins of traders to enable them to take care of their children, pay taxes for the development of the country and be able to pay their utility bills (electricity and water). Moreover, most consumers bought cheap okra fruits from July to September which also indicated that, okra fruits were available and easily accessible to consumers from July to September. Consumption of okra fruits reduces health conditions such as cancer, diabetes, strokes and heart diseases to get healthy citizens to help develop the country. Also, to reduce the huge money or budget used in importing drugs and machines to treat ailments such as cancer, diabetes, strokes and heart conditions which could be used in other developmental infrastructures such as good roads, electricity extension, schools etc.

The various processing methods mostly used by farmers, traders and consumers in the study area were pounding/ milling, slicing and roasting respectively. Pounding method was mostly used by farmers which demonstrated that, they used physical means (wooden pestle and mortar) to process okra fruits and it is less expensive, however, the physical pounding of okra fruits would make them tired easily, so they may not process more of harvested okra fruits and the unprocessed okra fruits would deteriorate. Again, most traders used slicing method which showed that, more okra fruits could be reduced into smaller sizes for easy handling of okra fruits but okra fruits are pre – disposed to microbial infections. In addition, roasting method mostly used by consumers improved flavour of okra fruits. Contrary, the use of charcoal could increase deforestation and degradation of the forest which could have adverse effect on the environment like global warming.

With regards to nutritional qualities, fiber, ash and calcium contents (18.47 %, 9.7 % and 0.43 %) were higher in sliced technique than the other processing methods. Consumption of sliced okra fruits would prevent constipation, helps to maintain healthy weight, reduces risk of diabetes, heart diseases, grout, arthritis, bladder problems, increases urine production and reduces some types of cancers. Again, consumption of sliced okra fruits would enhance healthy formation of bones and teeth, improves blood clotting, muscle contraction and regulates normal heart rhythms and nerve functions. However, carbohydrate content (48.34 %) was higher in roasted, hence, provides energy for the body and the brain.

Microbial contaminations were lower (1.24, 0.83, 1.73 and 0.66 log10 CFU/g of *Aspergillus flavus, Aspergillus niger, Penicillium digitatum and Penicillium spp*, respectively) in roasted okra fruits as compared to controlled okra fruits which were not processed (3.73,2.50, 2.26 and 3.51 log10 CFU/g of *Aspergillus flavus, Aspergillus niger, Penicillium digitatum and Penicillium spp*, respectively). This suggested that, there were reduction of microbes in roasted okra fruits which could be as a result of application of heat during roasting of okra fruits which destroyed most of the microbes. Also, consumption of roasted okra fruits could reduce the risk of disease infections caused by microbes.

5. RECOMMENDATIONS

i. Government agencies should intensify research to identify reasons for Quim Bomb variety of okra fruits not mostly cultivated by farmers, Ladyfinger not mostly sold and consumed by traders and consumers respectively, to reduce food insecurity, high unemployment rate and disease infections in the country.
ii. Research institutions should investigate the causes or reasons for low harvest of okra fruits in the months of April and June to improve okra production in the country.
iii. NGOs should support innovative or advanced technological research of processing okra fruits to improve quality of processing okra fruits.
iv. Consumption of roasted okra fruits should be complemented with foods rich in moisture, fats, fiber and ash to improve human nutrition. Furthermore, consumption of sliced and pounded okra fruits should be eaten with protein and calcium rich foods or diets to improve nutrition of consuming sliced and pounded okra fruits. Moreover, pounded okra fruits should be eaten with foods rich in carbohydrate to replenish inadequate

quantity of carbohydrate in pounded okra fruits.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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