The Effect of Fruit Age on the Apparent Kinematic Viscosity (AKV) and Crude Dietary Fibre Content of Okra (*Abelmoschus esculentus* (L) Moench) and *Abelmoschus caillei* (A.Chev) Stevels Cultivars

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Abstract

Evaluation of the responses of the apparent kinematic viscosities (akv) of the slurry of six early and three late okra cultivars, to changes in fruit age, was carried out as part of an ongoing research programme aimed at the improvement of local okra cultivars to meet the needs of local okra consumers. The results of the ANOVA showed that responses of all the cultivars at the various ages were very highly significant. The variation among the cultivars was equally very highly significant as well as the interaction between age and cultivar (AxC). The results further showed that irrespective of okra type and cultivar, akv responses decreased with increase in fruit age. The rate of decrease was more rapid with the early okra cultivars than with the late okra cultivars. With the exception of Ogolo, all the other okra cultivars developed crude dietary fibre at the fruit age of 12 days and crude dietary fibre content increased with increase in fruit age. However, as crude dietary fibre content increased, the akv of all the cultivars decreased. Five categories of okra were recognized based on this response: the excellent performers (EP), the good performers (GP), the fair performers (FP), the poor performers (PP) as well as the worse performer (WP). Two late okra cultivars, Ogolo and Oru ufie and two early okra cultivar, Awgu early and Kano dwarf were selected as sources of good germplasm for the mucilaginous character with age. Ladyfinger, which is exotic okra, was rejected as the worse performer considering its other undesirable characteristics. The need for local development of okra cultivars with both high, dietary fibre and mucilaginous character, for the good health of okra consumers in Nigeria and the West African coast, was highlighted

Keywords: Okra, Fruit age, Slurry, Apparent kinematic viscosity, Dietary fibre

Introduction

In West Africa two distinct okra types exist; *Abelmoschus esculentus* (L.) Moench, which is the conventional or early okra and *Abelmoschus caillei* (A.Chev) Stevels late okra (Siemonsma and Hamon 2004). Late okra is also called the West African okra, since its distribution is restricted to the West African region (Martin *et al* 1981, Siemonsma 1982). Differences in the physiological responses of the two okra types to changes in natural photoperiod have been a remarkable means of distinction between the two okra types. Early okra has a Critical Day Length (CDL) of 12.5 hours whereas late okra has a CDL of 12.25 hours (Njoku 1958, Oyolu 1977, Nwoke 1980, Siemonsma 1982 and Udengwu 1998). In his review of the economic uses of okra, Martin (1982) described okra as a potential multipurpose crop for the temperate zones and the tropics. This is in recognition of the economic importance of almost every part of the plant. The use of the mature dried seed, as a coffee substitute as well as a source of Gossypol (male sterilant) is well known. The mucilage is useful as an extender of serum albumin and an egg white extender or substitute (Martin 1982). Despite all these potentialities of the crop, its development has received little or no attention in Nigeria. Fatokun *et al* (1979) observed that considerable information is available regarding agronomic and cultural requirements of major food, fibre and cash crops grown in Nigeria as a result of research carried out in these crops. In many cases varieties suitable to the various climatic zones in the country have been developed, but unfortunately very little attention has been paid towards the improvement of okra and other indigenous vegetable crops.

In Nigeria and most countries of West Africa, okra is utilized essentially because of its high mucilage content which is used in the thickening of soup (Irvine 1952; Purseglove 1968; Wolfe *et a1*1977; Vickery and Vickery 1979; Fatokun and Chheda 1980; Uzo and Ojiakor 1980). According to Fatokun *et al* (1979), okra fruits considered to be of good quality in the Nigerian context must be smooth, green coloured, short and highly mucilaginous. Mucilage character of the okra soup menu of people of West Africa is so important that the mucilage character of okra fruit is often re-enforced with other known mucilaginous plant parts like ground seeds of *Irvingia spp*, sliced leaves of *Corchorus* spp as well as mucilaginous extracts from the leaves of *Adansonia digitata* (Udengwu 1999; 2008a).

Uzo and Orjiakor (1980) lamented that studies on the properties of okra mucilage are quite scanty owing to the fact that in most parts of the world, where okra is used as vegetable, selection is highly against high mucilage content. One unique feature of okra fruit is that as it ages it develops fibre, which many times proves too tough for the sharpest kitchen knife to cut through to make slices for soup making. While high dietary fibre in foods is a welcome healthy idea, okra consumers may be most unwilling to exchange it for high mucilage content. It is therefore important to investigate the effect of fruit age on the mucilaginous quality of okra. This is with a view to identifying cultivars that have the ability to retain their high mucilage quality as they age which can help the okra farmer to plan an economically favourable harvesting frequency to minimize excessive labour input or glut in the market because of very frequent harvesting of fruits. Such cultivars with late fibre development capabilities and high mucilage content will be utilized in the improvement of promising cultivars that develop fibre very quickly at the expense of mucilage content.

To the author's best knowledge, no known studies has been done, in this very important area of determining the effect of fruit age on the “apparent” kinematic viscosity of okra fruit slurry and development of dietary fibre. Wolfe *et al* (1977) did a chemical extraction of the mucilage of okra after boiling and precipitation to estimate the yield of mucilage per kilogram of okra fruit. They also studied the properties of the extracted mucilage. Uzo and Orjiakor (1980) studied a physical method for the determination of okra fruit quality based on “apparent” kinematic viscosity of okra fluid. In continuation of the pioneering work of Uzo and Orjiakor (1980), in this very important aspect of okra improvement, Udengwu (1999), studied the strength of relationship between fruit qualitative characters and "apparent" kinematic viscosities of okra cultivars. The aim of this study was to identify gene markers to facilitate transfer of the mucilaginous character to selected, high yielding but deficient (low mucilage) cultivars. This was followed by Udengwu (2008a) which reported on the effects of changes in temperature on the "apparent" kinematic viscosities of okra fruit slurry.

This present report is based on a comparative study of the effects of fruit age, on the "apparent" kinematic viscosities of the slurry of 6 early okra and 3 late okra cultivars and their crude dietary fibre content.

Materials and Methods

Six cultivars of early and 3 cultivars of late okra, from the okra gene bank maintained in the Botanic Garden, University of Nigeria, Nsukka were used for this study. The early okra types were Lady Finger, (an exotic okra), "Osukwu", Kano Dwarf, Awgu Early, "Mpi Ele," "Ogba Mkpe." The late okra types include "Ebi Ogwu", "Ogolo" and "Oru Ufie".

The field work was carried out in the Botanic Garden and Agric. farm, University of Nigeria, Nsukka, following standard agricultural practices, while the laboratory work was carried out in both the Pharmaceutical Chemistry and Botany laboratories. The 9 cultivars were grown in four replications using Randomized Complete Block Design (RBCD). The plantings were done on flat beds measuring 3.5m x 4.0 m. Well cured poultry manure was worked into the beds at the rate of 10.75 kg per plot, one week before planting.

The 9 cultivars were planted in randomized rows for the four blocks using the table of random numbers. Plants were spaced 30cm x 30cm. Three pre-germinated seeds of each cultivar were planted inside holes 2.5cm deep. Before the plantings were done, 1.5g of Furadan, a combined nematicide and insecticide, was introduced into each of the holes. The plants were later thinned down to one per stand, nine days after the emergence of the first two opposite cotyledonary leaves. There were 10 plants per row giving rise to 90 plants per block.

Weekly foliar application ofVetox-85 two weeks after germination was used to control the leaf borer *Podogrica uniforma* which is one of the most devastating pests of okra. The plants were rain-fed throughout the period of the studies. When the plants started flowering, the tagging of open flowers for the determination of the ages of the fruits to be used in the studies started. Age was calculated from one day after anthesis, which is the day the calyx and corolla dropped to expose the tender green ovary containing the fertilized seeds (young fruit). Fruits were harvested at the ages of 4, 8, 12, 16 and 20 days from the nine okra cultivars. For the different cultivars, all the fruits of the same age, harvested the same day, were bulked together. The four replicates for each fruit age per cultivar were drawn from forty fruits. The total number of samples analysed was 180, comprising of 4 replicates for each of the 5 different fruit ages for the 9 cultivars. After the removal of the seeds, (because Wolfe *et al* 1977 had reported that okra seeds do not contribute to the mucilage character) 40g of the fruit wall of each sample, for the different ages, was weighed and kept for blending prior to the extraction of the mucilage.

The extractions were carried out following the method of Udengwu (1999). The extracted slurries were now used to determine the "apparent" kinematic viscosities at 5 different fruit ages of 4, 8, 12, 16, and 20 days. Since kinematic viscosities are temperature sensitive, and for uniformity, all the determinations for all the ages were done at 25°C. This temperature was achieved by putting on, one 2 horse power Westinghouse air conditioner at high cool position inside a laboratory measuring 18 feet x 18 feet for 1 hour. Both the determinations of flow times for each cultivar at the five different ages using the U-tube British Standard Unit viscometer (300mm overall length), designation F, as well as the conversion of efflux time viscosity readings to centistokes and correction for kinetic energy changes were done following the methods of Udengwu (1999).

Results and Discussion

Table 1 shows the ANOVA of the effect of different ages of fruit on the viscosity of extracted mucilage of 9 okra cultivars. The age and cultivar effects as well as the interaction between age and cultivar were very highly significant ($P < .001$). The graphs of the responses of the various cultivars to different ages of fruit (Fig.1) showed that the apparent kinematic viscosity (akv) of all the cultivars decreased with increase in fruit age. The graph of the interaction between age and cultivar (A x C) followed exactly the same trend with that of effect of fruit age on the apparent kinematic viscosity of cultivars of early and late okra (Fig. 2).

Separation of the means of all the cultivars based on age as a treatment using Duncan's multiple range test revealed that all the means of the late okra cultivars; "Ebi Ogwu", "Ogolo" and "Oru Ufie" were significantly different at 1% level from each other as well as from that of all the early okra cultivars: Lady Finger, “Osukwu", Kano Dwarf, Awgu Early, "Mpi Ele" and “Ogba

Table 1: ANOVA of the Responses of the mucilage of 9 okra cultivars to changes due to different ages of fruits

Source	df	SS	MS	F Cal	5%	1%	0.50%
Total	179	2652261.04					
Age (A)	4	1209253.02	302313.25	135***	2.37	3.32	3.72
Cultivar (C)	8	239754.88	29989.36	13.45***	1.94	2.51	2.62
(A x C)	32	902641.671	28207.55	12.677***	1.46	1.7	1.79
Error	135	300611.469	2226.75				

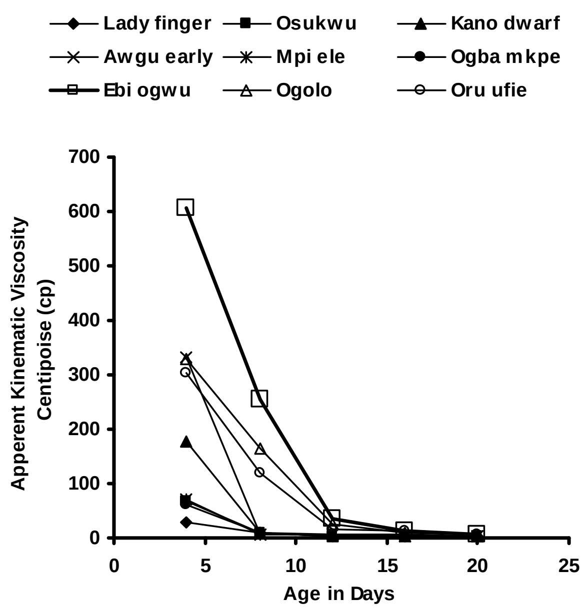

Fig. 1: The effect of fruit age on the apparent kinematic viscosity of mucilage from nine Okra cultivars.

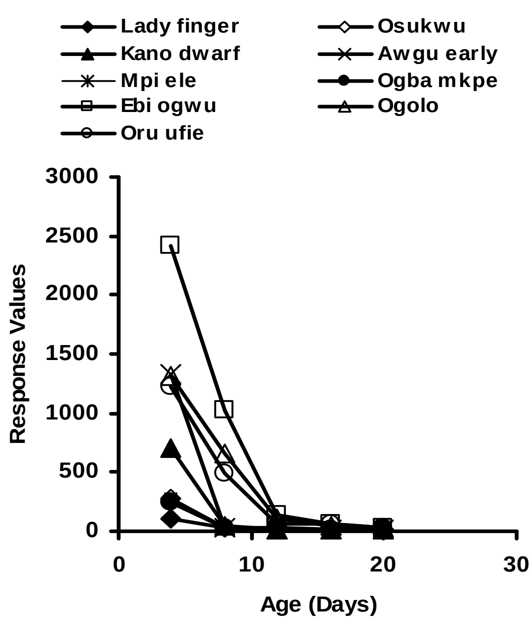

Fig. 2: Interaction between age and cultivar (A x C) of nine Okra cultivars used for kinematic viscosity studies.

Mkpe," (Table 2a). On the other hand whereas the akv of Kano dwarf differed significantly from that of all the other five early okra cultivars, they themselves did not differ significantly from each other. When the means of the responses of all the 9 cultivars based on different ages as treatment were separated, that of 4 and 8 days differed significantly, at 1% level using Duncan's multiple range test, from each other as well as from that of 12, 16 and 20 days. The responses of 12, 16 and 20 days however did not differ significantly from each other (Table 2b).

The very highly significant difference (P<.001), observed for the effects of fruit age on the akv of the nine okra cultivars, as well as the separation of the treatment means based on age of fruits at 4 days and cultivar means based on akv responses at 4 days old, are indicative of the fact that there exists an appreciable genetic diversity among the okra cultivars used for the studies, with respect to the effect of age on the akv response. This diversity was however more pronounced with the late okra cultivars than with the early okra cultivars whose responses did not essentially differ significantly among themselves.

A critical look at their responses as shown in Fig. 1 as well as the interaction between age and cultivar (AxC) Fig. 2, indicate that the nine cultivars can be placed into five categories at the age of 4 days. Ebi ogwu can be categorized as the excellent performer (EP), while Awgu early, Ogolo and Oru ufie can be categorized as the Good performers (GP). Kano dwarf is categorized as the Fair performer (FP), Mpi ele, Osukwu and Ogba mkpe are categorized as Poor performers (PP), while Lady finger is categorized as the Worst performer (WP).

It is interesting to note that the EP and two out of the three GP are late okra cultivars. This is indicative of the fact that the late okra group which has been grossly neglected in okra improvement programmes may actually hold the promise for many of the genes needed for the improvement of okra to meet consumer's demands in Nigeria as well as the West African sub region. According to Martin *et al* (1981), the late okra types appear to consist of a body of variation not formerly recognized by plant breeders. Being tropical they may not flower under temperate zone conditions, hence their relative neglect; they definitely constitute a pool of variation that should be very useful for the long term improvement of both temperate and tropical varieties.

The rating of Awgu early, an early okra cultivar, as a GP performer based on the effect of

Table 2a: Separation of cultivar means based on age of fruits (4 days) as treatment

Cultivars	Cultivar means based on age of fruits at 4 days as treatment
C1 = Lady Finger	40.04 a b c d
C6 = Ogba Mkpe	67.87 b c
C2 = Osukwu	69.59 d
C5 = Mpi Ele	74.06 d
C3 = Kano Dwarf	157.98 e
C4 = Awgu Early	282.91 f
C9 = Oru Ufie	371.08 g
C8 = Ogolo	429.21 h
C7 = Ebi Ogwu	734.55 i

Table 2b: Separation of treatment means based on different ages of fruits

20 days	16 days	12 days	8 days	4 days
4.90 abc	6.97 bc	12.04 c	65.99 d	219.45 e

Figures not followed by the same letters are significantly different at 1% level of probability using Duncan's multiple range test.

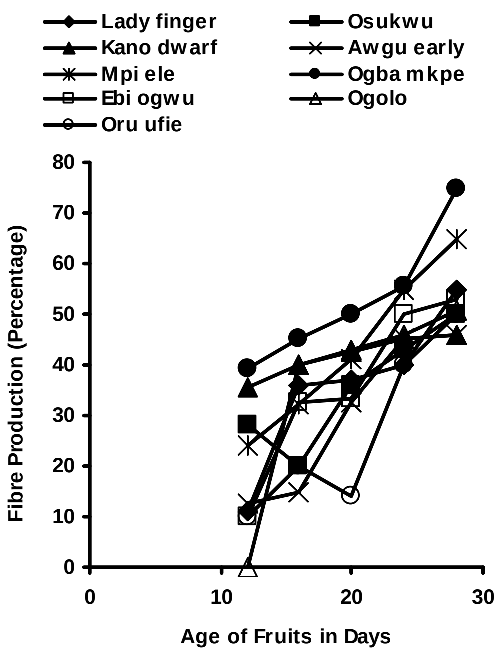

Fig. 3: The effect of fruit age on crude dietry fibre production in nine Okra cultivars

fruit age on the akv of okra cultivars, confirms its earlier selection by Udengwu (2008a and 2008b) as an elite early okra cultivar that can serve as a useful source of germplasm for the improvement of okra cultivar with respect to the mucilage character which is so desirable in West Africa. Joined to Awgu early, is Kano dwarf, a FP, and an early okra germplasm collected from Kano, in the Northern part of Nigeria. It equally holds some good promise as a good source of germplasm for okra akv improvement with respect to fruit age. The poor performers need serious improvement, in a planned breeding programme, which will be initiated once the much sought after gene markers for the control of the mucilage characters are identified as noted by (Udengwu, 1999). To be excluded from improvement programmes, with respect to the mucilage character and fruit age, is lady finger, an exotic okra cultivar introduced into the country, which was collected from the Enugu market garden. Its worst performance, with respect to the effect of fruit age on akv parallels its worst performance with respect to the effect of slurry temperature on akv (Udengwu, 2008a). This is not surprising since this is exotic okra developed to meet consumer's demand overseas where selection is strictly against high mucilage content: a nonnegotiable okra fruit attribute in Nigeria and other West African countries.

This point underscores the great need for basic research in Nigeria and other African countries, aimed at screening the locally available germplasm, for the discovery and documentation of their genetic potentials for use in improvement programmes to satisfy local needs. This current call once more reechoes the earlier call on this same very important issue by Fatokun *et al* (1979), Okonkwo (1984) and Udengwu (1999, 2008a and 2008b).

Though Ebi ogwu, turned out to be the EP, it was not however selected because of its possession of piercing still hairs, which is an undesirable fruit quality among okra consumers. It requires improvement by crossing with either Ogolo or Oru ufie, which are all GP late okra cultivars, with very smooth fruits, over a number of generations. Of interest again is that among the GP, the two late okra cultivars, Ogolo and Oru ufie showed a much more gradual loss of viscosity with increase in fruit age from 4 days to 8 days and then 12 days. This quality is termed consistency with fruit age. The two late okra cultivars are therefore considered to be more consistent than Awgu early, a GP, early okra cultivar.

Fig. 3 indicates that with exception of Ogolo, all the other okra cultivars developed crude dietary cultivar at the fruit age of 12 days. This was confirmed when 12 days old okra fruit wall sections taken from the fruit base were stained with conc. HCl and Phloroglucinol, they turned brick red, which is a confirmation of the presence of fibres. It therefore makes sense that as mucilaginous character decreases with advance in fruit age, crude dietary fibre increases from the fruit age of 12 days.

The development of fruit fibres as strengthening tissues for the protection of the seeds against many unfavourable factors is known to occur through lignification of the xylem vessels of the fruit. However, the exact mechanism of the possible metabolism or conversion of the polysaccharides, which are the basic constituent of okra mucilage (Wolfe *et al* 1977), with advancing fruit age, prior to the development of dietary fibre, is not known. This will form part of future studies on the mucilaginous quality of okra. A possible clue may come from anatomical as well as biochemical comparative studies of the fruit walls of Ogolo at the age of 12 days, which is still devoid of dietary fibre, alongside other okra cultivars that develop fibres at the age of 12 days. Such studies may reveal certain features which may serve as a marker for breeding for higher mucilage content at older fruit ages, even when fibres had developed. Medical authorities have emphasized the importance of high dietary fibre in our meals in this age and time when all forms of cancer afflict humanity. The development of okra cultivars with high dietary fibre content without compromising the very important high mucilaginous character will contribute in no small measures towards the good health of okra consumers in Nigeria and other West African countries.

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