

# EFFECT OF PROCESSING ON NUTRITIONAL VALUE AND MICROBIAL CHARACTERISTICS OF OKRA (*Abelmoschus esculentus*) FRUITS

## ABSTRACT

*Okra is consumed for its nutrients for healthy growth and development. Quality okra is essential for consumption and maximizing profit for okra producers and marketers. However, okra is perishable and limited in supply during the dry season. The stakeholders such as farmers, traders and consumers processed okra fruits to make it 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 the Sunyani Municipality Ghana, namely; Abesim, Atronie, Benu Nkwanta, Ayakomasu and Wawasua. The 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 analysis. The results indicated that, variety of okra most cultivated, sold and consumed was Asuntem, July to September were identified to be the months of bumper harvest for farmers, declined in prices of okra for traders and low purchasing prices for consumers. The processing methods of okra identified were slicing and sun drying, pounding/milling and roasting. fiber, ash and calcium contents (18.47 %, 9.7 % and 0.43 %) were higher in slicing, carbohydrate content (48.34 %) was higher in roasting. Microbial contaminations were lower (1.24, 0.83, 1.73 and 0.66 log<sub>10</sub> CFU/g of *Aspergillus flavus*, *Aspergillus niger*, *Penicillium digitatum* and *Penicillium spp*, respectively) in roasted okra.*

*Keywords: okra fruit, okra processing, nutritional qualities, microbial contamination*

## I. 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 level, which fights against diseases in human body such as stroke and cardiac-related diseases. Okra also prevents cataract and help with good vision. Again, it is used by diabetics to stabilize their blood sugar levels 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 which makes it a suitable complement to cereal-based diets [7] [8]. Okra plays an important role in human diet [9] [10] since it also contains vitamins and carbohydrates [11] [12] [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]. They are 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. They have high antioxidant levels, which fight against diseases in the human body such as stroke and cardiac-related diseases. They also prevent cataracts and help with good vision. They are used by diabetics to stabilize their blood sugar levels by slowing absorption from intestine. They are also rich in protein, carbohydrates, folic acid, vitamins, potassium, calcium, iron and glycan [4]. In Ghana, okra is consumed in diverse ways. They are used to prepare 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 a 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 temperatures between 25 – 35<sup>0</sup> 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,

thus between April and August [19]. This is where okra is abundant and cheap which affects product pricing and discourages 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; thus, 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 season, they are produced in large quantities much more than what the local populace can consume, thus 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 that was measured ranges 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 measured ranges from 7.87 – 22.29 (%). It was observed that fresh okra has 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 was measured ranging 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 the excessive heat involved in the boiled 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 measured ranges 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 has 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 a 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 are significantly affected by processing methods ( $P < 0.05$ ) [39]. A study on the effect of drying methods on the physico-chemical properties of okra also showed that moisture content

was reduced by drying which corresponded to increased protein, dry matter content, minerals (Zn, Ca, Mg and Fe) and ash in okra [23].

As the other green vegetable 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 [24]. 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 [25]. 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 [26]. In these conditions, dried okra is exposed to microbiological contamination [27]. 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 [28]. 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 [27]. Similarly, the load of moulds was very high in dried okra and dried hot chilli [29]. But other investigations also indicated decrease in microbial load in fresh okra after the drying process and explanation been attributed to the decrease of 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 [30] [31].

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 and its nutritional quality. These changes, however, do not necessarily render the food unfit for human consumption but they make it less palatable and sometimes unacceptable to consumers [32]. 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 [32]. 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 [33]. Per cent loss of vegetable crops in Ghana was estimated at 20% with most losses occurring during harvesting, transportation and grading and sorting [34]. However, 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 not considering the loss of quality in chemical and nutrition of food products because it is not an index for buying at the point of sale. 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 vegetable crops is cumulative: each incident of mishandling reduces the ultimate physical, chemical and nutritional quality 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. 30 to 70% of the global production of vegetables is lost annually with considerable maximum average post-harvest loss being attributed to developing countries like Ghana to be 50 per cent of the world's vegetable losses. These harvest losses have been linked to lack of knowledge, techniques in handling the crops, processing of the produce and adverse climatic conditions, which have a great impact on reducing profitability and efficiency of the supply chain [35]. 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 [36]. 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 processing okra fruits which affect the quality of the commodity which is dangerous for human health thus 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 [37]. The surplus from production of okra are processed into many forms called locally as "kyenkasi", which is the dried form of okra. Traditional sun drying, milling/powdering, slicing and roasting were the most observed processing practices of the commodity in the rural dwellers. These processing methods 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 the nutrient 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 infection in processed okra fruits [38]. Therefore, it is imperative to explore the effect processing on nutritional value and microbial characteristics of okra fruits to improve health benefits of consuming okra fruits and increase profitability of the sales of okra fruits.

## **II. 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 7° 20'N and 7° 05'N and longitudes 20° 30'W and 20° 10'W with altitudes of 229 – 376m above sea level [39]. 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 which support agricultural production in the Municipality [40].

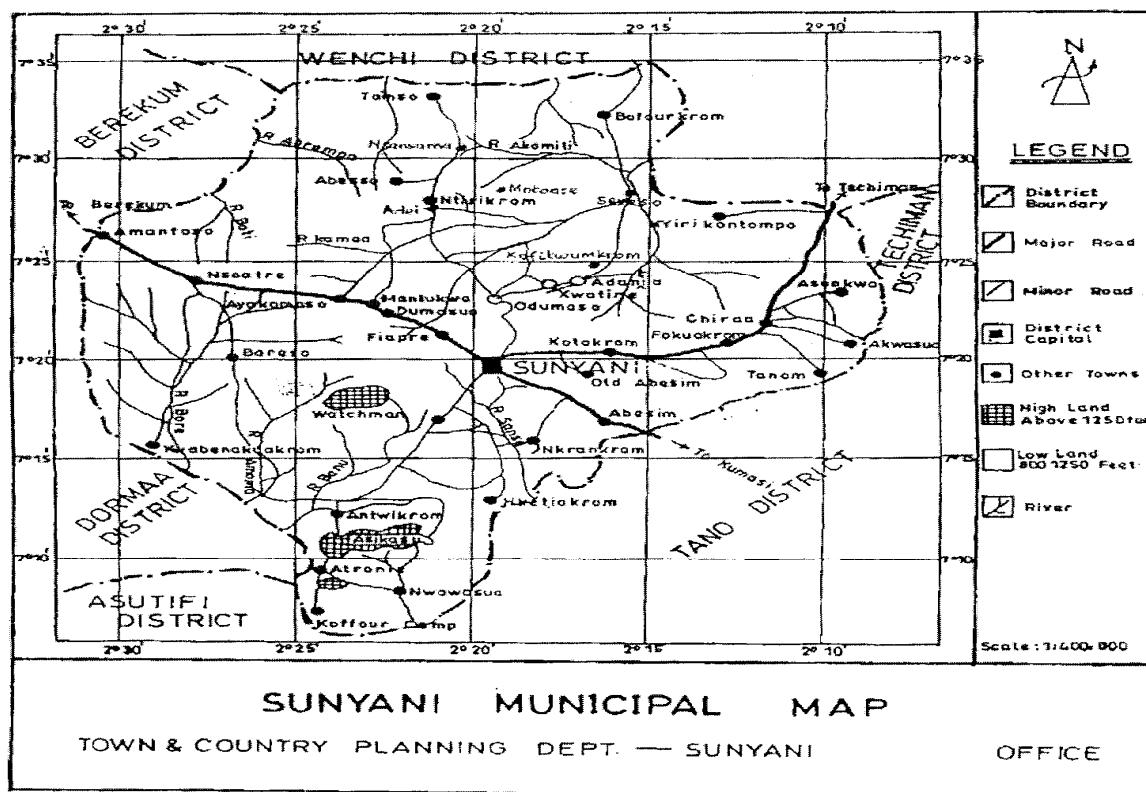


Figure 1 Map of Sunyani Municipality

## 2.2 Methods 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 Agriculture, and the Ministry of Food and Agriculture (MoFA) on which communities were involved in okra cultivation and processing. Stratified sampling was used to select farmers in five (5) communities (Abesim, Atronie, Benu Nkwanta, Ayakomasu and Wawasua). Semi-structured questionnaires were used with fifty (50) okra farmers, thirty – five (35) traders who bought their produce from farmers directly and Twenty-five (25) consumers who ate okra at least thrice a week were selected for the study. In order to ensure accuracy in their responses, respondents 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 for laboratory analysis**

### **2.3.1. Okra sample 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**

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 community 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 (2 cm) using kitchen knife, spread on black polythene sheet and allowed to sundried the cut okra fruits for two (2) weeks in each respective community. In case of pounding, the whole fresh okra fruits were spread on black polythene sheet and allowed to sundried for two (2) weeks in each respective community. 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 for collection of okra samples for laboratory procedures**

The processed okra fruits were carried - out by selected farmers, traders and consumers in each selected community. Randomized Complete Block Design (RCBD) with four (4) treatments (control, sliced, pounded and roasted) was used to collect samples for laboratory analysis. The experiment was blocked five (5) times. Samples were put in zip bags 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 analysis**

Survey data obtained from farmers, traders and consumers using the questionnaires were analyzed by using the statistical package for social scientist (SPSS) version 21 and results were expressed using tables, frequencies, percentages and chart. Data collected from the laboratory 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.

### **III. RESULTS AND DISCUSSION**

#### **3.1 Okra varieties cultivated, sold and consumed by respondents.**

Figure 2 revealed that, most of the farmers (68%) cultivated Asutem variety followed by lady finger (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 was Asutem. Therefore, plant breeders could investigate to improve Asutem variety of okra for easy cultivation such as reduced the long period of maturation of Asutem, drought tolerant Asutem, diseases and pest resistance Asutem in order to reduce difficulties in production of Asutem and encourage more Ghanaians to engage in the production of Asutem to reduce unemployment 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 currently 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 serve 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]

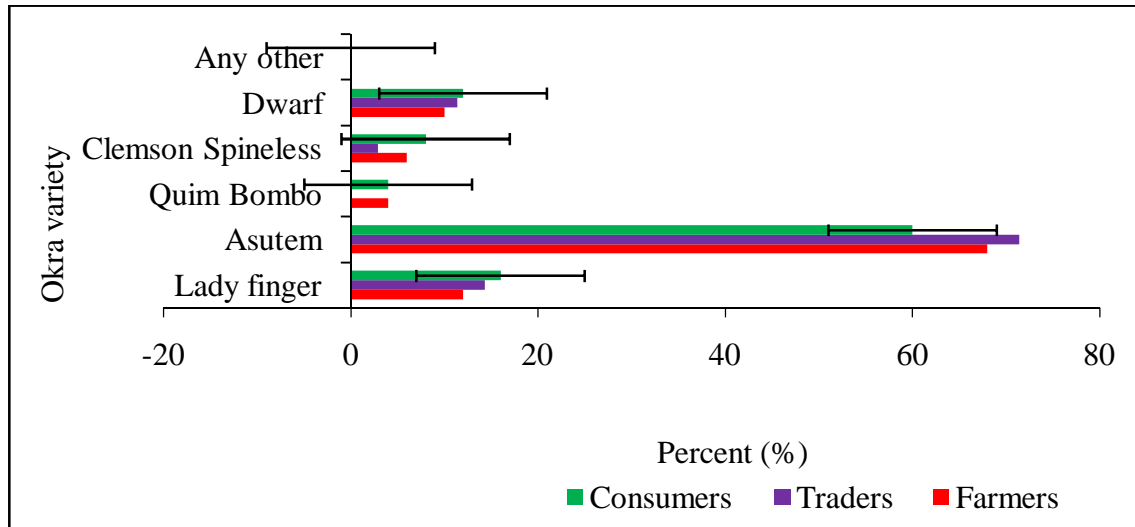


Figure 2. Okra varieties cultivated, sold and consumed by respondents.

### 3.2. Months of bumper harvest, decline in sales and cheap purchasing of okra by respondents.

Table 1 revealed that, majority of the Farmers (50%) had a bumper harvest between the months of July and September while 30% had theirs between April to June. Majority of the Traders (37.1%) experienced a decline in sales of the produce between July to September and 34.3% of traders between April and 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 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 Ghana government 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 thus import driven economy [46]. Again, traders experience low sales of okra mostly in the months of July – September. This suggest that, traders lose money to be used to take care of their children, pay taxes, utility bills (electricity, water), therefore, Ministry of Food and Agriculture (MoFA) and research institutions can investigate the best techniques to preserve okra for long period of time for traders to sell the okra when they are scarce and more appealing to consumers to improve their profit in okra business and not to lose more money in July to September. Ministry of Agriculture is mandated to improve the growth of incomes [47]. Again, most consumers bought cheap okra mostly from July to September which is an indication of sufficiency or availability and easy access of okra 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].

Table 1. Months of bumper harvest, decline in sales and cheap purchasing of 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 |

### 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 the consumers (40%) used roasting to process their okra but 28% of consumers used pounded/milled to process their okra fruits. This showed that, majority of farmers used pounding or milling technique (wooden pestle and mortar) to transform okra which is less expensive for use. However, since it involves physical activity small quantity of okra could be processed. Most of harvested products may not be processed and go waste [49]. Majority of traders used sliced method which reduced the size of okra for more okra to be preserved. However, the slicing technique of okra exposes okra to pathogenic infection. Slicing technique pre – disposes okra to contamination of micro – organisms [50]. Majority of consumers of okra 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].

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 |

### **3.4. Effect of processing techniques on nutritional qualities of okra fruits**

Proximate analysis was conducted to determine the effect of processing methods on the nutritional quality of okra and the results are 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. Control recorded the highest amount of moisture (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, lubricate and cushion joints, protect spinal cord and get rid of wastes through urination [53].

#### **b. Fat content**

Fat content was significantly ( $P < 0.05$ ) highest in the Control (1.75 %) was high among the processing methods while Roasted recorded least amount of fat (1.35 %). Fat gives energy to the body, protects organs, support 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 %) amount of fiber among the processing methods which was followed by the Control (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 contents followed a similar trend as the fiber contents with the Sliced significantly ( $P < 0.05$ ) recording the highest (9.7 %) with the least (7.31%) recorded in roasted. Ash reduces grout, fever, arthritis, bladder problems, constipation and increase urine production to relieve water retention (as a diuretic) [56].

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

| Processing method | Moisture        | Fat    | Fiber   | Ash    | Protein | Carbohydrate | Calcium |
|-------------------|-----------------|--------|---------|--------|---------|--------------|---------|
|                   | _____ (%) _____ |        |         |        |         |              |         |
| Control           | 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)

#### e. Protein content

The Control significantly ( $P < 0.05$ ) recorded the highest amount of protein (16.94 %) among the processing methods followed by the Roasted (15.49 %). A similar no significant difference ( $P > 0.05$ ) amount of protein was produced by the 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 %), Control (44.49 %) and Pounded recorded the least (44.12 %). Carbohydrate is the primary source of energy for the body and the brain [58].

#### 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 control and pounded fruits (Table 3) which also happen to be the least amount of calcium 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 numbers of fungi among all the processing methods (4.90, 5.41 and 4.36 log<sub>10</sub> CFU/g for *Aspergillus flavus*, *Penicillium digitatum* and *Penicillium spp.*, respectively). However, Roasted recorded the least numbers in all the four fungal species

that were identified which were significantly ( $P < 0.05$ ) lower than the numbers observed in the Control which were presented in table 4. The data suggested that, Roasted recorded lowest fungi contamination. This could be the application of heat during roasting of okra. Most yeast and moulds are heat sensitive and are destroyed by heat treatment at temperatures of 60 – 71<sup>0</sup> C [60].

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

| Processing method | <i>A. flavus</i> <i>A. niger</i> <i>P. digitatum</i> <i>Penecillium spp</i> |        |        |        |
|-------------------|---|--------|--------|--------|
|                   | (log10 CFU/g)   |        |        |        |
| Control           | 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). Control and Pounded (Table 5) which also happen to be the least amounts of calcium recorded.

Table 5. Effect of processing methods on microbial growth

| Processing method | <i>A. flavus</i> <i>A. niger</i> <i>P. digitatum</i> <i>Penecillium spp</i> |        |        |        |
|-------------------|---|--------|--------|--------|
|                   | (log10 CFU/g)   |        |        |        |
| Control           | 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   |

#### IV. CONCLUSION

The most cultivated, sold and consumed variety of okra was Asuntem, hence, plant breeders can further study Asutem variety of okra to improve difficulty in cultivating Asutem variety of okra such as reduction of long period of maturation of Asutem (3 – 4 months), drought tolerant Asutem, disease and pests resistance Asutem to encourage more Ghanaians to engage in Asutem production to reduce 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 since it is the variety that is most available for use.

Bumper harvesting of okra by farmers in the study area was mostly done in the months of July and September so government should intensify its policy implementation of One District One Factory to benefit the Study area to reduce postharvest loss of okra in the study area in order to achieve the aim of One District One Factory policy of reducing import dependency economy of Ghana. Furthermore, traders experienced decline of sales mostly in the months of July to September, therefore, Ministry of Agriculture (MoFA) and the research institutions could investigate to identify the best preservative methods to extend the shelf – life of okra to make okra available in the lean season and attractive to consumers to make okra 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 from July to September which also indicated that, okra is available and easily accessible to consumers for consumption to reduce health conditions such as cancer, diabetes, stroke and heart diseases to get healthy citizens to help develop the country. Also, to reduce the huge money used in importing drugs and machines to treat ailments such as cancer, diabetes, stroke and heart conditions which can 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 mostly used by farmers demonstrated that, they used physical means (wooden pestle and mortar) to process okra and it is less expensive, however, the physical pounding of okra would make them tired easily and so they cannot process more of harvested okra and the unprocessed okra would deteriorate. Again, most traders used slicing method which showed that, more okra could be reduced into small sizes for easy handling of okra but okra fruits are pre – disposed to microbial infection. In addition, roasted method mostly used by consumers improves flavour of okra. 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 quality, fiber, ash and calcium contents (18.47 %, 9.7 % and 0.43 %) were higher in slicing than the other processing methods. Consumption of sliced okra will prevent constipation, helps to maintain healthy weight, reduce risk of diabetes, heart diseases, grout, arthritis, bladder problems, increases urine production and reduces some types of cancers. Again, consumption of sliced okra would enhance healthy formation of bones and teeth, improve blood clotting, muscle contraction and regulates normal heart rhythms and nerve functions. However, carbohydrate content (48.34 %) was higher in roasting, hence, provides energy for the body and the brain.

Microbial contaminations were lower (1.24, 0.83, 1.73 and 0.66 log<sub>10</sub> CFU/g of *Aspergillus flavus*, *Aspergillus niger*, *Penicillium digitatum* and *Penicillium spp*, respectively) in roasted okra and okra processing method compared to the control okra which had not been processed (3.73, 2.50, 2.26 and 3.51 log<sub>10</sub> CFU/g of *Aspergillus flavus*, *Aspergillus niger*, *Penicillium digitatum* and *Penicillium spp*, respectively). The reduction of microbes in roasted okra could be the application of heat during roasting of okra destroyed most of the microbes. Again, consumption of roasted okra could reduce the risk of disease infections caused by microbes.

#### **IV.RECOMMENDATIONS**

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

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