Original Research Article

EXPLORING THE EFFECTS OF POST-HARVEST PROCESSING OF OKRA FRUITS ON THEIR NUTRITIONAL CHARACTERISTICS

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ABSTRACT

The study involved both field survey and laboratory work among Five (5)okra-producing communities within the Sunyani Municipality Ghana, namely; Abesim, Atronie, BenuNkwanta, 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 (110) respondents. Questionnaire, interview and observation were instruments used. 4×3 factorial design in Randomized Complete Block Design (RCBD) with twelve (12) treatments (four (4) levels of processing and three (3) levels of storage methods) with five (5) replications was used to obtain data for laboratory analysis.The processing methods of okra identifiedwere slicing and sun drying, pounding/milling and roasting and the storage methods were clay containers, glass bottle containers and polythene bags. Moisture, fibre, ash and calcium contents (12.05 %, 18.47 %, 9.7 % and 0.43 %) were higher in slicing, protein and carbohydrate contents (15.49 % and 48.34 %) were higher in roasting. Microbial contaminations were lowest (1.24, 0.83, 1.73 and 0.66 log10 CFU/g of Aspergillusflavus, Aspergillusniger, P. digitatumand Penicilliumspp, respectively) in roasted okra. Moisture, fat, fibre, ash, protein and carbohydrate contents were highest (13.62 %, 1.75 %, 18.55 %, 8.69 %, 15.91 % and 46.77 %, respectively) in okra stored in glass bottle containers. However, microbial contamination was found to be lowest (3.21,1.91,2.68 and 2.55 log10 CFU/g of Aspergillusflavus, Aspergillusniger, Penicilliumdigitatum and Penicilliumspp respectively) in okra stored in clay containers.

Keywords:okra fruit,okra processing, microbial contamination, Sunyani, Ghana

I. INTRODUCTION is very more abbreviatedto one paragraph

Okra (Abelmoschusesculentus) is a vegetable belonging to the family of Malvaceae[1]. It 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 [2]. In Ghana, total annual production of okra is about 63,860 tons. The largest producing regions include BrongAhafo, Western, Ashanti, Greater Accra, Northern and Volta [3].Okra thrives in warm weather which requires evenly distributed annual rainfall of 1000mm and temperatures between 25 – 350C.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 [3]. This is where okra is abundant and cheap which affects product pricing and discourages farmers from expanding their farms [4]. In Ghana, okra is consumed in diverse ways. They are used to prepare varieties of dishes such as stews and soups [5]. They are consumed in immature stage to provide health benefits such as prevention of constipation because pods contain mucilaginous substancesand high dietary ~~fibre~~fiber which serve as natural laxatives. They have high antioxidantlevels, 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 [6]. [7] revealed that 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 percent of the world's vegetable losses. These ~~post-~~postharvest losses have been linked to lack of knowledge, techniques in handling the crops, storage facilities, processing of the produce, adverse climatic conditions combined with perishable nature of vegetables, which had a great impact on reducing profitability and efficiency of the supply chain.According to [8], vegetables are susceptible to nutritional loss, especially vitamins after harvest and during processing, storage and cooking. The vitamins specifically ascorbic acid and vitamin A are soluble in water and sensitive to heat, light and oxygen. Traditional sun drying is the cheapest and most accessible vegetable preservation in developing countries, causing considerable destruction of nutrients and bioactive compounds particularly during storage of dried product. [9] revealed that mould and other spoilage organisms can grow on partly dried processing and storage methods of 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, which is potent natural carcinogen.The surplus from production of okra are processed into many forms called locally as ''kyenkasi'', which is the dried form of okra. They are stored in different forms such as polybags/containers, clay containers, metal containers, refrigerators and rubber containers for future use [10].Traditional sun drying, milling/powdering, slicing and roasting and the use of glass bottle containers, clay containers, metal containers, polybags/container gourds were the most observed processing and storage practices of the commodity. These processing and storage methods may cause substantial nutritional loss and influence mould growth by exposing the tender crop to relative heat and destroying bioactive compounds, especially during storage, which they presume to be the effective ways of preserving and retaining the nutrient or health benefits of the commodity. In addition, they also think the processing and storage methods used are not contaminated by mould growth on okra fruits. The study explored the effects on nutritional quality of the processing methods used by producers, traders and consumers in okra production in Sunyani Municipality.

~~**1.1 Okra production in Ghana**~~

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The average yield of okra is between 1.5 to 4.5 tons/ha [11]. The largest producing regions include Brong Ahafo, Western, Ashanti, Greater Accra, Northern and Volta [3]. Despite its importance, the crop, like all other fresh vegetables, has a problem of short shelf-life. The fresh fruits remain in usable quality for eight to ten days if held at 0-10°C at 90% relative humidity [12]. Those held at 2-13°C lasted for only four to six days and deteriorated rapidly on exposure to higher temperatures (20-26°C) [13]. Large quantities of okra fruits produced during the main production season are usually left to deteriorate, as they cannot be kept longer. Producers are forced under the circumstances to give their commodities out at "take-away" prices. In certain situations, market women have no alternative than to throw away the okra fruits in the market. Many growers depend mostly on daily sales for their income and hence are forced to accept a lower price under such situations of glut [14].

1.2 Uses of okra

[15] reported that, due to the numerous uses of the fresh leaves, buds, flowers, pods, stems and seeds of Okra are considered a multi-purpose crop. The immature fruits (green seed pods) of okra, are used in salads, soups and stews, fresh or dried, roasted or boiled [16]. Mostly to increase the consistency in different recipes like stews, soups and sauces the extract obtained from okra is added. In Egypt, Lebanon, Iran, Greece, Jordan, Turkey, Israel, Iraq and other parts of the eastern Mediterranean, okra is commonly used in thick stew made with meat and vegetables. In Indian cooking, it is added to gravy based preparations. The immature pods are also used in making pickles. The entire plant is edible and is used to have several foods [17] [18].Okra seeds are a source of oil and protein. Okra seeds have been used on a small scale for oil production. It can also be used as non-caffeinated substitute for coffee. Okra seeds may be roasted and ground to form a caffeine-free substitute for coffee [19].

1.3 Nutritional composition of okra

Okra is a repository of valuable nutrients [20]. It is less of a staple than diet food [21]. Okra is consumed in immature stage to provide health benefits such as prevention of constipation because pods contain mucilaginous substances and high dietary fibre 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 [6]. Okra seed oil is important for human nutrition since is a rich source of polyunsaturated fatty acid and linoleic acid [22].Because of the dietary fibrefiber, 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" [23]. The composition of the amino acids of okra seed protein is similar to that of soybean [24] which makes it a suitable complement to cereal-based diets [25]. Okra plays an important role in human diet [26] [27] since it also contains vitamins and carbohydrates [28] [29] [30]. Carbohydrates are mostly in the form of mucilage [31] [32]. 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 [33]. Practically fresh pods contain no fat, low in calories (20 per 100 g), are high in ~~fibre~~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) [33].

1.4 Post-harvest quality

Quality according to [35] is the totality of features and characteristics of a product that bear on its ability to satisfy stated or implied needs. Quality after harvest entails nutritional quality, transport quality, edible quality, internal quality, table quality, market quality and appearance quality. Consumers consider good quality with respect to color, flavor and nutrition. Researchers like [36] and[36] have reported that, 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 during storage 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.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 [36]. Depending on the crop, losses are estimated at 20-40% in developing countries and 10-15% in developed countries. [37] estimated that, about half of the losses are due to physical injuries and improper handling during storage and distribution. According to [38], the per cent loss of vegetable crops in Ghana was estimated at 20% with most losses occurring during harvesting, transportation, storage and grading and sorting. However, quality isone 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.

1.5 Effect of Processing on Nutritional and Microbial Qualities of Okra

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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 of food 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) [39]. 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 [40].

1.6 Effect of processing on the nutritional quality of okra

[39] worked on effect of processing methods on selected physical and chemical properties of okra. 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 fibre 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 physio-chemical properties of okra are significantly affected by processing methods ($P<0.05$).A study conducted by [41] on the effect of drying methods and storage on the physio-chemical properties of okra also showed that moisture content was reduced by drying which corresponded to increased protein, dry matter

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content, minerals (Zn, Ca, Mg and Fe) and ash in okra. Oven-dried okra samples stored in an air-tight container in a cool dry dark place kept the physio-chemical properties of the other treated samples.

1.7 Effect of processing on microbial quality of okra

As the other green vegetable, okra is perishable. So, the common conservation method used is drying. This process allows people to make okra more durable and preserve them for food insecure periods [42].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 [43]. 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 [44]. In these conditions, dried okra is exposed to microbiological contamination [45]. The incriminated germs (eg. yeasts and moulds) may be already present on fresh okra or could appear during the drying process if it is made under unhygienic conditions. Moreover, if dried okra is stored in dusty humidity weather, many microbes, especially fungi, can grow and secrete toxic substances which can induce hazardous risks to human health [46]. In fact, mycotoxins and fungal contamination indried vegetables have been investigated by some authors. [46] revealed the presence of moulds and their toxins in sundried okra on markets after 22 weeks of conservation. Similarly, [47] showed that a load of moulds was very high in dried okra and dried hot chilli. [48] reported that microbial load in fresh okra decreased after the drying process and explained that, it could be due to the water activity declining which results from the loss of humidity in samples, causing the inhibition of microbial growth [49].

1.8 Proximate Analysis

Proximate and nutrient analysis entails moisture, crude fibre, fat, crude protein, ash, carbohydrate, and mineral contents.

a. Moisture content

The measure of the water content of a material is moisture and is an important factor in food quality preservation and resistance to deterioration[50]. It is of great importance for many scientific, technical and economic reasons. Moisture content must be known in determining the nutritive value of food, in expressing results of analytical determinations on a uniform basis, and in meeting compositional standards. Products with relatively low moisture content should have good storage properties [51]. It, therefore, follows that the lower the moisture content of a product, the longer the shelf life of the product.

b. Fat content

[52] reported that fats and oils are commercially vital categorized substances grouped as lipids. They are vital in the human diet and above 90 % is used as a food ingredient. Usually are responsible for increased food palatability by retaining flavoursresulting in satiety due to sluggish digestion. In the body, with the exception of the nervous system and erythrocytes, the source of energy for all cells is fatty acids. Derivatives of these acids such as ketones in the body become of use during starvation by the brain. The absorption and transportation of fat-soluble vitamins is facilitated by dietary fats. [53] reportedthat these are concentrations of energy source

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with 9kCal per gram, which is twice the amount available from an equal mass of proteins and carbohydrates.

c. Fibre content

Theoretically, crude fibre includes materials that are not digestible in human and animal organisms. According to [49], crude fibre is assessed by measuring the amount of indigestible cellulose, pentosans, lignin, polysaccharides, oligosaccharides and associated plant substances. These fibres protect the body against colon cancer, diabetes and cardiovascular illnesses [54]. Dietary fibre is typical plant cell wall materials that are not digested by endogenous enzymes [55]. It is a challenge to exactly define dietary fibre. Fibre has historically been explained as the balance between nutritional significance and availability of adequate analytical methods, thus adapting the definition to the analytical procedure instead of the physiological effect of the fibre fractions. Insoluble dietary fibre is not degraded by microbial fermentation and could increase faecal output. Crude fibre can be calculated based on the loss on ignition of the dried residue remaining after digestion of the samples with 1.25 % sulphuric acid and 1.25 % sodium hydroxide solutions (AOAC, 1984). According to [28] 100g of edible portion of maize recorded 2.7g after loss of ignition of the dried maize sample.

d.a. Crude protein

Protein is the main structural and functional constituent of all cells. Additionally, the component of protein (amino acids) acts as precursors of several nucleic acids, hormones, coenzymes, and other molecules vital for life. Thus, the provision of sufficient dietary protein is important to keep cellular function, reproduction and integrity. Proteins should be supplied in terms of both quantity and quality. The quality refers to the amino acid component [56]. The idea of protein needs includes both total nitrogen and essential amino acid provisions. The utilization and amount of essential amino acids are considered to be an indicator of dietary protein quality, which is generally measured using the Protein Digestibility Corrected Amino Acid Score (PD-CAAS).

e. Carbohydrates

The primary carbohydrate in diets worldwide is starch; it is the stored carbohydrate of plants such as root vegetables, cereals and legumes and consists of only glucose molecules [57]. Carbohydrates have been separated into three major categories based on digestion; rapidly digestible, slowly digestible, and resistant [57]. Carbohydratesthat are rapidly digested take about 20 minutes to digest while carbohydrates that are lowly digested could take between 20 and 120 minutes [58]. Resistant carbohydrates, such as some legumes, consist of those that are not digested or absorbed in the small intestines [58].Carbohydrates play an important role in the metabolic processes of living organisms. They serve as energy sources and as structural elements in living cells. The major function of carbohydrates is to provide energy and act as a source of fuel to the working body [59]. Living cells are in active state constantly. To retain its "life," each cell relies on highly coordinated biochemical reactions which are driven by carbohydrates. Therefore, a carbohydrate that has the ability to provide sustained energy and maintain blood glucose might be ideal.The main energy nutrients found in rations are carbohydrates [60]. They are major constituent of vegetable food materials on dry matter basis and by far the biggest constituent of the food of domestic animals. Very little of it is found in the animal body. Carbohydrate is the most abundant form of energy in plant materials and, as such, is the most widely available source of energy [61]. According to [56], the carbohydrate content of a ration makes up the largest, although not all energy requirements. Some energy is derived from fats and oils in some instances from protein. All carbohydrates have about the same gross energy content of about 17.5 MJ/Kg DM [62]. The foods rich in starch and sugars (carbohydrate sources) are tubers and roots (e.g. cassava) and cereals (e.g. maize, sorghum, and millet).In general, carbohydrates cannot be absorbed naturally and must be digested to become useful [63]. Carbohydrate properties, such as digestion and absorption rate, viscosity, structural features, water-binding capacity and fermentation ability in the gastrointestinal tract, are of vital importance for their nutritional effects [63]. The basic process in carbohydrate digestion is considered to be hydrolysis [63]. Majority of carbohydrates in the diet are polysaccharides and disaccharides [63]. Through the process of hydrolysis, these larger carbohydrates are broken down into the smaller final product, monosaccharides for absorption into the bloodstream [63].

f. Ash and Minerals

The quantity of mineral matter which after combustion remains as incombustible residue of the tested substance is termed ash [64]. The ash component is a quantity of the total amount of minerals present within a food, whereas the mineral component is an estimate of the quantity of specific inorganic content within a food, such as Na, K, Ca and Cl [63]. The ash parts consist of sodium, calcium, potassium and magnesium, which are available in larger quantities as well as smaller amounts of iron, copper, aluminium, manganese or arsenic, iodine, zinc, fluorine and other trace elements. There are two forms of minerals: macro and trace minerals. Macro means "large" and implies that they are required in larger quantities for body needs as compared to trace minerals. Examples of macro minerals are i.e. calcium, phosphorus, magnesium, sodium, potassium, chloride, and sulfur. The mineral composition may be affected by the environment and area locations [65].It is often vital to know the mineral content of foods during processing because this affects the physio-chemical properties of foods [64]. Minerals act as co-factors for many biological reactions within the body, including muscle contraction, neuro transmission, production of hormones, digestion and utilization of nutrients [67]. The minerals regulate acid-base equilibrium, responsible for maintenance of colloidal systems, skeletal formation and compounds that are vital biologically. Deficiencies in mineral could result in structural, functional and biochemical pathologies which relies on a number of factors, such as the length and degree of mineral deficiency. physiologically mineral importance for humans and some animals are well documented. Nonetheless, several aspects of function, bioavailability and intake of trace minerals are still uncertain.

g. Calcium (Ca)

Calcium is utilized in large quantities by plants following N and K. It is a main constituent of the middle lamella (Ca-pectates) of the cell wall. It is involved in strengthening the cell walls, cell division and elongation, activation of a number of critical enzymes and membrane permeability

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~~[66]. According to its functions, calcium has an effect on the quality of crops and food. Less mobility of calcium makes its effect on crop quality easily noted with foliar application. Nutritionally, it ensures proper muscle action, a regular heartbeat and a steady concentration of ions both inside and outside body cells. It is also involved in blood clotting [68].~~

II. RESEARCH METHOD

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 altitudesof 229 – 376m above sea level. [68]. The main rainy season is between March and September, with minor rainy seasons between October and December. This offers the municipality two farming seasons in a year which support agricultural production in the Municipality [70].

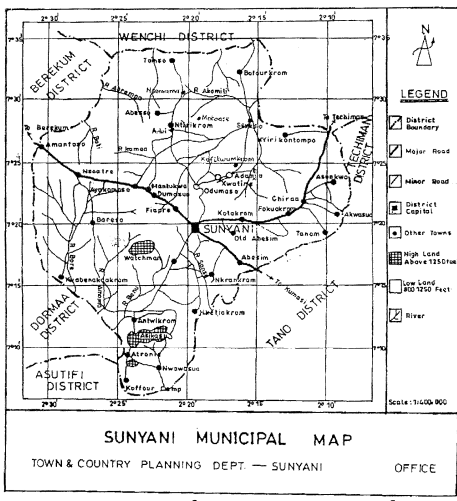

Figure 1 Map of Sunyani Municipality

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 Agriculture, and the Ministry of Food and Agriculture (MoFA) on which communities were involved in okra cultivation, processing and storage.Stratified sampling was used to select farmers in five (5) communities(Abesim, Atronie, BenuNkwanta, Ayakomasu and Wawasua).Individual interviewsand group discussions using semi-structured questionnaireswere conducted with Fifty (50) okra farmers, thirty – five (35) traderswho bought their produce from farmers directly and Twenty-five (25) consumers who ate okra at least thrice a week in the Sunyani Municipality. 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. The processed and stored okra samples carried out by farmers, traders and consumers plus control were transported to the Crops and Soil Science Department, KNUST within three (3) hours.A 4 × 3 factorial experimental design in Randomized Complete Block Design (RCBD) with twelve (12) treatments (four (4) levels of processing and three (3) levels of storage methods) replicated five (5) times was used. The levels of storage were Clay, Glass bottles and Polythene and the processing was Controlled, Roasted, Sliced and Pounded.The nutrition and mould growth contamination analysis of the various identified processed and stored samples was carried out at the Crops and Soil Science Department, Laboratory, KNUST. Procedures of AOAC (1990) were used to determine the proximate and mineral composition of processed okra. The following tests were conducted: Moisture content determination, Crude protein determination, Crude fat content determination, Crude fibre determination, Ash content determination, Carbohydrate content determination, Determination of mineral elements and the Determination of mould growth contamination. The following parameters were measured using standard protocols: Crude protein, Carbohydrate, crude fibre, crude ash, crude fat, calcium and mould growth contamination.Data obtained from farmers, traders and consumers using the questionnaires were analyzed by using the statistical package for social scientist (SPSS) version 20 and results were expressed using tables, frequencies, percentages and graphs.Data collected from the laboratory were subjected to analysis of variance (ANOVA) using Student Edition of Statistics 9.0. 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%).

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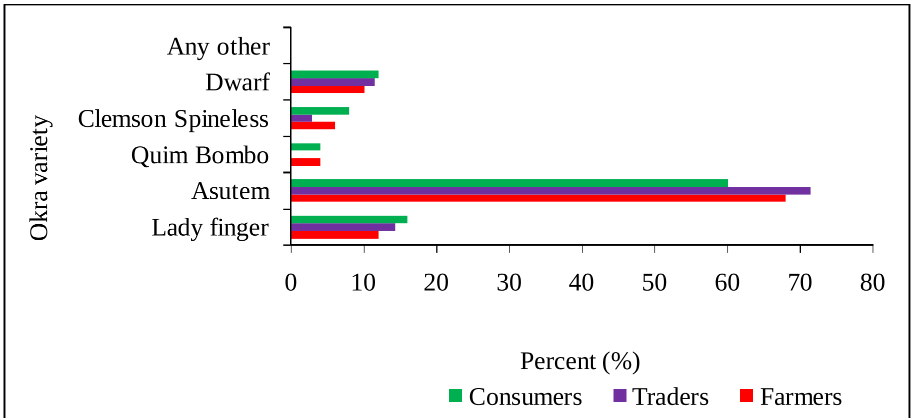

Figure 2. Okra varieties cultivated, sold and consumed by respondents.

Sources of planting materials for farmers

From Figure 3, it was observed that most of the farmers (44%) obtained their planting materials from their friends, 26% farmers from family members, 16% of farmers obtained from the market (Agro – chemical shop) and 14% farmers obtained from MoFA.

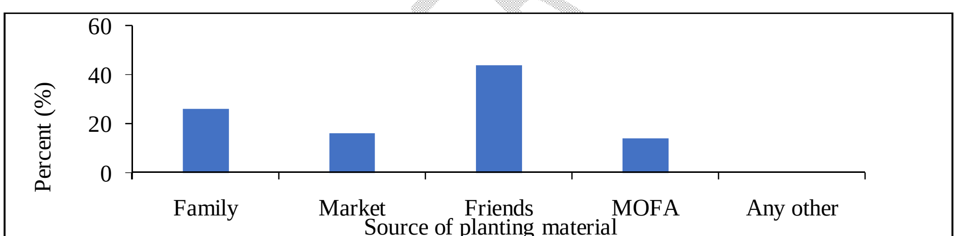

Figure 3 Source of planting materials for farmers

Harvesting, Post-Harvest Processing and its Effect on Nutritional Quality and Microbial Contamination on Okra

Figure 4 showed that 80% of farmers harvested mature okra fruits from their farms with their hands by twisting the okra fruits whiles 20% of farmers harvested mature okra fruits from their farms with the help of a simple machine (Knife).

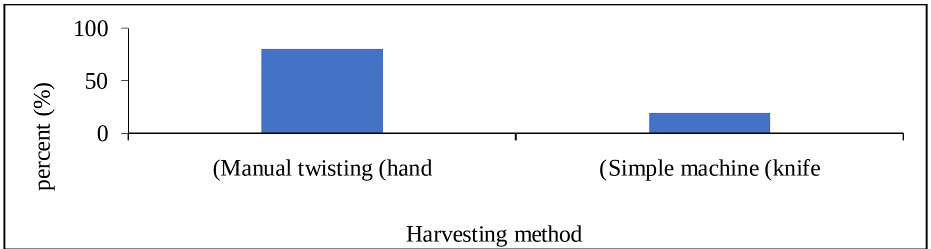

Figure 4Harvesting of mature okra fruits by farmers

Months of bumper harvest, decline in sales and cheap purchasing of the produce byrespondents.

Table 1 revealed that the 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. The 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.

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

Month	Farmers Frequency	%	Traders Frequency	%	Consumers 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

Post-harvest processing of okra fruits by respondents.

From Figure 5, majority of respondents processed their okra fruits, 80 % of farmers confirmed they processed their produce after bumper harvest while 20% of farmers did not. About 85 % of traders processed okra fruits for sales during bumper seasons and 14.3% did not. Majority of the consumers (68%) also indicated they bought and processed okra during the rainy seasons whiles 32% of consumers did not process okra fruits.

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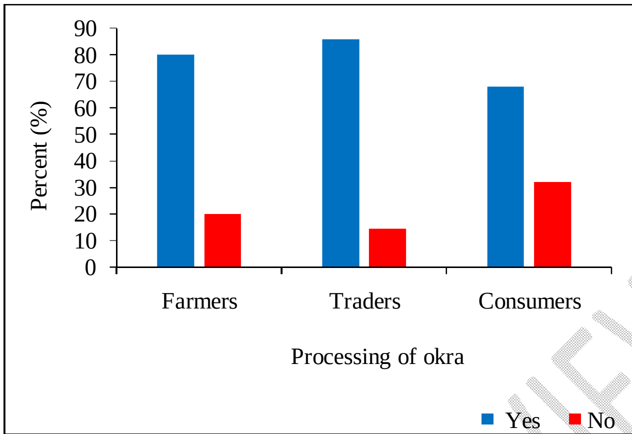

Figure 5 Post-harvest processing of okra fruits by respondents.

Post-harvest methods of processing okra fruits by respondents.

From Table 2, 40% of farmers processed okra fruits by pounding/ milling the dried okra fruits, 36% of farmers used slicing and sun drying the okra fruits, and 24% farmers processed okra fruits by roasting. Majority of the traders (40%) processed okra fruits by slicing and sun drying, 34.3% traders by pounding / milling and 25.7% traders by roasting. The majority of the consumers (40%) roasted their okra, 32% consumers sliced and sun-dried and28% of consumers pounded/milled their okra fruits.

Table 2.Post-harvest methods of processing okra by respondents.

	Farmers		Traders		Consumers	
Processing method	Frequency	%	Frequency	%	Frequency	%
Cooking	0	0	0	0	0	0
Slicing and sun drying	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

Availability of okra processing facilities in the respondents' communities.

Figure 6 revealed that 60% of farmers did not use any okra processing facilities in their communities, but 40% of farmers agreed, there were some privately owned processing facilities which sometimes used in the processing of okra fruits. Traders (70%) stressed that there were inadequate okra processing facilities in their various communities and 28.6% of traders expressed that there were few privately owned processing facilities in their various communities which they sometimes used in processing their okra fruits. Consumers (64%) said there were

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insufficient processing facilities in their various communities whilst 36% of consumers emphasized that there were few okra processing facilities in their communities which they sometimes used in processing okra fruits.

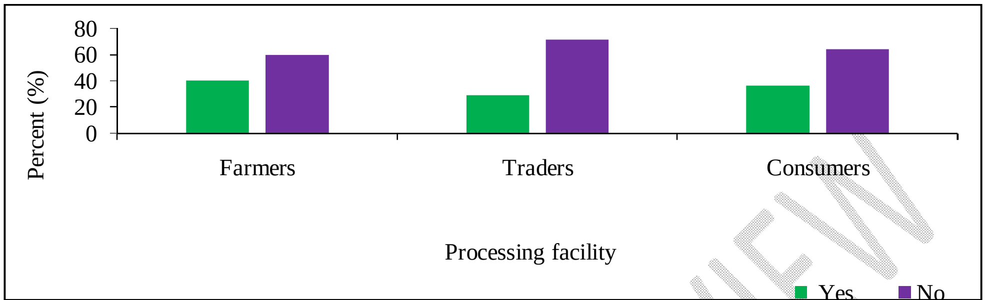

Figure 6 Availability of okra processing facilities in the respondents' communities.

Effect of processing on nutritional quality of okra by respondents.

From Figure 7, 70% of farmers confirmed that processing methods had the same nutritional status and 30% of farmers denied there might be variation in nutrient status of the various processing methods of okra fruits. Majority of the traders (62.9%) also confirmed the processing methods of okra fruits had the same nutritional value whiles 37.1% of traders thought there might be variation in the nutrient status of the various processing methods. About 7 of 6% of consumers agreed that the various processing methods of okra fruits had the same nutritional value but 24% of consumers thought there might be some variations of nutrient status of the various processing methods used in processing okra fruits.

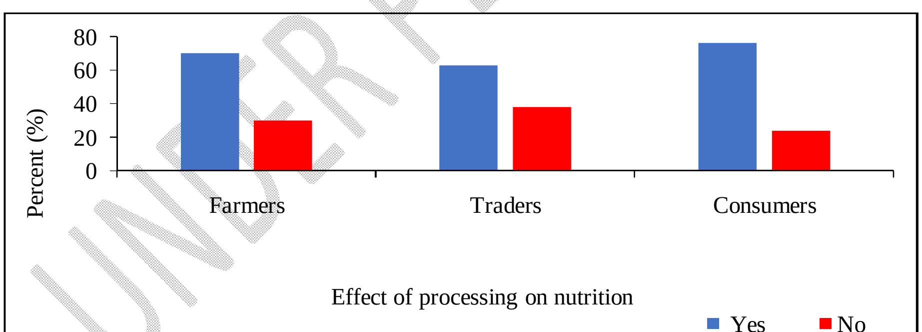

Figure 7 Effect of processing on the nutritional quality of okra

Effect of processing on microbial contamination on okra by respondents.

From Figure 8, 56% of Farmers believed processing had no effect on microbial contamination of okra while 44% of farmers believed there was a microbial effect. Again, majority of the Traders (62.9%) were with the idea that the processing did not induce mould growth but 37.1% of traders believed processing contaminated okra. Similar to the Farmers and Traders, majority of the Consumers (60%) believed processing okra after the harvest had no effect on microbial growth and 40% of consumers believed it had an effect on okra.

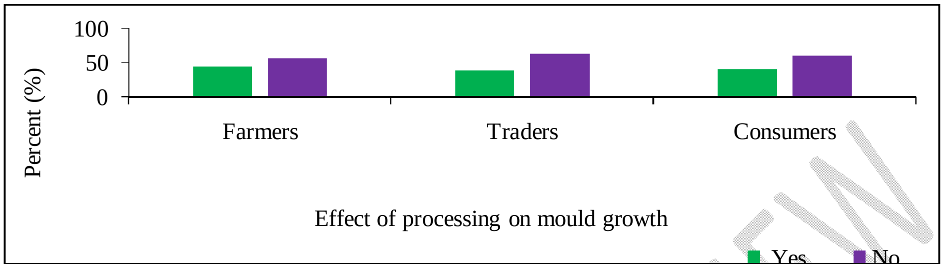

Figure 8 Mould growth contamination after processing

Special training on processing of okra fruits by respondents.

Table 3 revealed that 40% of farmers received special training from family members on how to process okra fruits, 30% of farmers received special training from friends on how to process okra fruits, 20% of farmers received special training from MoFA, 4% of farmers received training from Co–operative Society /Association and 6% farmsreceived special training from N.G.O. Traders (51.4%) received special training from family members on how to process okra fruits, 25.7% traders received special training from friends, 14.3% traders received special training from Okra Traders Association, 8% traders received special training on how to process okra fruits from N.G.O. Consumers (60%) received special training on how to process okra fruits from family members and 40% consumers received special training on how to process okra fruits from friends.

Table 3. Special training received on processing of okra fruits by respondents

	Farmers		Traders		Consumers	
Special training	Frequency	%	Frequency	%	Frequency	%
NGO	3	6	3	8	0	0
Co-operatives	2	4	5	14.3	0	0
Friends	15	30	9	25.7	10	40
MOFA	10	20	0	0	0	0
Family	20	40	18	51.4	15	60
Any other	0	0	0	0	0	0
Total	50	100	35	100	25	100

Harvesting, post-harvest processing and its effect on nutritional quality and microbial contamination on okra

About 80 % of the respondents in the study area used their hands to harvest matured okra due to inadequate facilities for mechanized harvest (Figure 9). This situation may result in drudgery and

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farmers' interest in production in large quantities may be lost as such calls for designing technologies appropriate for harvesting okra. Table 4 showed a clear picture of how supply and demand affect the price of a commodity. Between July and September which happens to be a period of bumper harvest for the farmers (50 %), majority of the Traders (37.1 %) experienced a decline in purchases thereby decreasing the prices of okra and as a result, majority of Consumers (44%) bought okra at cheap prices. There is a negative relationship between supply and price as an increase in supply results in a decrease in the price of okra. This observation confirmed the findings of [14]which stated that many growers rely mostly on day-to-day sales for their income, hence are compelled to take a lower price under such situations of glut.Though majority of the respondents processed their okra fruits after harvesting (Figure 9) with 40 % of the Farmers using pounding/milling, 40 % of the Traders using Slicing and sun drying and 40 % of the Consumers using Roasting to process their okra fruit, there are insufficient mechanized processing facilities in the study area as only 40 %, 28.6 % and 36 % of the Farmers, Traders and Consumers, respectively, confirmed they have access to some privately own processing facilities. This also called for strategies and manufacturing of intermediate technologies for processing okra.Quality after harvest entails nutritional quality, transport quality, edible quality, internal quality, table quality, market quality and appearance quality. Consumers consider good quality with respect to color, flavor and nutrition. The opinions of the respondents in relation to nutritional quality and microbial contamination on okra after processing show that, not only will processing help keep okra for a longer period of time but also the nutritional quality is maintained after processing.

Effect of processing on nutritional value of okra

Proximate analysis was conducted to determine the effect of processing methods on the nutritional quality of okra and the results are presented in Table 4. 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 contents 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 %).

b. Fat content.

Fat content was significantly ($P < 0.05$) highest in the Control (1.75 %) among the processing methods while the Roasted recorded the amount of fat (1.35 %). There was a significant difference between the Sliced and Pounded.

c. Fibre content.

Sliced significantly ($P < 0.05$) produced the highest (18.47 %) amount of fibre among the processing methods which was followed by the Control (16.71 %) while the Roasted recorded the least (14.3 %).

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d. Ash content

The ash contents followed a similar trend as the fibre contents with the Sliced significantly ($P < 0.05$) recording the highest (9.7 %) followed by the Control, Pounded and Roasted in that order (9.3 %, 7.9 % and 7.31%, respectively).

Table 4 Effect of processing methods on nutritional quality of okra

Processing method	Moisture	Fat	Fibre	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 ($P > 0.05$) amount of protein was produced by the Sliced and Pounded methods (14.99 % and 14.98 %, respectively).

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 %).

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

Effect of processing on microbial growth on okra

Four different species of fungi were identified, namely; *Aspergillusniger*, *Aspergillusflavus*, *Penicilliumdigitatum*and *Penicillium spp*. With the exception of the *A. niger*, Sliced, significantly ($P < 0.05$) recorded the largest numbers of fungi among all the processing methods (4.90, 5.41 and 4.36 log10 CFU/g for *A. flavus*, *P. digitatum* and *Penicilliumspp*, 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 (Table 5).

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Table 5. Effect of processing methods on microbial growth

Processing method	*A. flavus*	*A. niger*	*P. digitatum*	*Penecilliumspp*
	(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.

Where the discussion?

IV. CONCLUSION

The various processing methods of okra mostly used by farmers, traders and consumers in the study area were slicing and sun drying, pounding/milling and roasting and the storage methods that were identified in the study area were clay containers, glass bottle containers and polythene bags. Bumper harvesting of okra by farmers in the study area is between the months of July and September which also happen to be a period of decline in the price of okra for the traders and cheaper pricing for the consumers. With regards to nutritional quality, moisture, fibre, ash and calcium contents (12.05 %, 18.47 %, 9.7 % and 0.43 %) were higher in slicing than the other processing methods. However, protein and carbohydrate contents (15.49 % and 48.34 %) were higher in roasting. Microbial contaminations were lower (1.24, 0.83, 1.73 and 0.66 log10 CFU/g of *Aspergillusflavus*, *Aspergillusniger*, *P. digitatum*and*Penicilliumspp*, respectively) in roasted and okra processing method compare to the control okra which has not been processed (3.73,2.50, 2.26 and 3.51 log10 CFU/g of *Aspergillusflavus*, *Aspergillusniger*, *P.digitatum* and *Penicillium*spp, respectively).

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