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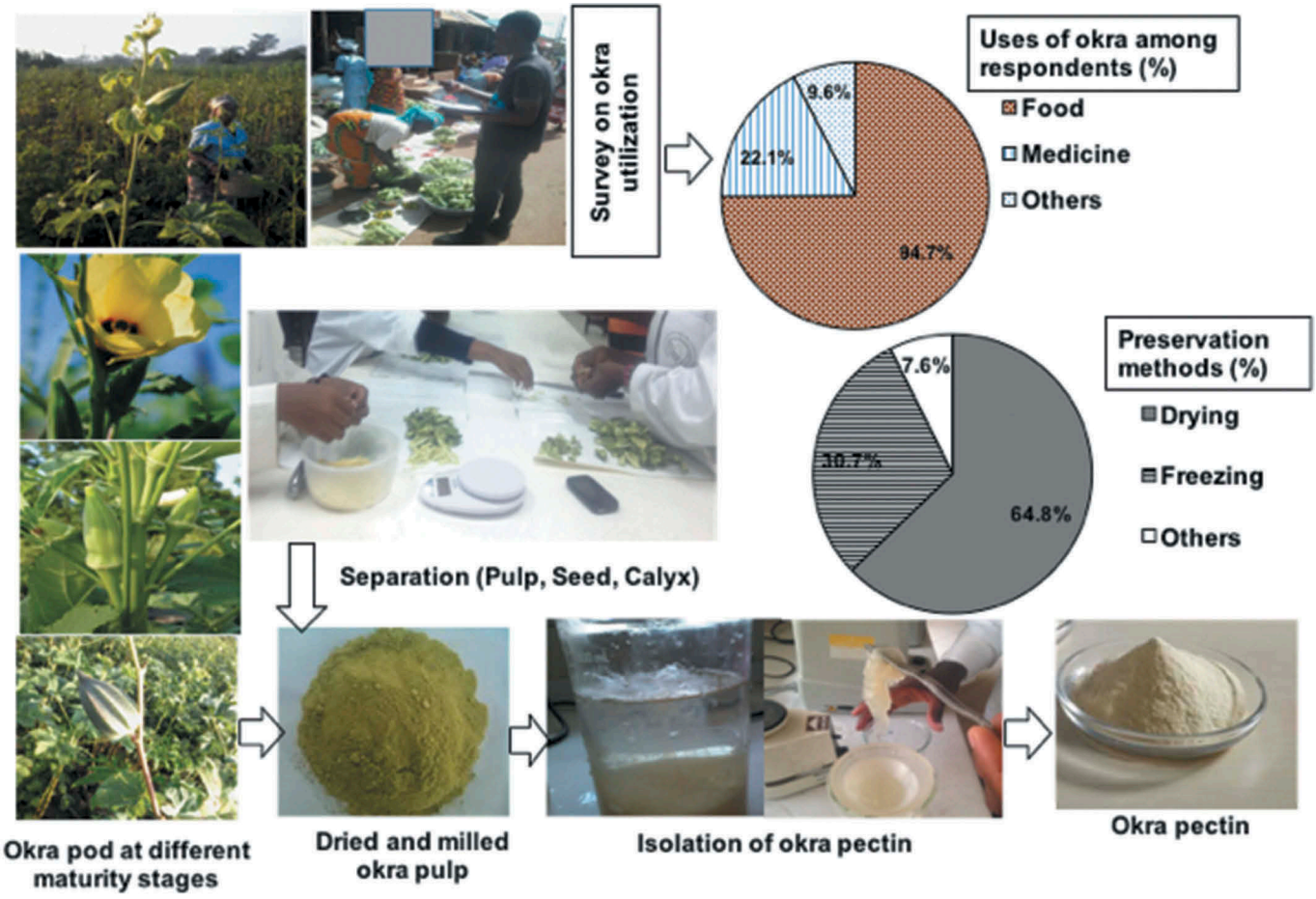

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Jacob K. Agbenorhevi[1]*, Fidelis M. Kpodo[2], Ben K. B. Banful[3], Ibok N. Oduro[1], Vincent Abe-Inge[1], Delight N. Datsomor[1], Juliana Atongo[1] and Beatrice Obeng[1]

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Abstract: Okra (*Abelmoschus esculentus*) is an economically important crop in sub-Saharan Africa. The vegetable is of major technological interest in food and medicinal applications. A survey was conducted by administering structured questionnaires (1560) in major okra-producing regions in Ghana to determine the level of okra utilization and nutritional and medicinal attributes of the crop. The okra pectin yield and intrinsic viscosity at different maturity stages were also investigated. Isolation of okra pectin from the pods at different harvest maturity was performed by aqueous extraction at pH 6.0. The intrinsic viscosity [η] of the okra pectin solutions was determined at 20°C using Ubbelohde capillary viscometer. The survey showed that okra is well known (96.9%) across the country among the various ethnic groups. The majority (94.7%) of the respondents use okra as food, whereas few utilized the crop as medicine (22.1%) and for other applications (9.6%). The respondents widely used okra in the form of soup (73.1%) and stew (68.7%) consumed popularly with *banku* (81.3%) and

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PUBLIC INTEREST STATEMENT

Okra is a common vegetable that could improve food security and livelihood but underutilized. The survey indicated that in Ghana okra has limited use mostly in soup or stew preparation. However, a greater number of the respondents showed interest in diverse utilization of the vegetable for the development of new products to increase production, improve its economic value, reduce postharvest losses and contribute to food security. The mucilage or polysaccharide content known as pectin is responsible for the slimy texture of okra extracts and is of major interest as a functional ingredient for food and pharmaceutical industries. Therefore, the okra pectin extract as influenced by the harvest maturity stage of the okra fruit/pods was studied. The findings show that harvesting at intermediate maturity level would be most suitable to achieve high okra pectin yield.

tuo zaafi (38.8%). The majority of respondents (65.2%) showed interest in the development of new products from okra. Highest pectin yield was obtained for intermediate matured fruits, followed by that of immature fruits and lowest for overgrown fruits. The intrinsic viscosity value, however, was highest for immature fruits. The study showed that okra is mainly used as food among various ethnic groups and that it is important to identify the most appropriate stage of development to harvest the okra fruit. This knowledge would enhance the potential of okra for specific use or functionality.

Keywords: *Abelmoschus esculentus*; mucilage; viscosity; utilization; food security

1. Introduction

Okra (*Abelmoschus esculentus*) is cultivated in the tropical, subtropical and warm temperate regions around the world (Petropoulos et al., 2018). The vegetable is important in the diet of Ghanaians and several African countries. Worldwide production of okra is estimated at over 7 million metric tonnes (MT), whereas that of Ghana is over 60,000 MT (FAOSTAT, 2012). Okra is mostly found in its fresh state in almost all markets in Ghana during the rainy season and in a dehydrated form during the dry season, particularly in Northern Ghana due to its strong commercial value for farmers and women/marketers (Oppong-Sekyere et al., 2012). Although okra is considered a robust crop, under large-scale commercial production, yield losses are very high due to the incidence of a number of biotic and abiotic stresses. Okra has a considerable area under cultivation in Africa and Asia with huge socio-economic potential. In West and Central Africa, okra is called *gombo* (French), *miyangro* (Hausa), *la* (Djerma), *layre* (Fulani), *gan* (Bambara), *kandia* (Mandign), *nkruma* (Akan) and *fetri* (Ewe) and is among the most frequently and popularly consumed traditional vegetables (Ahiakpa et al., 2013; Kumar et al., 2010).

Due to its local consumption and export potential, okra is considered as an important vegetable crop in Ghana. The fruit, leaves and flower buds are eaten as sources of protein, vitamins and minerals. The crop is produced in all the regions of Ghana, but the bulk of the producers come from Brong Ahafo, Northern, Volta, Ashanti and the Greater Accra regions (NARP, 1993). Okra has high economic value and good nutritional and functional properties and can improve food and nutrition security (Kpodo et al., 2018; Kumar et al., 2010). Okra is a multipurpose crop and serves as a source of nutrition, bio-medicine and functional ingredient for the food and pharmaceutical industry (Ghori et al., 2014; Kpodo et al., 2018). The slimy mucilage from okra (referred to as pectin) is of immense technological application in foods as emulsifiers, thickeners and stabilizers (Alba et al., 2015, 2013; Georgiadis et al., 2011; Kontogiorgos et al., 2012; Kpodo et al., 2017, 2018). Okra pectin can potentially replace egg white and fat in chocolate bars or frozen desserts (Romanchik-Cerpovicz et al., 2006) and has been used to strengthen dough used for bakery cakes and cookies due to its unique water-holding capacity and solubility properties (Alamri et al., 2012). The mucilage or pectin from okra has also been widely useful in drug formulations as a thickener, emulsifier, stabilizer, gelling agent, granulating agent, suspending agent, binder, film former and disintergrant and as sustained-release matrix (Ghori et al., 2014, 2017; Sangwan et al., 2011). The preference of natural ingredients from okra over the synthetic in drug formulations is because the plant is readily available, non-toxic, capable of chemical modification, biodegradable and biocompatible (Avachat et al., 2011; Jain et al., 2007; Sangwan et al., 2011).

Regardless of the immense benefits that can accrue to farmers/cultivators and marketers of okra in Ghana, there is limited market value for the vegetable. This is partly due to the limited knowledge of the specific variety/genotype for other food and medicinal uses. Inadequate knowledge of practices to produce varieties and maximize production for specific technological application has led to a situation where Ghanaian farmers are at a disadvantaged position.

Pectin content is influenced by the maturity at which the fruits are harvested since there is lignification of the cell walls during maturation and pods become tough due to thickening of fiber bundles present in the pericarp region (Noorlaila et al., 2015; Sahari et al., 2003; Sreeshma & Nair, 2013). Tough pods have less market value as well as their culinary value since they are not suitable for curry and soup preparation (Chutichudet et al., 2007).

Our previous studies showed that individual okra genotypes provide pectin with different physicochemical properties that could potentially provide a new source of functional pectin for various industrial applications (Datsomor et al., 2019; Kpodo et al., 2017).

The objectives of this study were to assess the knowledge of Ghanaians on the utilization and potential of the okra and also investigate the pectin yield and intrinsic viscosity of the okra pectin extract at different maturity.

2. Materials and methods

2.1. Survey on okra utilization

The survey was conducted in the major okra-producing and consumption regions in Ghana. The selected regions were Northern, Upper East, Eastern, Central, Western, Brong Ahafo, Ashanti, Volta and Greater Accra. Structured questionnaires (at least 200) were administered in each major okra-producing region to obtain information on different food and medicinal uses of the crop, consumption frequency and forms, methods of preservation, vegetable availability, etc. In all, a total of 1560 questionnaires were administered to the respondents. Information on popular okra types consumed in Ghana was also obtained. The survey was conducted using a convenient cross-sectional sampling technique. Morphological variations among the okra types as regards stem, petiole, leaf and fruit characteristics were scored using a standard international crop descriptor for okra (Resources, 1991). The study was conducted between June and November 2016. Translations were made in the native language where respondents could not speak English.

2.2. Isolation and evaluation of pectin from okra at different maturity stages

Chemical reagents used were all of analytical grade obtained from Sigma-Aldrich (Poole, UK). Deionized water was used throughout the extraction process. Okra samples were cultivated at Akrofu, Volta Region and experimental field at the Department of Horticulture, KNUST-Kumasi, Ghana. The okra pods were harvested at different ages (5–19 days) after flowering (immature, intermediate and overgrown). The okra pods were cut and the seeds removed. The separated okra pods were oven dried (Oven Drier, SN: 15-18,440, Tuttlingen, Germany) at 60°C for 6 h, milled using a kitchen blender (Binatone, model no: BLG-555, China) to powder of particle size 425 µm and then stored in zip-lock bags in a freezer until ready for extraction. Okra pectin was isolated using extraction method at pH 6.0 according to previous extraction protocol (Alba et al., 2015). The okra pectin yield (% w/w) was calculated on a dry weight basis using the following equation:

$$\text{Pectin yield } (\%) = \frac{\textit{weight of dried pectin extract}}{\textit{weight of dried okra powder}} \times 100$$

The intrinsic viscosities [η] of the okra pectin solutions were determined at 20 ± 0.1°C with an Ubbelohde capillary viscometer (PSL Rheotek OB. C 80,705) and calculations were done as previously reported (Agbenorhevi, 2011; Kpodo et al., 2017). Protein and total carbohydrate contents of the extract were also determined as previously reported (Kpodo et al., 2017).

2.3. Statistical analysis

The data obtained were analyzed using IBM SPSS Statistics 20 (IBM Corp., 2011). Analysis of variance was performed at 5% level of significance to test for differences among variables: pectin

yield, total carbohydrate, protein content and intrinsic viscosity of okra pectin samples extracted at different maturity stages. Thus, the independent variable was the okra maturity stage, whereas the dependent variables were the aforementioned properties of the okra pectin determined.

3. Results and discussion

3.1. Demographic characteristics of respondents

The demographic characteristics of 1560 respondents in the okra survey conducted are presented in Table 1. The majority of the respondents interviewed were females representing 61.1%, and most of them were aged between 21 and 40 (~64%). Vegetable farmers and sellers contributed to 10% and 25.3% of the total respondents, respectively. The results also indicated that 36.9% of the respondents had secondary education, whilst respondents with non-formal education contributed 16.7%. The northern ethnic groups contributed the largest percentage of 28.0% of respondents, whilst Ga-Adangbe ethnic groups were the least represented (13.1%).

3.2. Varietal differences among Ghanaian okra types

Okra in Ghana is locally known as *nkruma* (Akan), *fetri* (Ewe), *pora* (Kasem), *momi* (Krobo), *manna* (Dagbani) and *ma'na* (Nankam). Some okra genotypes were named as *asha, penkrumah, agba-goma, balabi, asontem* and *sengavi*. A wide genetic diversity of okra has been reported in Ghana (Ahiakpa et al., 2013; Kpodo et al., 2017; Oppong-Sekyere et al., 2012). Classification of the different varieties of the vegetable across ethnic groups has been based on colour (light green, dark green, dark and red varieties), surface nature of pod (smooth-skin varieties and rough-skin varieties), length (short and long varieties) and season of growth (dry season and wet season varieties). Although 96.9% of the respondents knew okra (Table 1), a minority (47.6%) had some knowledge of the various okra varieties owing to the vast number of landraces adapted to different agro-ecological regions in Ghana (Ahiakpa et al., 2017). The red okra variety (*porisongo*) was commonly reported among the Kasenas and Nankanas in the Upper East Region of Ghana. In order to provide information on the different okra varieties in Ghana, the morphological variations among some common local okra types were scored using the standard international crop descriptor for okra (Resources, 1991). The okra types showed relatively wide variations for all the morphological characteristics studied and were similar to the results that have been previously reported (Oppong-Sekyere et al., 2012). Most of the okra plants had erect growth characteristic, whilst leaf and stem colours were predominantly green. Petal or flower colour was predominantly yellow. Fruit was green to dark green, smooth and rough. The result showed that the fruit colour displayed different variations that ranged from green, with hairs to dark green.

3.3. Okra consumer preference, consumption frequency and forms

Consumer preference for a particular variety of okra was based on its sliminess and ability to increase the thickness of soup and stew. In Ghana, some respondents preferred the short dark green varieties due to its high ability to increase the thickness of soups and stews, whilst others preferred the long and white varieties which do not yield highly viscous soups and stews. The small immature okra fruits have also been reported to be very popular in various summer dishes in Greece and Turkey (Çalışır et al., 2005; Petropoulos et al., 2018). The study showed that 9.2% of the respondents do not eat okra with traditional perceived reasons such as okra causes (or aggravates) piles, impotency and nausea leading to vomiting after consumption. Others stated their dislike for okra due to its slimy nature in foods. Meanwhile, some respondents suggested the consumption of dried okra for minimal health risks. Despite the various buttressed dislikes for okra, most respondents were found to consume okra basically in the form of soup and stew. Majority of the respondents had no special reasons for eating okra.

As regards the consumption frequency of okra, majority of the respondents which represented 29.1% eat okra at least twice in a week, 24.3% also eat okra at least once in a week, whilst 5.2% consumed okra every day (Table 2). The consumption of okra in Ghana was based on its seasonal

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Table 1. Demographics of respondents and their knowledge of okra

Parameter	Frequency (%)
Gender	
Male	38.9
Female	61.1
Age group	
Below 20	11.6
21–30	36.4
31–40	28.5
41–50	15.2
Above 50	8.3
Occupation	
Farmers	10
Sellers	25.3
Others	64.7
Education	
Basic school	23.7
Secondary	36.9
Tertiary	22.7
Non-formal	16.7
Ethnic group	
Akan	22.5
Fante, Wasa, Nzema	14.5
Ewe	21.9
Northern (Gurisi, Dagbani, Frafra)	28.0
Ga-Adangbe	13.1
Know okra	
Yes	96.9
No	3.1
Know varieties of okra	
Yes	47.6
No	52.4

Table 2. Eating frequency of okra among respondents per week

Description	Frequency (%)
Do not eat okra	7.9
Once	24.3
Twice	29.1
Thrice	17.6
Four times	10.4
Five times	3.7
Six times	1.9
Everyday	5.2

availability, cost, suitability with certain foods, being a cultural food and medicinal benefits. Okra is widely used as a complementary food in the form of soup (73.1%) and stew (68.7%) consumed popularly with the core foods banku (81.3%) and tuo zaafi (38.8%) (Figures 1 and 2). The okra

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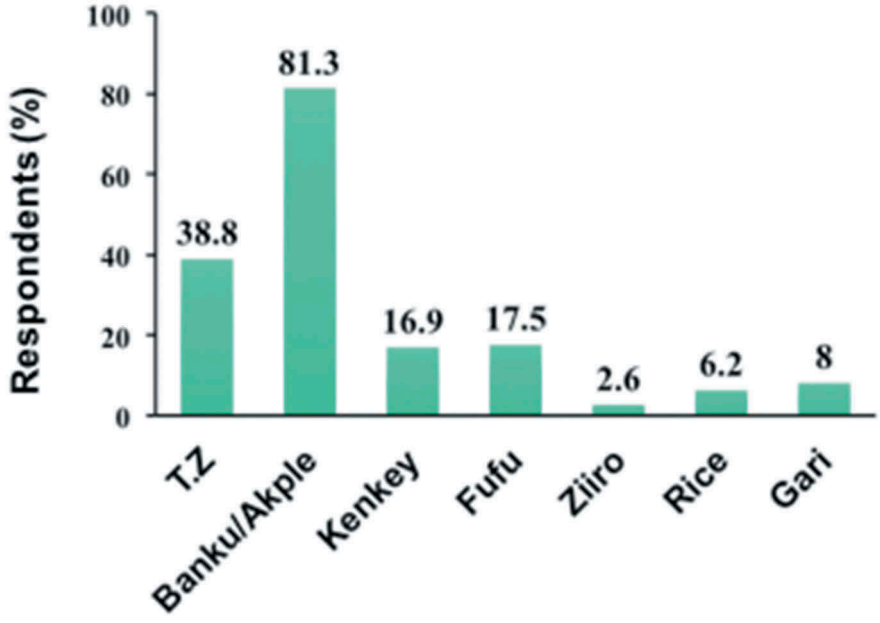

Figure 1. Foods consumed with okra among correspondents.

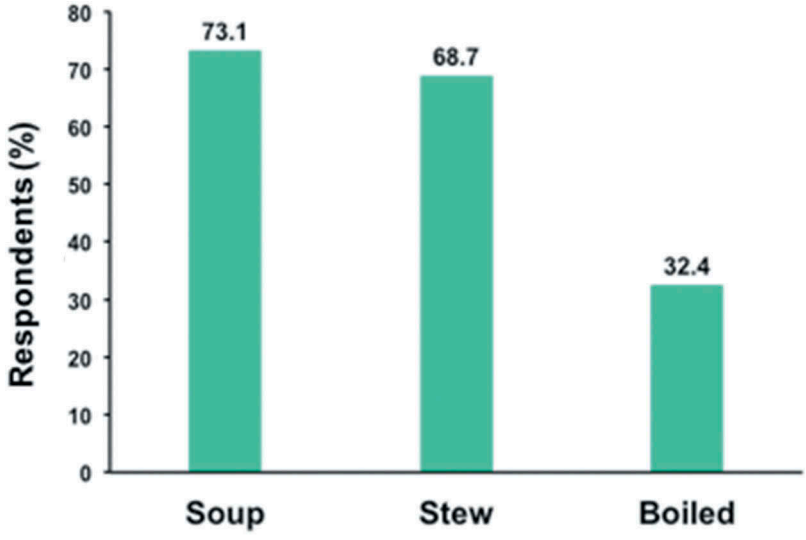

Figure 2. Forms of okra consumption among the respondents (%).

vegetable stew/soup pairing culturally combines to provide a nutritionally adequate meal and improve palatability (Çalışır et al., 2005). The survey demonstrated differences in consumption forms of okra among the different ethnic groups in Ghana. Whereas ethnic groups in the northern region of Ghana predominantly used okra as a complementary food in the form of soup (87.59%), Akans (78.22%) consumed okra mostly in the form of stew (Table 3).

3.4. Uses of the different parts of okra plant

The study showed that generally respondents used okra as food (94.7%), as medicine (22.1%) and for other applications (9.6%) (Table 4). The different parts of the okra plant have diverse useful applications (Kumar et al., 2010). The okra fruits were found to be the most utilized (89.9%) part of the okra plant in food. The leaves (34%) and flowers (1.5%) were also reported to be used in soups among the Frafras, Kasenas and Nankanas in Upper East Region (Table 4). The medicinal applications of the okra plant among respondents are shown in Figure 3. The stem (12.8%), fruit (11.5%)

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Table 3. Okra consumption forms among ethnic groups in Ghana

Ethnic group	Total (*n*)	Soup		Stew		Boiled	
		Count	Percent	Count	Percent	Count	Percent
Akan	349	239	68.48	273	78.22	102	29.23
Fante, Wasa, Nzema	223	107	47.98	133	59.64	56	25.11
Ewe	341	218	63.93	151	44.28	25	7.33
Northern (Gurisi, Frafra, Dagbani)	435	381	87.59	344	79.08	285	65.52
Ga-Adangbe	204	136	66.67	114	55.88	11	5.39

Table 4. Availability and utilization of okra

Description	Frequency (%)
Always available	
Yes	65.2
No	34.8
Personal use	
Leave	21.6
Fruits	90.6
Flowers	1.5
Knowledge of any okra product	
Yes	4.1
No	95.9
General uses of okra	
Food	94.7
Fruit for food	89.9
Leave for food	34.0
Others (flowers) for food	1.5
Medicine	22.1
Fruit for medicine	11.5
Leave for medicine	8.1
Stem for medicine	12.8
Others for medicine	4.0
Others (pito clarification, firewood)	9.6
Fruit for others	0.8
Stem for others	10.8

and leaves (8.1%) of the okra plant are applied traditionally in the treatment of boils, sores, cough, shingles, diarrhoea, fractures and dislocation. In addition to the food and medicinal uses, respondents in this study confirmed the use of fresh okra stem in pito production for clarification purposes (Djameh et al., 2015; Kpodo et al., 2019). The dried stems were also reported to be used as firewood for cooking, especially in the rural areas of Upper East Region, Ghana. The survey revealed that 95.9% of respondents had no knowledge of new products that can be developed utilizing mucilage/pectin from the okra fruit as an ingredient (Table 4). However, the use of okra mucilage in the production of new food and pharmaceutical products has the potential to increase the utilization and production of okra (Alba et al., 2013; Ghori et al., 2014; Kpodo et al., 2018). Most respondents including farmers and marketers of okra were interested in the development of new products utilizing okra (Figure 4). The majority (65.22%) of respondents with tertiary education

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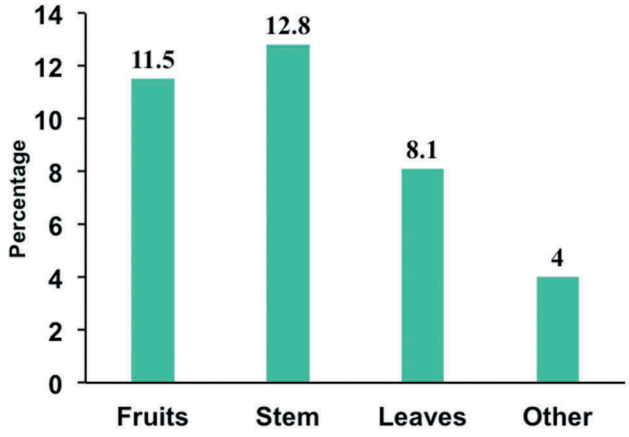

Figure 3. Utilization of various okra parts in traditional medicine.

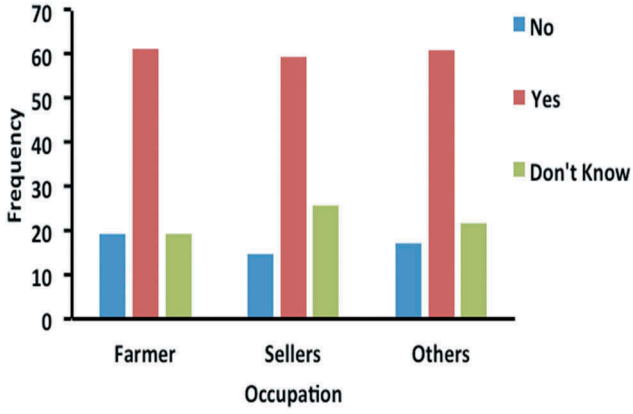

Figure 4. Type of occupation and interest in new okra products.

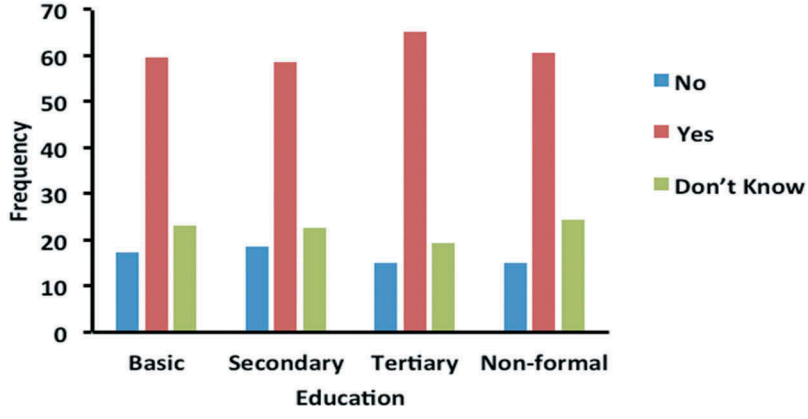

Figure 5. Educational level and interest in new okra products.

(in the education category) were interested in the development of new products from okra (Figure 5). However, individuals who were not interested in new okra products were of the view that the products may be slimy in nature, which might make them undesirable.

3.5. Okra availability and preservation methods

The availability of the okra was reported to be influenced by rainfall pattern, and most respondents obtained their okra from the market (75.7%) (Figure 6). About 65% of respondents stated that okra fruit is available throughout the year but abundant between June and September depending on the rainfall pattern (Table 5). The study showed that respondents preserved okra by sun-drying (64.8%),

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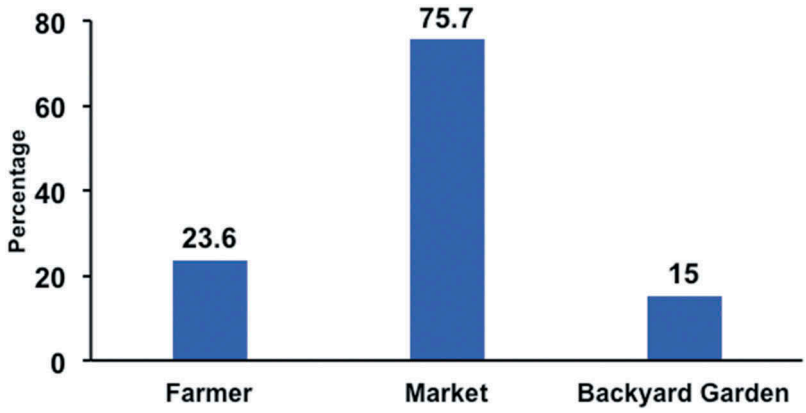

Figure 6. Sources of okra for respondents.

Table 5. Okra pectin yield and purity of balabi genotype at different maturity

Okra sample/ maturity (days*)	Pectin yield (%)	Total carbohydrate (%)	Protein (%)
5	12.5 ± 1.0^{a}	60.3 ± 0.1^{a}	11.6 ± 0.2^{a}
10–11	11.0 ± 1.0^{a}	60.1 ± 0.2^{a}	11.7 ± 0.1^{a}
14–15	20.7 ± 1.1^{b}	58.5 + 0.3^{a}	11.9 ± 0.1^{a}
18–19	8.7 ± 1.0^{c}	59.7 ± 0.2^{a}	11.8 ± 0.1^{a}

*Days after flowering. Values are mean ± SD. $^{a–c}$Mean values in the same column followed by different superscript letters are significantly different ($p < 0.05$).

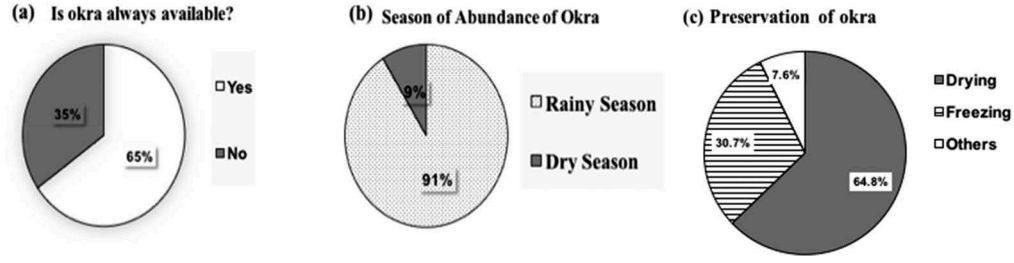

Figure 7. (a) Availability, (b) season of abundance and (c) preservation of okra among the respondents.

freezing (30.7%) and other methods (7.6%) (Figure 7). Freezing was mainly used for maintaining freshness though some consumers reported freezing had a negative impact on the taste and colour of okra. Other methods such as blanching/parboiling before freezing (or refrigeration), submerging in water (at room temperature) and covering with a moist cloth or jute bag were also found to be used in the preservation of the okra fruit. The result is indicative of limited preservation techniques for okra, and thus, there is a need to explore other preservation methods to extend produce shelf life.

3.6. Okra pectin yield and intrinsic viscosity at different maturity stages

The results indicate that okra at 14–15 days after flowering produced the highest pectin yield (Table 5). However, samples harvested after 18–19 days of maturity had the least pectin yield. Thus, pectin yield increased from the early maturity, peaked at 14–15 days and then decreased when overgrown. Similar results have been reported previously where okra mucilage content increased from index 1 (light green coloured with soft texture) to index 2 (light green coloured, but its texture is hard) and then gradually decreased from the fruit tissues at maturity index 3 (green whitish or green yellowish with a hard texture and tip not easily broken). The increasing pectin content of okra from the early maturity to the middle age could be attributed to growth and

Table 6. Pectin yield and intrinsic viscosity ([η]) of okra at three stages of maturity

Maturity level	Pectin yield (%)	[η] (dL/g)
Immature	16.82 ± 1.95[a]	11.9 ± 0.29[a]
Intermediate	17.65 ± 3.33[a]	4.5 ± 0.96[b]
Overgrown	8.97 ± 0.69[b]	5.0 ± 0.82[b]

Values are means ± SD. [a–b]Values with different superscript letters in a column are not significantly different ($p < 0.05$).

development of the okra itself (Noorlaila et al., 2015; Sreeshma & Nair, 2013). The mucilage in okra contributes to the moisture balance of the fruit and prevent it from drying out (Sreeshma & Nair, 2013). However, the declining mucilage content as okra matures is possibly due to the degradation process and lignification of the cell walls. The mucilage or pectinous matrix of cell layers also undergoes degradation process as it enters senescence period (Noorlaila et al., 2015; Sreeshma & Nair, 2013; Western et al., 2000). There were no significant differences ($p > 0.05$) in the protein (11.6–11.9%) and total carbohydrate contents of the crude okra pectin extracts obtained (58–60%) at different maturity (Table 5). This is simply because the crude extracts were not further purified by dialysis. The results obtained, however, were similar to previous findings for both yield and purity of okra pectin extracts (Alba et al., 2015; Kpodo et al., 2017).

Though the highest pectin yield was observed for intermediate matured fruits (17.65%), followed by that of immature fruits (16.82%) and lowest (8.97%) observed for overgrown fruits, the intrinsic viscosity value, however, was highest for immature fruits as compared to the intermediate (4.5 dL/g) and overgrown okra fruits (5.0 dL/g) (Table 6). Intrinsic viscosity values of the present work are either similar to those reported by Kpodo et al. (2017) (Alba et al., 2015; Ndjouenkeu et al., 1996) or higher than those obtained using the sequential extraction methods (Kontogiorgos et al., 2012), exemplifying the influence of maturity, purity of extract and isolation protocol on the molecular structure of the samples. Other studies also reported significant varietal effect on yield and quality of sunflower pectin (Lin et al., 1975; Sahari et al., 2003).

The results clearly indicate that it is important to harvest okra fruit at the appropriate harvest maturity stage for the desired pectin content or yield and viscosity of pectin extract. Further studies can be done to engineer or breed okra with desired texture and okra pectin qualities.

4. Conclusion

Okra is a popular vegetable consumed predominantly as food among the various ethnic groups in Ghana. The study revealed that okra is commonly used as food, whereas few utilized the crop as medicine and for other applications. Differences in educational level, occupation and ethnic group influenced the utilization of okra in Ghana. Respondents showed high interest in the development of new products from okra to increase utilization and contribute to food and nutrition security. Intermediate matured fruits had the highest pectin yield, followed by that of immature fruits and lowest for overgrown fruits. The intrinsic viscosity value also varied with highest in immature fruits as compared to the intermediate and overgrown okra fruits. The findings show that harvesting at intermediate maturity would be most appropriate if high okra pectin yield is desired.

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Competing Interests
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