Journal of Food Research; Vol. 1, No. 4; 2012
ISSN 1927-0887 E-ISSN 1927-0895
Published by Canadian Center of Science and Education

Quality Attributes of Okra (*Abelmoschus esculentus* L. Moench) Pods as Affected by Cultivar and Fruit Size

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Received: September 4, 2012 Accepted: September 27, 2012 Online Published: October 30, 2012

doi:10.5539/jfr.v1n4p224 URL: http://dx.doi.org/10.5539/jfr.v1n4p224

Abstract

Okra is a vegetable widely grown in the tropics, sub-tropics and warmer areas of the temperate zones. Fruit quality plays an important role in marketability and it is mainly related to the characteristic pod length. This work was intended to classify okra fruits belonging to different genotypes (a local variety - LV - and the cultivars Emerald, Clemson Spineless and Annie Oakley II) according to their length and to compare certain quality attributes. LV fruits were considerably firm although they were smaller, thus they should be more suitable for canning or pickling. The hybrid material (Annie Oakley II) yielded high quality fruits. These fruits may be destined for fresh consumption, given that they showed lower fibrousness. At the same time, they had high dry matter content, being suitable for dehydration. Okra fruits highlighted for their contribution of phenolic compounds.Total phenols levels significantly increased with fruit size in LV fruits, meanwhile no significant difference was observed for Annie Oakley II samples. Total flavonoids content showed a similar tendency although values did not differ significantly. Total flavonoids represented between 18-22% of the total phenols contents for the analyzed samples.

Keywords: tropical vegetables, guino-gombo, quality standards, local varieties, introduced cultivars

1. Introduction

Okra (*Abelmoschus esculentus* L. Moench) also known as Lady's finger, Bhindi, Gombo, or Gumbo is widely grown in the tropics, sub-tropics and warmer areas of the temperate zones (Camciuc, Deplagne, Vilarem, & Gaset, 1998). Higher yields are obtained with hot weather (temperatures above 26ºC), especially in regions with warm nights (>20ºC).

According to FAO database, the five highest okra producing countries in 2008 were India, Nigeria, Sudan, Iraq and Côte d'Ivoire (FAOSTAT, 2010). Particularly, in India okra has a vast potential as one of the foreign exchange earner crops, since it accounted for about 60% of the export of fresh vegetables excluding potato, onion and garlic (Sankar et al., 2008).

Okra immature fruits (pods), which are consumed as vegetables, can be used in salads, soups and stews, fresh or dried, fried or boiled (Ndunguru & Rajabu, 2004). Fibrousness of the pods increases rapidly after harvest, rendering them inedible. The extended fruit set period makes okra harvesting labor-intensive (Marsh, Jones, & Ellersieck, 1990). Okra pods are often preserved by freezing, dehydration or canning since they have a relatively short shelf life and are susceptible to chilling injury. Thus, refrigeration has a limited application. Likewise, the harvest of okra fruits cannot be deferred.

According to Diaz Franco, Ortegón Morales and Loera Gallardo (1997), in addition to yield, fruit quality plays an important role in okra productivity and marketability. Criteria defining fruit quality are not completely clear except for the characteristic pod length, which is indicated by the United States Department of Agriculture

(USDA 1965-1997; Díaz-Franco et al., 1997). Several desirable quality characteristics of okra fruit are length, diameter, greenness, mucilage and fiber content. Industry and commercial preference is oriented to fruits 8.9-12.7 cm long (medium), although smaller fruits are commonly accepted. A specific greenness and fruit diameter are also required, but they are often arbitrarily indicated (e.g. very dark and reduced fruit diameter are the most preferred) (Díaz-Franco et al., 1997). Martin et al. (1981) have pointed out that greenness; length and weight of the fruit were associated with okra genotype (Díaz-Franco et al., 1997).

In several parts of the world, okra cultivation has gained place in urban and peri-urban areas partly because of the introduction of foreign high yielding varieties by seed companies (Ndunguru & Rajabu, 2004). Most okra cultivars require about 4 months from sowing to harvest, though some early maturing varieties can produce fruits after 50 days in the tropics. At the same time, these varieties are more tolerant to cooler temperate conditions, so they could be grown outdoors. These include 'Clemson Spineless', 'Emerald', 'Long Green' and 'Green Velvet'. Clemson Spineless is the standard open pollinated variety grown for over 40 years in the United States and other countries. It is still used because of low seed cost and wide adaptation (Bisht & Bhat, 2006). Clemson Spineless has been described as a uniform spineless variety with medium dark green, angular pods. Emerald is a spineless variety with dark green, smooth, round pods (Sanders, 2001).

The first experimental hybrids of okra emerged in USA at the beginning of the 90's, as a new alternative production technology (Díaz-Franco et al., 2007). Okra hybrids show the advantage of a shorter life cycle and a higher yield. Annie Oakley is a hybrid, with bright green, angular pods.

In spite of the numerous advantages of available okra commercial varieties and hybrids, the importance of traditional varieties has recently been pointed out by farmers, scientists and technologists of developing countries (Winarto & Ardhianto, 2007). These local varieties (LV) are the result of a non-programmed selection process conducted by the horticulturalists in every crop cycle from originally introduced varieties (González Idiarte, 1999). LV standout for their productive adaptation to local conditions, showing advantages related to growth cycle, disease resistance and yield stability. Unfortunately, the loss of LV has been accelerated in recent decades. Thus, the availability of genetic basis to develop genotypes adapted to local agro-ecological conditions becomes critical.

The objectives of the present work were: a) to classify okra (*Abelmoschus esculentus*) fruits belonging to different genotypes (LV and selected cultivars) according to their length; b) to characterize comparatively certain physical and chemical quality attributes of okra fruits, in order to assess the best use alternative/s for each one.

2. Method

2.1 Plant Material and Crop Conditions

Okra (*Abelmoschus esculentus* L. Moench) plants were field-grown in the horticultural belt of La Plata (Buenos Aires, Argentina), during 2006-2008. Geographical location corresponds to 34º56' 44.29 S, 58º06' 20.59 W. Okra materials assayed were a local variety (LV); the cultivars Clemson Spineless and Emerald; and the hybrid Annie Oakley II. For the purposes of the present work, okra fruits were harvested from February, 15th to February, 25th, depending on the material.

Okra pods were harvested early in the morning and immediately carried to the laboratory. Fruits showing physical damage and/or disease symptoms were discarded. Pods (250-400 fruits depending on the cultivar) were classified according to their length (cm).

2.2 Measurements

2.2.1 Length and Diameter

Length was measured as the distance from the fruit cap scar at the base to the tip end of the pod (USDA, 1997). According to this characteristic, five groups for LV, six groups for the hybrid Annie Oakley II, seven groups for Clemson Spineless and eight groups for Emerald cultivars were established (Table 1; Figure 1a-d). The diameter (cm) of the fruits in the peduncle insertion zone was measured using a standard graduated scale Vernier calliper.

2.2.2 Mean Fresh Weight

Mean fresh weight (g) of okra fruits was determined by weighing fruits individually in a digital analytical balance (±0.001 g). Reported values correspond to the average of at least 50 fruits per category and per cultivar.

2.2.3 Dry Matter Content (%)

Approximately 5 g of samples were placed into previously weighed capsules and dried in a vacuum oven at 70ºC until constant weight was reached. After removing the capsules from the oven, they were allowed to cool in a desiccator and then weighed. Determinations were carried out by duplicate.

2.2.4 Total Ash Content (%)

Total ash content of okra fruits was determined by placing 2 g of the dried samples in previously burned (900ºC) and tared crucibles, weighed accurately and slowly carbonized and incinerated using a muffle furnace (Indef 331, Córdoba, Argentina) at 525ºC until samples turned into white ash and constant weight was reached (AOAC, 1990; method 923.03). The crucibles were weighed and the percentage (%) of total ash was calculated. Determinations were carried out by duplicate.

2.2.5 Mineral Content

Calcium, magnesium, sodium and potassium contents (mg / 100 g dry weight) were quantified. Ash samples (0.3 g) were weighed (with accuracy of 0.1 mg) and dissolved in 0.14 M HNO_3. For calcium content determination, samples were dissolved in lanthanum oxide to a final concentration of 0.5%. The dissolutions were filtered through cellulose acetate membrane (pore diameter: 0.45 µm) and diluted conveniently. The analyses of Ca (λ = 422.7 nm) and Mg (λ = 285.2 nm) were carried out by atomic absorption spectroscopy and the quantification of Na (λ = 589.0 nm) and K (λ = 766.5 nm) by atomic emission spectroscopy. Measurements were carried out in a spectrophotometer Shimadzu AA-6650. Determinations were carried out by duplicate.

Table 1. Size categories based on fruit length for the different cultivars of okra

Size category	Length (cm)			
	Emerald	Clemson Spineless	Annie Oakley II	Local variety
1	Less than 4	Less than 4	Less than 4	Less than 2.5
2	4 – 5	4 – 5	4 – 5	2.5 – 3.5
3	5 – 6	5 – 6	5 – 6	3.5 – 4.5
4	6 – 7	6 – 7	6 – 7	4.5 – 5.5
5	7 – 8	7 – 8	7 – 8	5.5 – 7.5
6	8 – 10	8 – 10	8 – 10	--
7	10 – 12	10 – 12	--	--
8	12 - 14	--	--	--

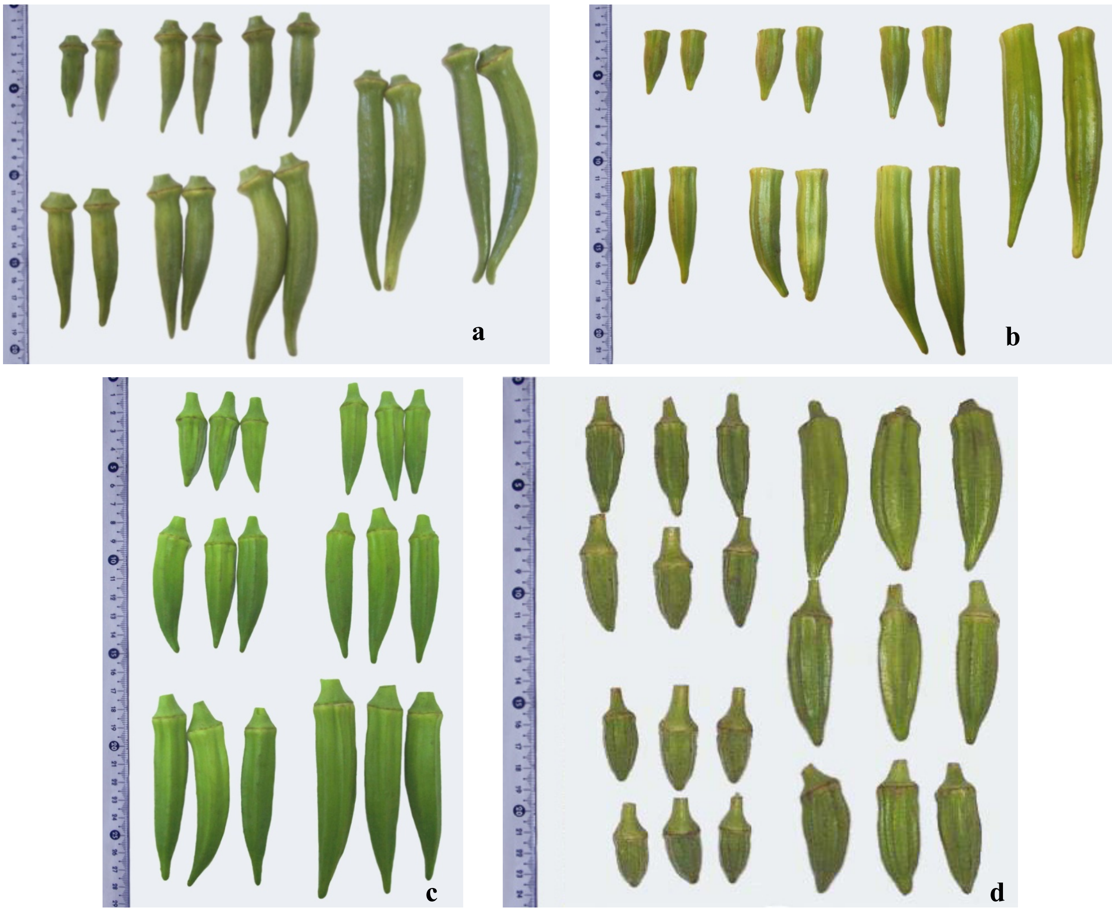

Figure 1. Okra fruits belonging to different cultivars, classified according to fruit size; a) Emerald; b) Clemson Spineless; c) Annie Oakley II; d) Local variety

2.2.6 Texture

Maximum shear force (MSF) of okra pods was measured with a texturometer TA-XT2i (Stable Micro Systems Ltd, Godalming, Surrey, UK) operating in the compression mode and using a 25 kg load cell. The equipment was fitted with a Warner-Bratzler knife. Knife displacement rate was 0.5 mm s^{-1}. Maximum Shear Force was measured on 10 different fruits for each cultivar and fruit size group. Results were expressed as the MSF applied before breaking, in Newtons (N).

2.2.7 Surface Colour

This attribute was determined using a Minolta CR 300 colorimeter, with an 8 mm diameter measuring area. The instrument was calibrated with a standard white plate. Readings were conducted by directly applying the colorimeter head on the fruit surface. Colour was measured in 10 different pods for each cultivar and fruit size group. The co-ordinates recorded were L*, a* and b* of the CIE scale in order to analyse the derived functions hue [$h^o = \tan^{-1}(b^*/a^*)$] and Chroma [$C = (a^{*2} + b^{*2})^{½}$].

2.2.8 Total Phenols and Flavonoids

Fruits from LV and Annie Oakley II were frozen in liquid N_2 and crushed in a mill (Janke and Kunkel IkaLabortechnik A10, Staufen, Germany). From the obtained powder, exactly weighed samples (1 g) were taken and treated with 5 mL ethanol 96% w/w for 60 min and then centrifuged (11,500×g, 10ºC, 30 min). On the extracts, total phenols (TP) and flavonoids (TF) were quantified. TP were dosed employing the Folin–Ciocalteu reagent (Swain & Hillis, 1959). Absorbance readings were carried out at 760 nm. TF content was determined by the technique described by Kim, Jeong and Lee (2003). Absorbance at 510 nm was measured. Catechin was used as standard. Duplicated extractions and determinations were conducted. Final results were expressed as mg catechin/100 g fresh tissue.

2.3 Statistical Analysis

Data were subjected to the analysis of variance (ANOVA). Sources of variation were cultivar and fruit size category. Means were compared by the least significant difference (LSD) test, at a significance level p = 0.05.

3. Results and Discussion

Okra fruits are harvested at physiologically immature state. Thus, commercial (or horticultural) maturity precedes physiological maturity. Special care must be taken in all handling operations to prevent product damage and the associated loss of visual appearance, increased water loss, and increased decay (Cantwell & Kasmire, 2002).

The United States Department of Agriculture (USDA) has established the US standards for grades of okra for processing which are intended to apply only to okra pods delivered to a freezing or canning plant for processing purposes. In this guide, two grades are pointed out (U.S. Nº 1 and U. S. Nº 2). A size classification is included in connection with the grade on the basis of specified lengths in inches. The “very small” group includes okra pods less than 1.75 inches (<4.4 cm) in length; the “small” (or baby) group includes okra pods not less than 1.75 inches or more than 3.5 inches (4.4 to 8.9 cm); the “medium” class includes okra pods more than 3.5 inches and not more than 5 inches (8.9 cm to 12.7 cm) in length; and the “large” group that comprises, unless otherwise specified, pods more than 5 inches (>12.7 cm) (Marsh et al., 1990).

Amongst the materials assayed in this work, fruits belonging to LV were characterized as the smallest ones and they were divided into five categories (Table 1). The classification proposed in this paper for LV fruits comprises three groups that fall below the size range specified by the USDA classification.

Annie Oakley II and Clemson Spineless fruits were classified mostly in correspondence with the “very small”, “small” and “medium” groups of the USDA classification. Emerald fruits were divided into a higher number of categories and in this case the proposed classification showed a better adjustment with the USDA categories (Table 1).

Provisions concerning sizing from the Thai Agricultural Standard (TAS 1501-2004) state three size codes as follows: size code 1 (pod length -excluding peduncle- >12-14 cm); size code 2 (pod length -excluding peduncle- >10-12 cm); size code 3 (pod length -excluding peduncle- ≤10 cm).

Concerning fruit diameter, LV and Clemson Spineless fruits had similar diameters (1.6-2.1 cm), showing LV fruits lower L/D ratio. Amongst the assayed material, Emerald cultivar had the highest L/D ratio. The practical guide to export okra to USA (IICA, 2006) mentions that the minimum standards for okra pods specify about half an inch (1.27 cm) in diameter for fruits classified into U.S. Nº 1. Díaz-Franco et al. (1997) have pointed out that some okra processing companies in South Texas require small diameter and fruit length comprised between 8.9-12.7 cm; smaller fruits are often accepted but bigger fruits are rejected. Taking into account these criteria, cultivars Clemson Spineless and Emerald would be suitable for processing purposes.

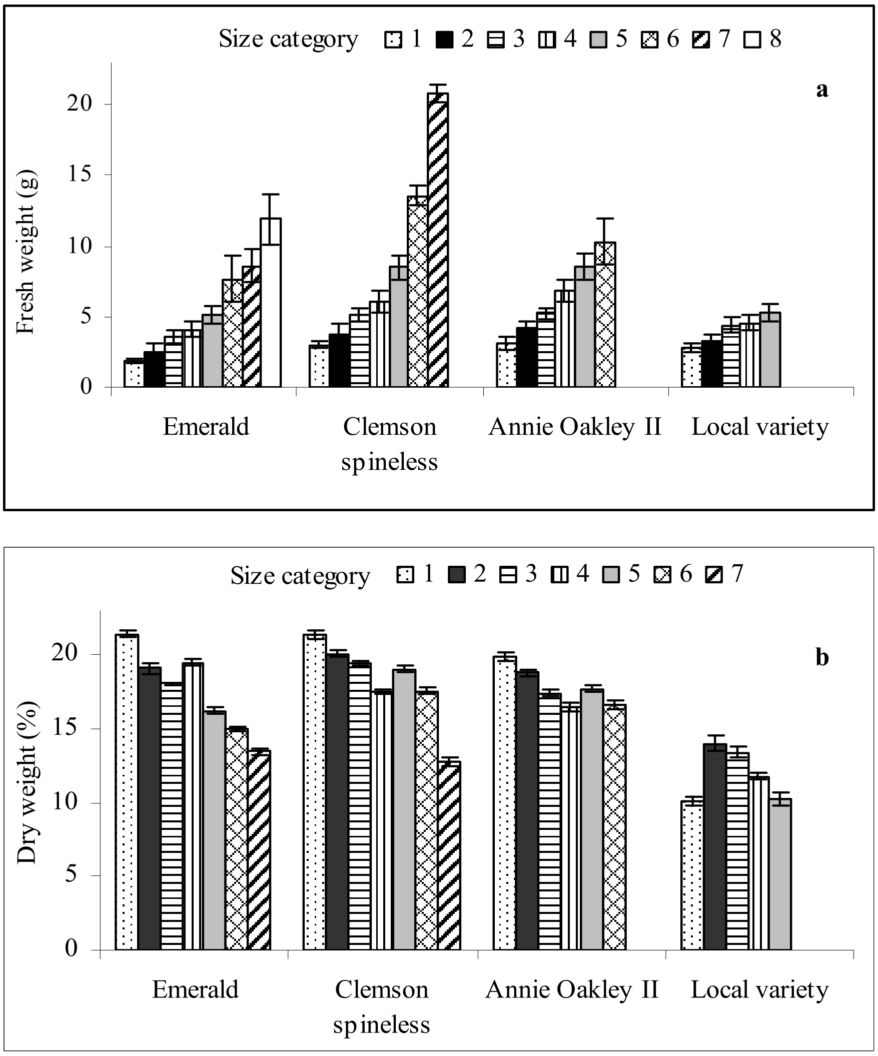

Figure 2. a) Mean fresh weight (g) and b) Dry matter content (%) of okra fruits according to cultivar and size category. Error bars represent the standard deviation of the reported values

Figure 2a shows the average fresh weight values for different cultivars and their size categories. When comparing fruits of the same size (categories 1 to 6) of the commercial varieties, the fruits of Clemson Spineless and Annie Oakley II showed higher ($p<0.05$) fresh weight than the fruits of Emerald. There was no significant difference between fresh weight of Clemson Spineless and Annie Oakley II except for the category 6 (8 to 10 cm).

Lowest fresh weight was found for the smallest fruits of Emerald. Although LV had smaller fruits than Emerald, LV fruits showed significantly higher values of fresh weight. The mean increase per category on fruit fresh weight for the first five categories were 0.6 g for LV, 0.8 g for Emerald and 1.4 g for Annie Oakley II and Clemson Spineless. For Clemson Spineless and Emerald cultivars the increases on fruit fresh weight were more notorious from group 6 on.

Figure 2b shows dry matter content of okra fruits depending on cultivar and size category. Results revealed that most fruit categories of cultivars Emerald, Clemson Spineless and Annie Oakley II had more than 15% of dry matter content. There was no significant difference ($p>0.05$) on dry matter content of fruits from the same size belonging to the cultivars Emerald, Clemson Spineless and Annie Oakley. None of the categories of the local variety fruits reached 15% of dry matter content.

Results from total ash content quantification are shown in Table 2. Total ash levels found in this work for cultivars Emerald and Clemson Spineless were similar to those reported by Moyin-Jesu (2007) for okra crops fertilized with NPK 15-15-15, wood ash, cocoa husk and spent grain. For cultivars Emerald and Clemson

Spineless, total ash content was significantly higher in the smaller fruits. The hybrid Annie Oakley II had the highest ash content ($p<0.05$) in all the analyzed categories. Regardless the cultivar, the ash levels found in whole okra pods were significantly higher than the contents found in okra seed flour by Adelakun et al. (2009).

Table 2. Total ash content (g/100g dry basis) of okra fruits from commercial cultivars according to size category

Size category	Total ash content (g/100g db)		
	Emerald	Clemson Spineless	Annie Oakley II
1+2	8.1±0.1 a,x	8.1±0.1 a, x	8.6±0.1 a, y
3+4	7.1±0.1 b,x	7.7±0.1 b, y	8.6±0.1 a, z
5+6	7.5±0.1 c,x	7.5±0.1 b, x	8.3±0.1 b, y
7+8	7.3±0.1 bc,x	8.0±0.1 a, y	--

Note: reported values correspond to the mean ± standard deviation. Values followed by the same letters in a column (a, b, c) or in a row (x, y, z) do not differ significantly ($p>0.05$). Fruit size categories 1+2, 3+4, 5+6 were grouped. For cultivar Emerald categories 7+8 were grouped too.

According to the results of minerals quantification, the major element within those tested was potassium followed by calcium, magnesium and sodium (Table 3). Sen and Mukherji (2002) have pointed out that in okra fruits the mineral contents were in the order of P > K >Ca> Mg > Na > Fe, which also signify their relative functional importance in growth and metabolism.

Table 3. Ca, K, Mg and Na content (mg/100g on dry basis) of okra fruits from commercial cultivars according to size category

Size category	Ca (mg/100g db)			K (mg/100g db)			Mg (mg/100g db)			Na (mg/100g db)		
	Emerald	Clemson Spineless	Annie Oakley II	Emerald	Clemson Spineless	Annie Oakley II	Emerald	Clemson Spineless	Annie Oakley II	Emerald	Clemson Spineless	Annie Oakley II
1+2	$657±16.2^{a,x}$	$715±32.1^{a,y}$	$909±1.7^{a,z}$	$1971±8.1^{a,x}$	$2089±241.1^{a,x}$	$2444±9.4^{a,y}$	$414±8.1^{a,x}$	$434±16.1^{a,x}$	$309±7.7^{a,y}$	$19±0.8^{a,x}$	$18±1.6^{a,x}$	$32±6.8^{a,y}$
3+4	$573±7.1^{b,x}$	$662±30.8^{a,y}$	$871±17.0^{b,z}$	$1720±56.6^{b,x}$	$2308±230.8^{a,y}$	$2443±127.7^{a,y}$	$375±7.1^{b,x}$	$400±7.7^{b,y}$	$343±25.5^{b,x}$	$15±0.7^{b,x}$	$21±3.8^{a,y}$	$30±0.3^{a,z}$
5+6	$556±30.1^{b,x}$	$671±74.6^{a,y}$	$577±21.4^{c,xy}$	$1827±52.6^{b,x}$	$2089±149.2^{a,y}$	$2381±82.1^{a,z}$	$414±30.1^{a,x}$	$410±22.4^{ab,x}$	$328±39.4^{ab,y}$	$18±0.8^{a,x}$	$14±1.5^{b,y}$	$29±1.6^{a,z}$

Note: reported values correspond to the mean ± standard deviation. Values followed by the same letters in a column (a, b, c) or in a row (x, y, z) do not differ significantly ($p>0.05$). Fruit size categories 1+2, 3+4, 5+6 from cultivars Emerald and Clemson Spineless were grouped.

For cultivars Emerald and Annie Oakley II, the smallest fruits (categories 1+2) had significantly higher Ca content than fruits from larger categories (Table 3). Ca levels of Clemson Spineless fruits did not vary significantly with fruit size. When comparing Ca contents from different cultivars, they followed the order Annie Oakley II > Clemson Spineless > Emerald, for fruit size categories 1+2 and 3+4.

For categories 1+2 and 5+6, Annie Oakley II fruits had the highest potassium and sodium content. Conversely, they showed the lowest magnesium level. Considering a recommended daily intake (RDI) of 2g of K for an adult organism, the consumption of 100 g of fresh okra would cover about 25% of the RDI.

Table 4 shows maximum shear force (MSF) of okra fruits belonging to different cultivars and size category. In some crops, fibre content increases with maturity, which can result in undesirable texture if the crop is harvested at a stage which is too mature. For example, crops such as peas, asparagus, beans, and broccoli become fibrous and tougher with advancing maturity (Sams, 1999). Tenderness is one of the attributes mostly valued for fresh market destination and maximum shear force was considered an indicator of the tenderness of okra fruits. Results showed that there were no significant differences between MSF values of different fruit size categories for Emerald, Clemson Spineless and LV okra samples. Conversely, maximum shear force of Annie Oakley II fruits significantly increased with fruit size (between categories 2-3 and 4-5).

Although LV fruits were smaller in size, they had significantly higher maximum shear force values, thus they were less tender. High maximum shear force values for LV fruits were the limiting factor when considering larger fruits in the classification proposed in this paper.

When comparing fruits of the same size from the commercial varieties, the tenderest fruits belonged to the hybrid Annie Oakley II for categories 1 and 2 and to Annie Oakley II and Emerald from higher categories (Table 4).

Plant nutrition has a major influence on fruit and vegetable quality. According to Sams (1999), calcium is directly involved in strengthening plant cell walls through its ability to cross link with pectins by ionic association between C'6 carboxyl groups of inter and intra galacturonosyl residues. The cellular role of calcium in maintaining firmness is supported by the fact that postharvest calcium treatments, which increase fruit calcium, maintain fruit firmness in a wide variety of fruits. Nevertheless, excessive potassium content, relative to calcium, has been reported to increase the occurrence of fruit disorders associated with undesirable texture (Sharples, 1984; Clark & Smith, 1990). From this point of view, the nutrients balance registered for Annie Oakley fruits seemed to be adequate, since they showed the highest contents of calcium and potassium without undesirable consequences on fruit tenderness.

Table 4. Maximum shear force (N) of okra fruits according to cultivar and size category

Size category	Maximum Shear Force (N)			
	Emerald	Clemson Spineless	Annie Oakley II	Local variety
1	35±5.3 a,x	38±3.3 a, x	25±3.3 a, y	47±7.5 a, x
2	33±1.9 a,x	38±5.5 a, y	27±3.5 a, z	54±5.1 a, y
3	37±3.2 a,x	43±7.1 a, y	35±2.7 b, x	64±5.1 a, z
4	36±3.5 a,x	47±5.1 a, y	34±2.7 b, x	68±9.0 a, z
5	38±5.4 a,x	49±3.2 a, y	42±4.0 c, x	64±6.2 a, z
6	41±5.8 a,x	54±7.4 a, y	48±7.2 c, xy	--
7	38±5.3 a,x	56±6.1 a, y	--	--
8	49±11.2 a,x	--	--	--

Note: reported values correspond to the mean ± standard deviation. Values followed by the same letters (a, b, c) in a column or in a row (x, y, z) do not differ significantly ($p>0.05$).

Regarding surface colour determinations (Table 5), Emerald and Clemson Spineless cultivars showed no significant differences in the coordinate L* (lightness) between different categories. Coordinate L* of Annie Oakley II fruits increased between categories 1 and 2 and, for LV fruits, L* value differed significantly when comparing categories 1 and 5.

Table 5. L*, hue and Chroma values of okra fruits from commercial cultivars and a local variety according to size category

Size	Emerald			Clemson Spineless			Annie Oakley II			Local Variety		
category	L*	hue (°)	Chroma	L*	hue (°)	Chroma	L*	hue (°)	Chroma	L*	hue (°)	Chroma
1	51.4±2.9^{a,x}	117.0±1.1^{a,x}	32.8±2.3^{a,x,y}	49.8±1.0^{a,x}	115.3±2.6^{a,x}	36.2±2.1^{a,x}	39.8±2.8^{a,y}	116.7±3.2^{a,x}	30.5±3.1^{a,y}	52.9±2.3^{a,x}	119.9±1.6^{a,x}	34.5±2.8^{a,x,y}
2	51.4±3.3^{a,x}	119.0±0.9^{a,b,x,z}	33.9±3.1^{a,x}	50.7±1.7^{a,x}	115.4±1.4^{a,y}	36.0±2.4^{a,x}	47.7±4.7^{b,x}	116.8±1.3^{a,x,y}	35.0±3.6^{a,b,x}	53.8±1.8^{a,x}	120.1±1.2^{a,z}	38.4±2.8^{a,b,x}
3	54.3±3.1^{a,x}	118.0±0.8^{a,b,x}	34.5±1.6^{a,x}	52.5±2.6^{a,x}	116.5±1.7^{a,x}	35.6±1.6^{a,x}	50.1±2.8^{b,x}	118.1±2.2^{a,b,x}	35.5±2.1^{a,b,x,y}	55.6±3.1^{a,x}	119.2±1.7^{a,x}	40.6±3.1^{b,y}
4	51.9±5.5^{a,x}	120.0±3.1^{a,b,x,y}	33.0±3.6^{a,x}	52.6±2.1^{a,x}	117.0±1.5^{a,x}	36.6±1.7^{a,x}	51.3±2.6^{b,x}	118.5±1.3^{a,b,x,y}	36.4±2.6^{b,x}	58.4±3.8^{a,b,x}	119.7±0.9^{a,y}	41.4±1.7^{b,y}
5	50.1±4.3^{a,x}	119.6±3.1^{a,b,x}	32.2±2.1^{a,x}	48.4±3.4^{a,x}	119.8±3.2^{a,b,x}	33.4±3.2^{a,x,y}	51.2±1.1^{b,x}	119.3±0.5^{b,x}	37.9±1.3^{b,y}	62.8±2.7^{b,y}	117.9±1.6^{a,x}	43.3±2.3^{b,z}
6	53.4±4.2^{a,x}	119.1±0.8^{b,x}	35.0±2.9^{a,x}	52.4±5.2^{a,x}	120.1±2.9^{a,b,x}	35.0±3.3^{a,x}	51.8±2.8^{b,x}	119.2±0.9^{b,x}	38.4±2.1^{b,x}	--	--	--
7	46.7±6.0^{a,x}	122.1±3.3^{b,x}	29.5±5.6^{a,x}	51.8±0.7^{a,x}	120.2±1.2^{b,x}	36.5±0.5^{a,y}	--	--	--	--	--	--
8	50.6±3.6^{a,x}	120.7±1.0^{b,x}	32.7±2.7^{a,x}	--	--	--	--	--	--	--	--	--

Note: reported values correspond to the mean ± standard deviation. Values followed by the same letters in a column (a, b, c) or in a row (x, y, z) do not differ significantly (p>0.05).

Figure 3 shows total phenols and flavonoids content measured for okra fruits from LV and Annie Oakley II cultivars and they were determined for the smallest, medium and largest fruits categories. LV was selected for this determination since it is the most adapted material amongst the assayed ones and its seeds are easily available at a relatively low cost. Annie Oakley II was selected as the cultivar that showed highest uniformity and very good quality characteristics.

Total phenols levels (Figure 3a) significantly increased with fruit size in LV fruits, meanwhile no significant difference was observed for Annie Oakley II samples. Total flavonoids content (Figure 3b) showed a similar tendency, although values did not differ significantly. Total flavonoids represented between 18-22% of the total phenols contents for the analyzed samples. Both phenols and flavonoids levels were significantly higher in Annie Oakley II than LV fruits, considering the smallest fruit category. Conversely, for the largest fruit category Annie Oakley II fruits had lower total phenols and flavonoids contents than LV fruits.

According to Martins et al. (2011), great attention has been paid to bioactive compounds such as phenolics due to their ability to reduce the incidence of some degenerative diseases like cancer and diabetes. They also show antioxidant, anti-mutagenic, anti-allergenic, anti-inflammatory, and anti-microbial effects, among others (Martins et al., 2011). Due to these countless beneficial characteristics for human health, researches have been intensified aiming to find fruits and vegetables as sources of bioactive phenolic compounds (Martins et al., 2011).

Sreeramulu and Raghunath (2010) evaluated the antioxidant activity and phenolic content of 19 vegetables commonly consumed in India and okra fruits (ladies finger) were ranked on the third place according to their phenolic content (167.70 mg gallic acid /100 g), behind red cabbage and broad beans.

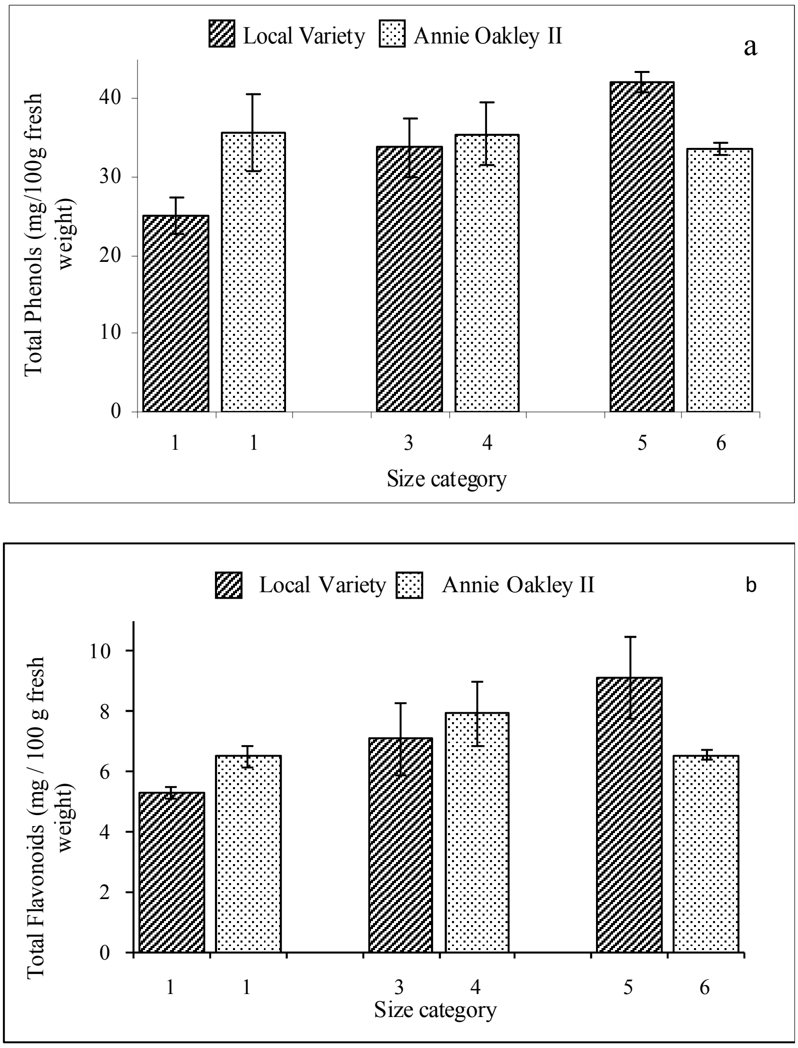

Figure 3 a) Total Phenols content (mg/100g fresh weight) and b) Total Flavonoids content (mg/100g fresh weight) of Local Variety (size categories 1, 3 and 5) and Annie Oakley II (size categories 1, 4, 6) okra fruits. Error bars represent the standard deviation of the reported values

4. Conclusions

In general, the classification developed by the USDA considers longer okra fruits than the ones used in the present work. As can be seen, LV fruits were considerably smaller than the first category pointed out by the USDA classification. Longer fruits of the LV had a markedly higher firmness, and they would not be suitable for fresh consumption. However, small fruit consumption is common locally.

The proposed classification based on fruits length was intended to establish a theoretical relationship with the use assigned to the product. Thus, smaller whole fruits could be used for canning or pickling. Fruits of intermediate size would be suitable for fresh consumption unless they develop excessive fibrousness, as well as fruits showing high fresh weight. On the other hand, larger fruits could be processed into slices, provided they are uniform.

The hybrid material (Annie Oakley II) would be more suitable for fresh consumption, since its fruits showed lower fibrousness. The texture of the largest fruits of Annie Oakley II was comparable to the texture of the smallest fruits of the local variety (LV).

Likewise, Annie Oakley II fruits would be a suitable material for dehydration because of its high dry matter content, regardless of fruit size. Both local variety and Annie Oakley II fruits would adapt to freezing.

Acknowledgements

Authors thank the financial support given by Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), UNLP and Agencia Nacional de Promoción Científica y Tecnológica (ANPCyT), from Argentina.

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