State Of Knowledge Report

State Of Knowledge Review

The East African Highland Cooking Banana (Matooke)

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ABSTRACT

The East African highland cooking bananas are a major source of carbohydrate for over 30 million people in East Africa and is mainly utilised at mature green stage. Its’ fruit composition show low levels of fat, protein and tannin but high amounts of starch at over 80% on dry basis. At cellular level, the fresh raw matooke fruit displays well packed and turgid cells. Microstructure examination of matooke and non-matooke brewing bananas reveal that the brewing banana contain more intensely stained and larger laticifer cells than matooke bananas, which could explain their differences in amounts of latex and levels of astringency. Astringency is an easy indicator used to differentiate cooking and non-cooking bananas In Uganda. Matooke starch diameter ranges between 16.31 and 21.98 μm with amylose content of between 11% and 13%, peak viscosity of between 488.4 and 558.7 RVU, pasting temperatures at <75°C and high level of viscosity breakdown (235.0–311.9 RVU). The matooke starches also exhibit low set-back values (61.2–104.3 RVU), maximum swelling power at 12.4–14.3 g water/g starch and solubility of 12.5%–14.2% values obtained at 90°C. The onset temperature for gelatinization of the matooke starches was 65.7°C compared to 59.7 - 67.8°C, other bananas. Matooke are prepared by harvesting at mature green stage, peeling and boiling or wrapping in banana leaves and steamed; and eaten with a stew. Preferred attributes of matooke include a uniquely insipid taste, golden yellow appearance and a tender texture. These attributes are described by scientists as ‘tookeness’ a term stemming from the term ‘matooke’ used to describe a cooked meal of the EAHCB. Any new hybrids that do not meet these attributes are rejected by consumers. The biochemical components that underpin these attributes remain unknown. This has impacted on the ability to breed and select banana hybrids that combine agronomic and consumer preferred attributes. Most compositional studies have used different methods, making it difficult to compare the results. There is no reliable literature on studies relating composition and sensory attributes of matooke bananas, making it difficult to associate composition attributes with sensory attributes, making such research imperative. The RTB Food project aims to bridge this gap.

1 INTRODUCTION

The East African Highland cooking banana (EAHCB) belongs to the triploid genome group 'AAA'; of bananas and is uniquely adapted to the highlands of the East African Great Lakes region (Karamura, 1999). Over 30 million people subsist on the crop as their principal source of dietary carbohydrate. There are many clones of the East African highland banana cultivars, but the cooking varieties fall in four *distinct clone groups (Karamura et al , 1999), namely 'Nakitembe' characterized by a male inflorescence rachis with persistent neuter flowers and imbricate male bud;* 'Nakabululu' characterised by sub-horizontal bunch orientation and ovate male buds; 'Musakala' characterized by truncate or cylindrical bunch shapes and slender fruits with bottle-necked apices and 'Nfuuka' characterized by rectangular compact bunches, inflated or rounded fruits with intermediate shaped apices. They are all considered members of the Musa sub-group AAA (Karamura, 1999, Stover and Simmonds, 1987). Recently, new hybrids have been developed by the National Agricultural Research Organisation (NARO)-Uganda, using classical breeding tools by improving the landrace cultivars above. Some of the newly developed Matooke hybrids include M9 and M2; which have been released to farmers (Note: M stands for matooke hybrid).

The EAHCB matures in 12-15 months from plant sucker emergency to harvest maturity. The fruits are harvested when still green. According to farmers, a banana bunch is ready for harvesting when the fingers appear more round i.e. the disappearance of angularity. A bunch is cut from the plant, fingers plucked off, peeled, and washed or not. The peeled banana is either put in a saucepan or boiled with/or without a sauce (commonly beans, peas, ground nuts, meat), or wrapped in banana leaves, steamed, mashed and eaten with a sauce (Nowakunda et al. 2004). This is the most common food eaten in Uganda (and areas around the great lakes region of East Africa).

Information reported in this state of knowledge review was obtained through reviews of previous research reports (2), journal papers (8) and books (3). This was complimented with Interactions with key informants selected among farmers, traders, researchers and extension agencies.

2 COMPOSITION AND STRUCTURE OF RAW MATERIAL

2.1 Composition

Compositional data (Tables 1,2 and 3) of the East African Highland cooking bananas (matooke) show low levels of fat and protein (Komatsu *et al,* 2010). The data also show starch contents of over 80% (dB) and while generally exhibiting high levels of potassium (Dufour et al. 2009; Komatsu et al, 2010).

Matooke bananas have low levels of amylose content, ranging between 11-13% (Komatsu*et al.* 2010) compared to other bananas, most of which range between 15-24% (Dufour et al, 2009). The low levels of amylose minimise cooking loss in pre-gelatinisation process. Also, amylose has a large influence on the starch properties due to its structural contribution to the amorphous component of the starch granules (Komatsu*et al.* 2010).

Table 1. Composition (dB, %) of East African Highland Cooking Banana

Cultivar	Starch	Protein	Fat	Crude fibre	Ash	Ca	K	Mg	Tannins *(abs @500nm)*
Embururu	82.9	4.01	0.56	1.33	4.1	0.0052	1.84	0.01	0.012
Nakhaki	83.9	3.99	TR	1.11	4.09	0.0053	1.71	0.09	0.192
Nandigobe	81.8	4.71	0.87	1,25	4.34	0.058	1.9	0.09	0.111
Bukumu	*82.5*	*5.1*	*ND*	*ND*	*3.58*	*0.0044*	*1.82*	*0.09*	0.181
+Guineo	*84.1*	*4.09*	-	*2.5*	*3.9*	*0.018*	*1.11*	*0.11*	-

Source: Komatsu *et al.(2010), + Guineo from Gibert et al (2009)*

Table 2. Chemical analysis of the EAHB starch from five cultivars (Sonko and Muranga, 2017)

Starch origin	Starch DB (%)	Amylose (%)	Ash (%)	Protein (%)	Lipids (%)
Mbwazirume	99.6^{a}	11.96^{a}	0.37^{a}	0.1^{a}	ND
Mpologoma	99.4^{b}	12.13^{b}	0.47^{b}	0.1^{a}	ND
Enyeru	99.5^{a,b}	12.83^{c}	0.37^{a}	0.1^{a}	ND
Bukumu	99.7^{a}	12.74^{d}	0.24^{c}	0.1^{a}	ND
Nandigobe	99.[1]6^{a}	12.59^{e}	0.23^{c}	0.1^{a}	ND

Matooke bananas have low condensed tannin content (Kyamuhangire et. al., 2006, Komatsu, et al., 2010). Condensed tannins in ripe and unripe matooke and non-matooke bananas determined using the spectrophotometric method (Kyamuhangire et al (2006) indicated that the water extractible condensed tanning ranged between 0.521- 0.544 (g kg−1 dry basis, as tannic acid) in unripe matooke bananas and 0.799 - 0.841(g kg−1 dry basis, as tannic acid) in non-matooke bananas (Table 3).

Table 3.Levels of water-extractable tannins (g kg−1 dry basis, as tannic acid) in unripe and ripe fruits, spent pulp and juice of different banana cultivars (Kyamuhangire et al, 2006)

Banana cultivar `	**Tannin content *(*gkg−1*)***			
	Unripe	Ripe	Spent pulp	Juice
Non-matooke				
Kayinja	0.841	4.799	1.439	0.838
Katalibwambuzi	0.634	1.182	0.700	0.979
Matooke				
Musakara	0.544	0.576	NA	NA
Kibuzi	0.521	0.834	NA	NA

LSDb (*P* = 0.05) 0.18 0.25 0.31 0.35

[1]Methods : Chemical analysis according to *AOAC, 1995*

Komatsu*et al,* 2010, using the Vanillin assay method, reported absorbance values of 0.012 and 0.111 for unripe matooke bananas and 0.192 and 0.181 for non-matooke bananas (Table 3). Both results indicate low levels of intensity of condensed tannins in matooke bananas which render the cooked matooke free from bitterness/astringency a key criteria that differentiate matooke from non-matooke bananas.

2.2 Structure

2.2.1 Cellular structure of matooke bananas

Under microscope, raw fresh banana displays well packed and turgid cells that could account for the firm texture of raw bananas (Figure 1).

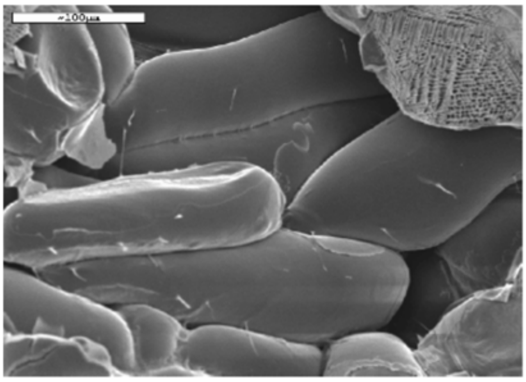

Figure 1. Scan electron micrograph of a cross-section of raw matooke banana *Musakara*

A microstructure examination (Kyamuhangire et al. 2006) of two East African Highland bananas, *Mbidde (Kataribwambuzi,* non-cooking bananas used for juice or brewing) and *Matooke* cultivars showed that the *Mbidde* bananas contained many more intensely stained and larger laticifer cells (LL in pictures below) than pulp tissues of *Matooke banana* (Figure 2).This could explain the differences in amounts of latex found the two types of bananas. Presence of latex and astringency is an easy indicator used to differentiate cooking and non-cooking bananas In Uganda.

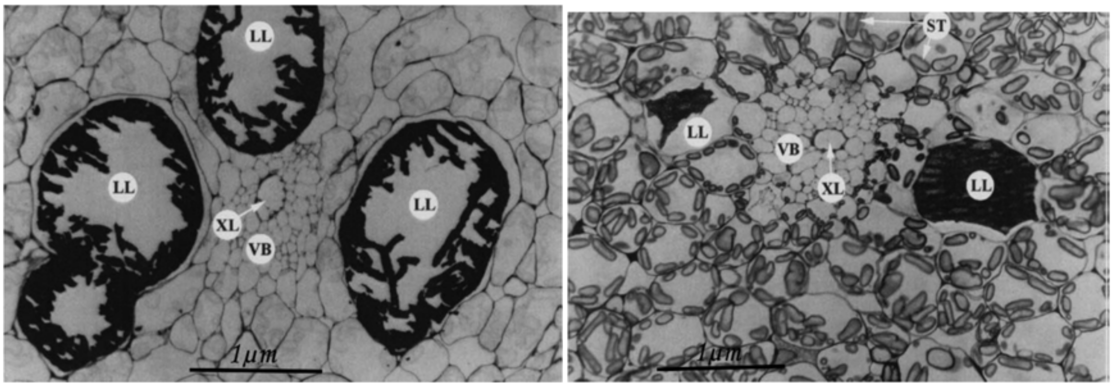

Figure 2. Light micrographs of longitudinal sections of *Mbidde* (a) Katalibwambuzi and (b) *Matooke (*Kibuzi). LL is laticifer, VB are vascular bundles, and XL is xylem vessels while ST is the starch grains.

2.2.2 Starch of matooke bananas

Size and physical behaviour: The average diameter size of starches from five matooke varieties ranged between 16.31 and 21.98 µm. Amylose content was between 11% and 13%, peak viscosity ranged between 488.4 and 558.7 RVU, pasting temperatures (<75°C), a high peak viscosity (488.42–558.71 RVU), high level of viscosity breakdown (235.0–311.9 RVU) and low set-back values (61.2–104.3 RVU), maximum swelling power (12.4–14.3 g water/g starch) and solubility (12.5%–14.2%) values obtained at 90°C (Ssonko and Muranga, 2017).Comparatively, Dufour et al. (2009) reported the onset temperature for gelatinization of starches measured by differential scanning calorimetry (DSC) to vary from 59.7 to 67.8°C, at 63.2°Cfor dessert banana and by 65.7°Cfor cooking bananas. The pasting temperature was 69.5°Cfor dessert bananas and 72.8°C for non-plantain cooking bananas

Native starch under heating: Swelling Power: Matooke bananas exhibited maximum swelling power at 90°C (Table 4). Differences between the different matooke clones were apparent after 70°C.The maximum swelling power was obtained at 90°C (12.43–14.27 g water/g starch) (Ssonko and Muranga, 2017). These are similar to those observed in other banana varieties as reported by Sabrina et al, 2017 and Dufour et al., 2009).

Table 4. Swelling power of native starch from matooke banana (Ssonko and Muranga, 2017)

Sample	50°C (g/g)	60°C (g/g)	70°C (g/g)	80°C (g/g)	90°C (g/g)
Mbwazirume	0.69[a]	0.86[a]	2.45[a]	8.87[a]	12.61[a]
Mpologoma	0.72[a]	0.79[a]	2.84[b]	7.48[b]	12.43[a]
Enyeru	0.70[a]	0.85[a]	3.28[c]	7.68[b]	14.27[b]
Bukumu	0.74[a]	0.82[a]	2.93[b]	7.75[b,c]	13.98[c]
Nandigobe	0.76[a]	0.78[a]	3.89[d]	8.95[a]	14.10[b]

starch solubility at 50-90^{0}C: As Table 5 below shows, the starch solubility of the EAHB cultivars varied from 0.65% to 14.19% in the 50°C to 90°C temperature range. At ≤70°C, the starch solubility increased only slightly (2.48%–3.8%), however, at 80°C the starch solubility of all the EAHB cultivars increased considerably (7.53%–8.9%). The maximum starch solubility (12.52%–14.19%) for all cultivars was observed at 90°C and at temperatures beyond or equal to 70°C (Ssonko and Muranga, 2017, Gafuma *et. al.* 2018).

Table 5. Matooke starch solubility (Ssonko and Muranga, 2017.

Starch source	50°C (%)	60°C (%)	70°C (%)	80°C (%)	90°C (%)
Mbwazirume	0.65[a]	0.85[a]	2.48[a]	8.80[a]	12.80[a]
Mpologoma	0.68[a]	0.80[a]	3.80[b]	8.90[a]	12.52[a]
Enyeru	0.69[a]	0.85[a]	3.26[c]	7.67[b]	14.14[b]
Bukumu	0.74[a]	0.80[a]	2.90[d]	7.92[b]	13.90[b]
Nandigobe	0.65[a]	0.82[a]	2.88[c]	7.53[b,c]	14.19[b]

Banana starch pasting profile: Matooke starches exhibit gradual viscosity increase with increasing temperature (Ssonko and Muranga 2017). Peak viscosity has been observed at between 488.42 and 558.71 RVUs for different matooke bananas. As table 6 shows, matooke bananas exhibit high pasting temperatures, a high peak viscosity, high level of viscosity breakdown and lower set-back values (Ssonko and Muranga, 2017). These results agree with those obtained by Dufour et al, 2009), who reported pasting temperature of 72.8°C for non-plantain cooking bananas compared to 69.5°C for dessert bananas and 75.8°C for plantains

Table 6. Pasting properties of starches from five matooke bananas (Ssonko and Muranga, 2017)

Sample	Pasting time (min)	Pasting temperature (°C)	Peak viscosity (RVU)	Minimum viscosity (RVU)	Final viscosity (RVU)	Breakdown viscosity (RVU)	Setback viscosity (RVU)
Mbwazirume	4.67[a]	74.50[a]	492.08[a]	215.08[a]	319.42[a]	277.00[a]	104.33[a]
Mpologoma	4.60[b]	73.05[b]	488.42[a]	242.71[b]	314.13[b]	245.71[b]	71.42[b]
Enyeru	4.64[c]	74.48[a]	510.79[b]	221.88[c]	325.33[c]	288.92[c]	103.46[a]

Sample	Pasting time (min)	Pasting temperature (°C)	Peak viscosity (RVU)	Minimum viscosity (RVU)	Final viscosity (RVU)	Breakdown viscosity (RVU)	Setback viscosity (RVU)
Bukumu	4.62^{d}	73.90^{c}	520.08^{c}	285.08^{d}	363.33^{d}	235.00^{d}	78.25^{c}
Nandigobe[2]	4.44^{e}	70.20^{d}	558.71^{d}	246.79^{e}	308.00^{e}	311.92^{e}	61.21^{d}

3 PROCESSING CONDITION

The process for processing matooke (Figure 3):

a) Mature green bananas are harvested, dehanded and individual fingers peeled with a knife to remove the inedible part-the peel. This is done by first cutting off the tips at each end. The skin is then removed by cutting along the length of the skin from the upper tip to the lower end. This is done carefully with a knife to ensure it does not cut deeply into the flesh of the banana.
b) It is then wrapped in fresh banana leaves using banana fibres and put in a saucepan for steaming. The midrib of the banana leaves or the peduncle are removed and put at the base of the saucepan. This is for good steaming to ensure they do not get in direct contact with the cooking water.
c) It is steamed for about one and half hours
d) It is mashed/pressed using hands while still in the wrap to ensure uniformity of the mash.
e) It is then put back on fire to cook again for about an hour. This time the fire is little, just enough to keep it hot since it is already cooked.

Figure 3. Processing Matooke

[2]**Methods:** Pasting properties by Rapid Visco Analyser (RVA-4, 1998, Newport Scientific Pty. Ltd, Australia), Solubility and swelling power done according to Waliszewski et al., 2003.

4 PRODUCT CHARACTERIZATION AND RELATIONSHIP WITH SENSORY EVALUATION

4.1 Sensory analysis and consumer preference

Figure 4 A community shares out cooked EAHCB at a village function in Uganda

When cooked, the matooke bananas are characterized by a unique insipid taste and aroma, golden yellow colour and a tender texture (Table 7). These attributes have endeared an EAHCB meal to consumers and constitute the unique quality described as 'tookeness' (NBRP, 2007), originating from the term 'matooke' used to describe a cooked meal of the EAHCB. Any consumers look for these attributes in the hybrids. Most of the banana hybrids developed so far have been rated by consumers as inferior to EAHCB with respect to nearly all sensory attributes implying that they lack the 'tookeness' qualities (Nowakunda *et al*. 2000, Nowakunda and Tushemereirwe, 2004). Only one hybrid (M9) combines moderate pest and disease resistance with high 'tookeness' attributes. However, it is strongly believed that some appropriate hybrids could have been missed among the hundreds of matooke lines that had the right pest/disease resistance but were discarded after failing to sail through taste panels. A more precise tool for use in screening generated genotypes for 'tookeness' taste would increase the chances of selecting an acceptable hybrid at least three fold and would reduce selection time from about 10 years to about 6 years.

Table 7. Consumer preferred sensory attributes of raw and cooked matooke

Product	Sensory attributes	References
Raw matooke banana	1. Smooth skin 2. Deep green skin 3. Easy to peel 4. Straight or slightly curved fingers 5.Big and not very short fingers (Better cvs : *Muvubo*, *Musakala* and *Nakitembe)* *6. Yellowish appearance when peeled*	1.Feed back from matooke consumers (NARO) 2. Ssemwanga et al, 1994) 3. Nowakunda *et al* 2004 4. Akankwasa, 2014
Cooked Matooke	1. Golden yellow 2. Soft texture 3. Flat taste (Insipid), no astringency 4. Good aroma	

A high yielding banana hybrid FHIA 03 introduced in Uganda in 1990s was compared with the landrace matooke bananas using both trained and untrained consumer panels. Attributes evaluated by the consumers included softness, lumpiness, stickiness, sweetness, astringency, aroma, yellow color intensity, color uniformity and overall acceptability Ssemwanga et al, 1994, Ssemwanga et al, 2000). The panels also evaluated the physical attributes including bunch compactness and fruit sheen which are known to be important in the market. The results indicated that whereas appreciated some of the physical attributes such as size, they rejected the hybrid, mainly due to astringency and poor appearance of the cooked product.

4.2 Instrumental Texture assessment and relationship with sensory evaluation

The hardness of 11 raw matooke bananas was measured (Gafuma et al, 2018) using a texture analyser Texture Analyzer (*TA.XTplus stable micro-systems, Surrey, UK*). The methodology used involved penetration using a penetration probe (6 mm diameter). The Texture Analyzer was set in *Return-to-start* mode with the following test settings:-penetration distance into the sample -20 mm, pre-test speed –1.0 mm/s, test speed into sample –2.0 mm/s, post-test speed –10 mm/s, a trigger force of 0.049 N and calibrated using a 2 kg load cell. Banana samples were positioned in the middle of the Texture Analyzer platform and commanded to start. The measurements were performed in duplicate using two independent samples. The profile of the force in form of texture curves was monitored on a Personal Computer (PC) interfaced to the Texture Analyzer and the force needed to fracture or penetrate the banana sample was recorded as the first peak under the force-time curves and was taken as the hardness of the sample

The results showed (Gafuma *et al.,* 2018) that the raw non-cooking banana (the juice bananas) were significantly harder (36.1 N - 42.43 N) than the matooke bananas (22.30 N - 26.72 N) (Table 8). In Uganda, the term ‘Juice bananas’ is used to refer to both East African high land non-matooke (*Mbidde*) bananas and introduced varieties used for juice extraction and brewing.

Table 8. Textural hardness of raw matooke bananas and non-matooke bananas (bold characters) (Gafuma *et al.*, 2018)

Local name	***Clone set***	**Textural Hardness (N)**
Namande	*Nfuuka*	23.81abc± 3.19
Nakawere	*Nfuuka*	22.81ab± 1.98
Namweezi	*Nfuuka*	22.80ab± 1.97
Nakitembe	*Nakitembe*	25.40abc± 1.49
Nakyetengu	*Nakitembe*	22.53ab± 2.79
Kibuzi	*Nakitembe*	22.37a± 1.59
Musakala	*Musakala*	25.10abc± 1.00
Mpologoma	*Musakala*	23.65abc± 1.50
Kisansa	*Musakala*	26.00bc± 2.03
Nakabululu	*Nakabululu*	26.36bc± 1.98
Kazirakwe	*Nakabululu*	25.14abc± 1.15
Kisubi	**Ney Poovan AB**	**36.17d± 1.45**
Ndiizi(Apple banana)	**Ney Poovan AB**	**42.43e± 3.73**
Kayinja	**Bluggoes ABB**	**36.86d± 2.16**

All banana cultivars both cooking and non-cooking (juice banana) were subjected to boiling, steaming and mashing treatments and sampled for hardness tests at 30, 50, 70, 90, 110 and 130 min. The boiling temperature ranged between 97 to 98°C while that of steaming ranged between 98 to 99°C. Boiling caused a rapid decrease in textural hardness of all bananas, again, the non-cooking bananas (Juice bananas) were significantly harder than the matooke cooking bananas (P<0.05) (Table 9) (Gafuma et al, 2018).

Table 9. Changes in textural hardness of selected indigenous cooking and juice banana cultivars during "boiling"(Gafuma *et al.*, 2018)

Boiling						
Cooking time (min)	30	50	70	90	110	130
Namande	*0.64ff±0.28*	*0.62ff±0.19*	*0.36ff±0.18*	*0.43ff±0.12*	*0.35ff±0.14*	*0.38gf±0.10*
Nakawere	*0.69ff±0.18*	*0.47ff±0.18*	*0.47ff±0.10*	*0.41ff±0.17*	*0.34ff±0.07*	*0.35gf±0.11*
Namwezi	*0.5ff±0.11*	*0.7ff±0.23*	*0.52ff±0.20*	*0.39ff±0.08*	*0.33ff±0.04*	*0.37gf±0.10*
Nakitembe	*1.08fg±0.24*	*0.94ffg±0.09*	*0.77ffg±0.12*	*0.65ffg±0.09*	*0.62ffg±0.10*	*0.56gf±0.30*
Nakyetengu	*0.65ff±0.19*	*0.5ff± 0.21*	*0.45ff±0.12*	*0.42ff±0.11*	*0.42ff±0.08*	*0.35gf±0.12*
Kibizi	*0.56ff±0.14*	*0.5ff± 0.27*	*0.43ff±0.15*	*0.42ff±0.10*	*0.38ff±0.21*	*0.34ff±0.20*
Musakala	*1.1fg±0.42*	*0.99ffg±0.19*	*0.64ff±0.14*	*0.55ff±0.13*	*0.54ff±0.24*	*0.52gf±0.15*
Mpologoma	*0.68ff±0.13*	*0.64ff±0.21*	*0.58ff±0.17*	*0.54ff±0.11*	*0.43ff±0.18*	*0.35gf±0.12*
Kisansa	*1.11ff±0.47*	*1.07ff±0.50*	*0.87ff±0.22*	*0.69ff±0.26*	*0.73gf±0.29*	*0.54gf±0.22*
Nakabululu	*1.47fh±0.23*	*1.14fgh±0.27*	*0.83ffg±0.26*	*0.82gfg±0.26*	*0.69gfg±0.16*	*0.51gf±0.16*
Kazirakwe	*1.67fh±0.17*	*1.13fgh±0.5*	*1.03fgh±0.16*	*0.98ggh±0.14*	*0.89gg±0.25*	*0.68gg±0.10*

Kisubi	***6.58gk±0.87***	***4.82gjk±0.97***	***3.77gij±0.69***	***3.49hij±0.85***	***2.73hi±0.44***	***2.67hi±0.49***
Ndizi	***6.29gk±1.48***	***4.14gjk±0.67***	***2.79gij±0.68***	***1.74gi±0.43***	***1.49gi±0.43***	***1.38gi±0.67***
Kayinja	***8.89hm±1.75***	***6.79hkl±0.74***	***6.5hkl± 0.84***	***6.22ikl±0.52***	***4.97ijk±0.59***	***4.9ijk±0.83***

Table 10. Changes in textural hardness of selected indigenous cooking and juice banana cultivars during "steaming"(Gafuma *et al.*, 2018)

Steaming time (min)	30	50	70	90	110	130
Namande	1.52fgf±0.29	1.18ffg±0.24	0.99ffg±0.11	0.95fg±0.19	0.92fg±0.11	0.78fg±0.17
Nakawere	1.82fgf±0.45	1.19ffg±0.16	0.97fg±0.17	0.91fg±0.26	0.85fg±0.14	0.61fg±0.11
Namwezi	2.73fgf±0.74	1.1fg± 0.15	1.05fg±0.13	1.04fg±0.08	0.92fg±0.18	0.74fg±0.15
Nakitembe	1.48fgf±0.17	1.18ffg±0.18	0.98ffg±0.33	0.89fg±0.12	0.94ffg± 0.12	0.76fg±0.19
Nakyetengu	1.82fgf±0.23	1.26ffg±0.18	1.03fg±0.34	0.97fg±0.25	0.95fg±0.33	0.8fg± 0.09
Kibizi	1.34ff±0.18	1.05ffg±0.16	0.72fgh±0.19	0.70fgh± 0.14	0.64fh±0.05	0.60fh±0.12
Musakala	3.95gf±0.24	1.29fg±0.22	1.13fgh±0.16	0.74fh±0.12	0.73fh±0.12	0.72fh±0.15
Mpologoma	1.85fgf±0.35	1.1fg± 0.27	1.05fg±0.21	0.72fg±0.11	0.71fg±0.12	0.6fg± 0.06
Kisansa	3.14gf±0.70	1.82fg±0.62	1.13fg±0.43	1.10fg±0.19	1.04fg±0.29	0.97fg±0.30
Nakabululu	3.67gf±0.76	1.65fg±0.33	1.36fgg±0.23	1.27fg±0.26	1.19fg±0.18	1.05fg±0.14
Kazirakwe	2.5fgf± 0.33	1.76ffg±0.30	1.47fgg±0.28	1.44fg±0.45	1.45fg±0.19	1.24fg±0.15
Kisubi	**6.93hf±1.34**	**4.8ffg± 1.36**	**3.97gg±0.60**	**3.77gg±0.22**	**3.18gg± 0.37**	**2.95gg±0.49**
Ndizi	**9.91if±1.87**	**4.58fg±1.43**	**4.13gg±0.78**	**3.00gg±1.39**	**2.91gg± 0.47**	**2.67gg±0.24**
Kayinja	**13.3jf±1.75**	**10.0ffg±1.65**	**8.19hgh± 3.06**	**6.40hgh± 1.00**	**6.5hgh8 ±0.95**	**5.29hi±0.56**

Table 11. Textural hardness of cooled bananas obtained from different cooking treatments

(Gafuma *et al.*, 2018)

		BOILED BANANAS	STEAMED BANANAS		MASHED BANANAS	
Hardness (N) at 130 min boiling	Hardness (N) when readily cooled (4h)	Hardness (N) at 130min steaming	Hardness (N) when readily cooled (4h)		Hardness (N) at 130min steaming	Hardness (N) when readily cooled (4h)
Namande	0.38± 0.10a	1.95± 1.19b	0.78± 0.17a	4.77± 0.95b	0.70± 0.16a	6.89± 0.53b
Nakawere	0.35± 0.11a	2.16± 0.86b	0.61± 0.11a	3.82± 0.47b	0.52± 0.03a	5.22± 0.39b
Namwezi	0.37± 0.10a	2.19± 0.51b	0.74± 0.15a	5.31± 1.07b	0.58± 0.09a	5.99± 0.34b
Nakitembe	0.56± 0.30a	2.16± 1.52b	0.76± 0.19a	4.13± 0.49b	0.60± 0.12a	s.p
Nakyetengu	0.35± 0.12a	1.49± 0.36b	0.80± 0.09a	4.48± 0.62b	0.59± 0.07a	5.09± 0.62b
Kibizi	0.34± 0.20a	1.04± 0.17b	0.60± 0.12a	2.97± 0.50b	0.49± 0.05a	3.84± 0.36b
Musakala	0.52± 0.15a	2.85± 0.43b	0.72± 0.15a	4.05± 0.46b	0.48± 0.07a	6.15± 0.62b
Mpologoma	0.35± 0.12a	3.61± 0.31b	0.60± 0.06a	4.11± 1.32b	0.50± 0.06a	5.62± 1.97b
Kisansa	0.54± 0.22a	2.51± 0.50b	0.97± 0.30a	3.44± 1.02b	0.54± 0.12a	5.62±0.77b
Nakabululu	0.51± 0.16a	4.02± 1.48b	1.05± 0.14a	5.12± 0.63b	0.61± 0.06a	4.79± 0.30b
Kazirakwe	0.68± 0.10a	3.88± 1.19b	1.24±0.15a	5.39± 1.23b	0.88± 0.22a	6.14± 0.63b
Kisubi	**2.67± 0.49a**	**9.36± 1.28b**	**2.95± 0.49a**	**15.85±2.23 b**	**2.61± 0.34a**	**14.41± 1.24b**
Ndizi	**1.38± 0.67a**	**9.54± 1.33b**	**2.67± 0.24a**	**18.22± 3.73b**	**2.24± 0.20a**	**20.44± 0.98b**
Kayinja	**4.90± 0.83a**	**12.65±1.60 b**	**5.29± 0.56a**	**18.33± 1.66b**	**4.30± 0.56a**	**19.15± 1.07b**

The different methods of cooking reduced textural hardness. Among the matooke cooking bananas, *Kibuzi*was was the softest while *Nakabululu*, *Kazirakwe, Kisansa and Musakala* were among the hardest both in raw and cooked forms. Indeed, Kibuzi is one of the most preferred cooking banana cultivars. Steaming resulted in a harder texture of cooked bananas relative to mashing and boiling. Cooked bananas rapidly hardened in the first hour (Table 11) upon cooling and mashed bananas were the hardest hence should be consumed in less than 30 min of serving when texture is still soft. Bananas cooked longer had lower hardness regardless of cooking method (Gazump et al, 2018). Namawejje et al 2011, while investigating the effect of wraping materials (traditional banana leaves and polythene) on color and texture changes of matooke reported better textural measurements on samples wraped in polyethne, though these were not confirmed with consumer .

4.3 Relationship between composition and sensory evaluation

There is no trusted refereed literature on the relationship between composition and sensory attributes of the East African highland cooking banana. Such data would help to quantify predictors of traits preferred by end-users. Lack of this information limits quantitative traits to aid selection of consumer preferred hybrids, a justification for the interventions proposed under the RTBFoods project.

5 Conclusion and perspectives

Despite being a key livelihood source, the East African Highland cooking banana (matooke bananas) are not well studied, especially the fruit characteristics and composition. As a result, the chemical components that underpin the unique taste, appearance and textural attributes that endear the crop to its consumers remain unknown. There are isolated studies on proximate composition, color, texture and behavior of starch under different processing conditions. However, most of the analyses were done using different methodologies, making the results difficult to compare. For example, textural studies were done using either puncture tests or texture analyzers; whereas some components such as tannins where analysed indirectly by recording their absorbance values while other studies quantified the tannins in metric units. It is also noted that most studies used assay methods compared to other tools like high performance liquid chromatography, which are more robust. Moreover, there are no studies that have linked compositional attributes to sensory attributes. This would help breeding programmes to select hybrids with acceptable qualities early in the hybrid evaluation process. The RTB foods project; 'Breeding RTB products for end-users preferences aims to fill this gap.

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