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Potential of cooking bananas in addressing food security in East Africa

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Abstract

Banana is a very popular fruit in the world market and serves as an ideal and low-cost staple food in East Africa whose residents rely mostly on bananas as a source of food. Banana is practically non-seasonal crop that reliably grown by local farmers primarily for food. It has been categorised as the dessert bananas and the cooking bananas. Cooking banana is one of the most important staple food and cash crops in East Africa. It plays a central role in food security; it serves as a source of carbohydrate, minerals and vitamins all year-round. The banana crop provides a household annual income of about $ 1,500; this is the highest smallholder income-generating crop in the region. Currently, several indigenous and improved cultivars exist in East Africa. However, only a few popular cultivars are produced for commercial purposes. It is, therefore, important know the nutritional value, physicochemical quality parameters and sensory attributes of different cultivars from the literature review and seek to know how such information can help researchers in improving the challenging cultivars. There are wide-ranging variations reported in different banana cultivars for nutrients, minerals and other quality properties. In the present review, an overview of popular banana cultivars; nutritional value and health benefits; sensory and physicochemical properties and the role of breeding in improving quality of cooking bananas are thoroughly discussed.

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Introduction

With a production of 145 million metric tons worth approximately $ 30.8 billion globally, banana (*Musa spp*.) is one of the world's most important staple food and cash crops and arguably the world's most popular fruit in terms of international trade (FAOSTAT, 2014). In fact, it is one of the most produced and consumed fresh fruit worldwide (Affognon *et al*., 2015). Bartoshuk and Klee (2013) reported that different varieties grown in various parts of the world have markedly different sensory characteristics. The world main banana producers are India (27.6mil. tons), China (12.1mil. tons), Uganda (9mil. tons), the Philippines (8.6mil. tons), Brazil (6.9mil. tons) and Ecuador (6.0mil. tons), making banana a significant contributor to the world economy (Sheth, 2017; Statistica, 2016). While developed countries consider banana mainly as a dessert food, in many developing countries banana is cooked as an essential meal and contributes notably to food security and income generation to more than 70 million Africans (Adeniji *et al*., 2010). The literature review shows that there are various types of banana unique to Africa, and these can be eaten fresh, cooked, fried, processed as baby food, juice or beer (Chandler, 1995). Cooking bananas represent a major food source and a major income source for smallholder farmers (Karamura *et al*., 2012). In fact, the East African Highland cooking banana (EAHB) and plantain make up over 50% of all bananas grown in Africa (Kilimo-Trust, 2012), and the people living in the Eastern and Central Highlands of Africa consume more bananas than anyone else in the world, deriving up to 12% of their daily calories from the crop (Karamura *et al*., 2012). In the lowland of the Congo basin, farmers grow a greater diversity of banana plantains than any other place in the world (Lejju *et al*., 2006). Moreover, these perennial plants are the backbone of many farming systems as they produce fruits the year round, protect the soil from erosion and survive floods, drought and civil conflicts (Karamura *et al*., 1996).

Perrier *et al*. (2011) reported that nearly all African countries produce substantial amounts of bananas, however only a few exports them. Despite the fact that East Africa is one of the leading regions of banana production in Africa, most of the produced crop is for local consumption and sale rather than export (Price, 2006). In countries such as Uganda, Tanzania, Burundi, and Rwanda, the per capita annual consumption is estimated to be over 100 kilograms which is the highest in the world (Fungo and Pillay, 2011). Although Uganda is the largest banana producer in Africa (Ssonko and Muranga, 2017), the country consistently remains as one of many smaller exporters of banana in the continent, with the crop being used mostly for local consumption (Kilimo-Trust, 2012). West African countries, on the other hand, according to BananaLink (2015) they produce nearly all of Africa's banana exports, with Cameroon and Côte d'Ivoire being the two largest banana exporters. Diop and Jaffee (2005) reported that banana production in these two countries has grown hastily over the past two decades and that they contribute to approximately 4.1% bananas exports in the global market.

It has been documented that bananas are rich in carbohydrates, vitamins and dietary fibres and although they contain 75% water, they also contain alkali-forming minerals, lots of potassium and little protein and fat (Haslinda *et al*., 2009). Additionally, the ripe bananas are easy to digest and the food of choice for many professional athletes because they provide quick energy and provide potassium lost during exercise (Kachru *et al*., 1995), it has also for long been considered as the best food for babies. Several studies have reported the nutritional and sensory attributes of local ripe banana (Ohizua *et al*., 2017; Pareek 2016; Suntharalingam 1990), but published data on the same attributes of the unripe local banana are to a few varieties in Eastern Africa.

Therefore, investigation on the biochemical and nutrient components of the cooking bananas are necessary with the purpose of providing handy information that will help to improve the existing varieties, which are being challenged by pests, diseases and poor agronomic traits. In an effort to contribute in bringing possible answers to these challenges and information that uncover the knowledge gaps in this area, this review direct attention to the physicochemical, sensory and nutritional potentials of the cooking varieties of banana for the welfare of people's health and nutrition not only in developing countries but elsewhere in the world.

Impact of Banana on Food Security in East Africa

Kilimo-Trust (2012) reported that banana (*Musa spp*.) is one of the most important staples and nutritional food in East Africa, it plays a central role in addressing food security to over 35 million people and reliable source of income for small-holder farmers in the local market. Bananas provide an annual income of about $ 1,500 to about 4 million small-holder households; this is one of the major smallholder income-generating agricultural produce in the region (Mgenzi *et al*., 2008). Banana is a practically non-seasonal crop that reliably grown in the region. Tanzania and Uganda alone produce over 50% of all bananas in Africa (Jacobsen, 2014). In fact, banana consumption per capita in Tanzania (100kg/year) and Uganda (350kg/year) are amongst the highest in the global rankings while banana production is estimated to be about 4 and 9 million metric tons per annum respectively (Kilimo-Trust, 2012).

Banana is a climacteric fruit that is consumed in the ripe state. As a result, Affognon *et al*. (2015) observed that large quantities of fruit are lost during commercialization due to poor postharvest practices. These bananas are produced primarily for local consumption and sale and rarely for export (BananaLink, 2015). A large number of unripe banana rejections or post-harvest losses are used as raw materials for domestic artisanal flour preparation (Aurore *et al*., 2009). They have the potential of being used as staple food in many developing countries and many researchers have studied applications of cooking banana flour as ingredients in various food products (Sardá *et al*., 2016; Ohizua *et al*., 2017; Salih *et al*., 2017; Savlak *et al*., 2016; Wang *et al*., 2012).

Aurore *et al*. (2009) figured out that cooking bananas denote an alternative source of carbohydrates due to the relatively high starch content of the pulp, hemicellulose and lignin levels, as well as the low cost of the fruit that may allow preparation of cooked recipes with appealing sensory and functional features. Previous studies have shown that cooking banana remains, among other crops, the forerunner of food security in the highland regions of Tanzania, Central and some other parts of Uganda, Rwanda and Eastern Democratic Republic of Congo, where the crop has been staple food for local residents consuming about 70% of harvested bananas in their households (De Langhe *et al*., 2001; Smale and Tushemereirwe, 2007) while secondary banana products such as beer (*Lubisi*, *Tonto*, *Waragi*, *Mulamba*), wine, banana crisps, chips, cooked dried bananas, juice, banana flour composites for making bread, chapattis and pastries) account for only about 30% (Carter *et al*., 2010). Furthermore, banana is a key commercial crop and/or a major source of raw materials for not only food, beverage and handicraft industries but also the crop has great cultural and social implication (Ndunguru, 2009).

Bananas remain to be one of the reliable staple food in East Africa. The nutritional benefits of spending a dollar on banana are comparatively higher than other popular food crops such as maize, rice, cassava and wheat. Bananas are rich in antioxidants, potassium, energy, and vitamin C (Caballero, 2012). The other nutrients found in the fruit are vitamin B6, protein, dietary fibre, riboflavin, niacin and iron (Haslinda *et al*., 2009; Suntharalingam, 1990). Potassium in banana is important in controlling the blood pressure. Magnesium, among other health benefits, helps in treating depression as helps in the relaxation of muscles and Vitamin B_6 helps to have a good sleep (Lescot, 2000). Other advantageous benefits of banana consumption include weight loss, vision improvement, improvement of digestion, stronger bones (Ohizua *et al*., 2017). Table 1 compares nutritional benefits one US Dollar on various food crops in East Africa with reference to banana.

Table 1. Comparative nutrition benefits of spending $ 1 on food crops in East Africa.

Nutrient	Unit	Banana	Rice	Sweet potato	Cassava	Maize Grain	Sorghum grain	Wheat	Beans
Energy	kcal	2745	3066	3233	5312	7446	8068	3449	5851
Proteins	g	29	60	59	45	192	269	100	414
Total fibre	g	52	11	113	60	55	150	136	437
Iron	mg	13	7	23	9	55	105	39	144
Potassium	mg	11224	966	12668	8997	5855	8330	4094	24703
Zinc	mg	3	9	11	11	45	27	31	49
Vitamin A	µg	1260	0	26651	33	0	0	0	0
Vitamin C	mg	414	0	90	684	0	0	0	79
Vitamin D	IU	16	0	0	0	0	0	0	0

Source: Modified table adopted from Kilimo-Trust Banana Analysis Survey, 2012

De Langhe *et al.* (2001) reported that some communities of banana farmers in East Africa such as *Chagga*, *Haya* and *Nyakyusa* in Tanzania; and *Buganda* in Central and some other parts of Uganda, Kisii, Central and Eastern regions of Kenya have consistently categorised the banana as one of their most essential crops since they produce fruits all-year-long, a property that places it above others as a food and income security crop. However, not all local communities substantially grow and prefer cooking bananas as a staple food, for example, *Sukuma*, *Kuria* and *Jita* in Tanzania are among them. The banana plant is beneficial in several aspects, being a perennial crop with a root network and broad leaves they maintain soil structure and provides a soil cover throughout the year hence reducing land degradation (Mohapatra *et al.*, 2010). This feature makes the crop a central element in environmental conservation. Banana has multi-purpose usages such as food, snacks, feedstuff, industrial spirits, soft and alcoholic drinks; and a number of crafts, medicinal and therapeutic potential (Neumann and Hildebrand, 2009; Nguthi *et al.*, 1999). Studies have shown that banana produces a relatively cheapest carbohydrate and they are able to grow in a wide environmental spectrum and farming systems such as pure-stand, livestock-crop and intercropping, farming systems (Ouma and Jagwe, 2010).

From the above description of the impact of cooking in the region, it can be noticed how much the crop is important for human nutrition and other uses. There is a need to prioritize banana crops in reluctant banana-growing areas in agriculture system in the region in order to be able to feed the rapidly increasing population. This calls for a need in addressing the importance of banana in solving food security and hidden hunger. This might also raise political awareness in integration, consolidation and rationalization of governments' policies of banana-growing countries.

An Overview of Banana Cultivars in East Africa

There are countless types of banana native to East Africa, and these can be consumed fresh, fried, boiled and processed to be served as baby food, soft and/or alcoholic drinks (Bugaud *et al.*, 2009; Salih *et al.*, 2017). Banana cultivars have been given several names, which is a depiction of both their morphological variations and of the socio-linguistic diversity of the people naming them in numerous vernacular tongues around the globe (Karamura, 1999). The commonly grown cultivars are the East Africa Highland bananas (*Musa* AAA-EA), Cavendish subgroup bananas, AAB banana cultivars, *Musa* AB banana cultivars and ABB cultivars.

East African Highland Bananas (EAHBs) are a subgroup of triploid (AAA-EA) bananas that significantly address food security issues in Eastern Africa. Until recently, there has been no reliable evidence about their inherent variation, populace network and evolutionary account. They show some phenotypic variations, however, Kitavi *et al.* (2016) recently reported that all East African Highland banana cultivars are genetically identical having descended from the first prototype brought to the African continent. EAHBs are by far the most widely distributed in the region stretching from the Eastern Democratic Republic of Congo to the Southern fringes of the Ethiopian highlands, and down to Mbeya in Southern Tanzania (Karamura, 1999). They are believed to be indigenous to this region with no clear similarity elsewhere in the world (Kitavi *et al.*, 2016). Altitude is the leading key reason accountable for the group distribution (Perrier *et al.*, 2011). The plant will grow optimally between 950 - 2250 metres above sea level and below that range growth of the plant is severely stunted (Karamura *et al.*, 2012). Several authors have tried to describe the characteristics of the group (Karamura *et al.*, 2006; Karamura, 1999). Despite the fact that this group has high production and occupies large land, the crop remains underexplored in relation to both research and development (Hippolyte *et al.*, 2012). EAHB is mainly a sustenance crop, essential only for food security and with no substantial export (Kilimo-Trust, 2012). In each of the East African country, some clones have been used by societies for fairly a long time both as food as well as in traditional functions. In Tanzania, mature green EAHB fruits are well known as *Embirabire, Enzinga, Endeishya, Matoke, Ndizi za kupika* and *Ekitoke Kisamunyu*; in Uganda known as *Kibiddebidde*, *Lwezinga*, *Nakawere*, *Nakhaki* and *Nakinyika*; in Rwanda and Burundi green EAHB bananas are famously known as *Mbirabire*, *Bakurura*, *Ingumba Inyamunyu, Inzirabu shera* and *Insira* are usually cooked, steamed or boiled before consumption (Karamura *et al.*, 2012; Shepherd, 1957). The increasing population density and related land crumbling tied together with growing pest harms and destruction of available natural resources are all collectively limiting the throughput of AAA-EA farming schemes (Onyango *et al.*, 2009).

Cavendish bananas fit the AAA genome group, i.e., the cultivars that possess three copies of each gene-bearing chromosome (Vézina, 2018). Cavendish bananas are some of the fairly studied banana cultivars. This AAA typical group, which includes Lacatan, Red Banana, Gros Michel and Cavendish bananas, is the most widely grown group of edible bananas. Unlike EAHBs, Cavendish dessert bananas are sweet and grow better in lower altitudes below 1000 metres above sea level usually along coastal regions (Hippolyte *et al.*, 2012).

Gros Michel exceptionally found around Lake Victoria region at a marginally higher altitude range, and now creates an important cooking banana in the area (Lejju *et al.*, 2006). Bananas in this group being sweet fruits, some parts around the Great Lake region consumers, mainly use the crushed ripe bananas usually mixed with millet flour or other cereal flour for fermentation. The hazy beer produced has long been distilled locally where residents use the beverage as a refreshment drink (Karamura *et al.*, 2012) In East Africa, the clones in this group recognized as *Enkundi, Ng'ombe, Kiguruwe, Kimalindi, Israeli, Omutsiri, Kiise, Ntotomya, Giant Cavendish* and *Malindi* (Karamura, 1999). Most cultivars of this group are prone to black leaf streak and Panama disease while they are usually relatively resistant to weevil plague (Perrier *et al.*, 2011; Vézina, 2018). These banana cultivars serve as dessert food and they are also important for local sale but exports remain low (Kilimo-Trust, 2012).

AAB banana cultivars is a lowland cultivar growing best below 700 metres above sea level and grow scarcely above 1000 metres above sea level (De Langhe, 1986b). Most of the clones of this group are identified, however, are yet to be investigated nutritionally (De Langhe *et al.*, 2001). The typical examples in this group are *Nkonjwa, Prata, Gonja, Ndizi ya kuchoma, Mzuzu* in Tanzania; *Ngongia* in Kenya; *Makemba*, *Mzuzu* or *Misheba* in Democratic Republic of Congo; *Muzuzu* in Burundi; *Umushaba* in Rwanda; *Gonja*, *Gonje*, *Wette* and *Adeke* in Uganda (Karamura *et al.*, 2012). Cultivars in this group are also called plantains that are usually roasted and sometimes cooked. The AAB cultivars, however in Kagera region of Tanzania, still does well where they are grown extensively but not intensively, plantain is a major food in the coastal regions and low plains of East Africa as well (De Langhe *et al.*, 2001). Plantains appear to be predominantly susceptible to weevil occurrence. Likewise, pratas are grown widely in the identical ecological ranges, however in Burundi, yet perform better at high altitude (De Langhe, 1986b). *Musa* AAB "Apple" banana is another clone in this group that is popular in the region. *Apple* bananas are widely grown in the banana producing areas.

In Tanzania for example, bananas are largely produced in Morogoro, Kagera, Kilimanjaro, Zanzibar, and Usambara mountain ranges in the north-eastern region of the country while in Kenya *Apple* bananas are grown in Western, Nyanza and Central Provinces. Other regions in East Africa are Rwanda and Wakiso, Masaka, Luweero and Bushenyi Mubende districts in Uganda. In Rwanda, they are well known as *Kamaramasenge* and in Uganda as *Sukari* or *Sukari Ndiizi* (De Langhe, 1986a; Karamura *et al.*, 2012). The AAB bananas are grown for sustenance reasons and local market.

ABB banana cultivars are a group of banana cultivars belonging to the three subgroups, namely *Pisang Awak*, *Monathan* and *Bluggoe* (Karamura, 1999). Again, Karamura *et al.* (2012) reported that there are nearly 13 to 14 other cultivars belonging to this group. Very little is exposed about this group in terms of both nutritional value and agronomic potentials. The plants are moderately flexible regarding ecological conditions, even though they grow optimally in regions below 1000 metres above sea level (Price, 2006). In Southern Tanzania for example, the ABB cultivars have been accepted for use as cooking bananas. Again, it is very widely spread and often an important food crop. Furthermore, most cultivars in this group were later adopted as beer bananas in Uganda and Rwanda, generally because of their capability to increase production regardless of unfavouring growing conditions (Karamura *et al.*, 1998). The cultivars are, therefore, the backbone for the local beer industries. The ABB bananas display good environmental tolerance, believed to be hardly affected by the nematodes, black Sigatoka and weevil attack (Karamura, 1999) may be advantageous to local beverage industry owners.

AB banana cultivars are another group of banana cultivars with a genome category comprising all the cultivars that possess a double set of chromosomes, one contributed by *Musa acuminata* and the other by *Musa balbisiana* (Kitavi *et al.*, 2016; Simmonds and Shepherd, 1955). So far, however, little attention has been paid to this banana group. The most common cultivars include *Ndizi Kisukari, Kipakapaka Ndogo, Ganda, Kipukucha, Subi, Gisubi kagogo, Kasubi, Kasukari, Barwokole* and *Kisubi*. Some varieties like *Ndizi Kisukari, Gisubi kagogo, Kasukari* are primarily dessert bananas, not to mention its high juice-yielding property (Staver and Capra, 2017) while *Kisubi/Kasubi* are harsh in flavour, this restricts them to both beer and juice processing (Karamura *et al.*, 1998). Currently, farming of the AB bananas remains dispersed across the East Africa region (Ndunguru, 2009).

Several banana cultivars other than those mentioned above have been imported into the region along with improved varieties such as Honduran Foundation for Agricultural Research (FHIA) hybrids that are optimistic indeed (Ndayitegeye *et al.*, 2017; Rowe and Rosales, 1993). Other improved banana cultivars are being developed by the International Institute of Tropical Agriculture (IITA) in Tanzania and Uganda and Bioversity International for evaluation and improvement purposes across East Africa. Another group of cultivars “endemic” to the area have yet to be characterised (Onyango *et al.*, 2009), they comprise the *acuminata* species all over Kilimanjaro region and two *acuminata* wild sorts in Zanzibar assemblage (Karamura *et al.*, 1998). These cultivars are believed to be peculiar from the EAHBs of the Great Lakes Zone but the key differences among them are not yet clearly understood. Apart from the *acuminata* spices of Zanzibar Islands in Tanzania, the characteristics of divergent materials in the region’s collections have yet to be studied (Karamura *et al.*, 2012; Karamura, 1998).

From the above overview, it can be noticed that there is a huge and wide diversity of banana cultivars in East Africa but only a few of them are studied. As indicated earlier, more work is necessary to characterise not only desirable agronomic characteristics but also the biochemical, sensory and physical quality parameters of under-privileged cultivars across the region for public nutrition welfare which may also stabilize food security. Some cultivars, as noted above, are resistant/tolerant to harsh environmental conditions, this advantage may be a breakthrough if used appropriately in fighting against agronomic threats yet addressing the food security even more effectively.

Nutritional value and health benefits of cooking bananas

Bananas and plantains are available in most tropical domestic farmyards and are readily acceptable and preferable. In fact, bananas with sweet potatoes are often the first solid foods fed to infants in most East African families (Davies, 1995). There are numerous procedures for preparing cooking bananas, which differs across different ethnical groups (Onyango *et al.*, 2009). Bananas have substantial quantities of carbohydrate content and have low-fat contents making them particularly useful in low-fat diets. Bananas, including plantains, are also a good source of many vitamins and minerals, particularly vitamins A, B_6 and C and a substantial quantity of potassium (Haslinda *et al.*, 2009). The low sodium and high potassium contents of the fruit are of sound implication in dietary terms and are recommended for better cardiovascular health (Elmadfa, 2005). However, as it is generally known, the protein level is relatively low to the major staple food crops such as maize, sorghum, wheat and in this case cooking bananas (Caballero *et al.*, 2003). Despite high nutrient density of banana, Reis *et al.* (2016) reported that the method of preparation may affect the nutritional value of the banana recipe. For instance, if fried, the oil used considerably boosts its energy value. Additionally, cooking may also destroy bioactivity and availability of vital heat-sensitive food components such as vitamins (Pareek, 2016). Nevertheless, this is not the case with ripe bananas. Other minerals such as calcium, iron, zinc, and copper found in cooking bananas can help to optimize the metabolism by providing a stable, complex carbohydrate base for energy generation in the body (Elmadfa, 2005). Although fresh green bananas are a good source of vitamin C, almost 65% is lost during the preparation of banana products such as recipes, flour, drinks and snacks (Suntharalingam and Ravindran, 1993). Other less known advantages of banana consumption include vision improvement, bone strengthening and weight loss (Caballero, 2012). Biochemical characteristics of cooking banana suggest nutrients essential for human health. The average ranges of proximate compositions and dietary fibre concentration of cooking banana genotypes reported by some studies are shown in Table 2.

Table 2. Estimate of proximate composition of cooking banana genotypes (g/100g Dry Matter).

Parameter	Quantity	References
Carbohydrate	16.1 – 80.0[2,4,5]	[1]Anuonye *et al.* (2012)
Moisture content	1.0 – 27.7[1,2,6]	[2]Aurore *et al.* (2009)
Crude protein	1.1 – 4.7[2,4,6]	[3]Deshmukh *et al.* (2009)
Crude fat	0.4 – 4.2[3,4,6]	[4]Haslinda *et al.* (2009)
Dietary Fibre	6.0 – 7.5[1,2,5]	[5]Savlak *et al.* (2016)
Total ash	2.4 – 11.7[1,2,5]	[6]Schmidt *et al.* (2015)

Tapsell *et al.* (2016) reported that one of the recent dietary trends in nutrition and health is to consume low-carbohydrate food products. Consumers are demanding foods showing two main properties: the first one deals with the traditional nutritional aspects of the food, whereas, as a second feature, additional health benefits are expected from its regular ingestion (American-Diabetes-Association, 2012). There has been a substantial discussion about the metabolic effects of limiting carbohydrate intake in weight and diabetes control (Anderson *et al.*, 2003; Franz *et al.*, 2002). However, the American-Diabetes-Association (2012) has noted that weight and metabolic improvements can be achieved with low carbohydrate and low fat. Cooking bananas are rich in fibrous carbohydrates, which can offer the named benefits. In a rapidly changing world, with altered food habits, sedentary and stressful lifestyles, it is more and more recognized that a healthy digestive system is essential (Brouns *et al.*, 2002). In the case of cooking bananas, the parenchymatous tissues and cell walls supply the dietary fibres. In the digestive tract, for example, fibre exercises a safeguarding effect that links excess of acid in the stomach and stimulates the intestinal evacuation (Slavin, 2013); moreover, it provides a favourable environment for the growth of the beneficial intestinal flora (Drzikova *et al.*, 2005). Fibre can also bind cholesterol and get rid of it. More importantly, fibre plays a central role in the preclusion and management of diabetes, obesity, atherosclerosis, and cardiovascular diseases (Peters *et al.*, 2003; Terry *et al.*, 2001). Some carbohydrates in cooking bananas can speed up the calorie-burning process in the body, thanks to the short-chain fatty acids found in them (Hijova and Chmelarova, 2007).

Researchers have found that this type of fatty acids can improve the body's ability to absorb nutrients, particularly calcium (Jenkins *et al.*, 1998). Table 3 shows potassium as the principal mineral in banana; other essential minerals found in a banana are iron, zinc, calcium, sodium and magnesium. Fresh green banana is a good source of vitamin C, but almost 65% is lost during the preparation of banana products such as recipes, flour, drinks and snacks (Suntharalingam and Ravindran, 1993).

Table 3. Estimate of mineral contents of cooking banana genotypes (mg/100 g Dry Matter).

Element	Quantity	References
Potassium	259.0 – 733.9[1,4]	[1]Arvanitoyannis and Mavromatis (2009)
Magnesium	21.2 – 106.0[2,5,6]	[2]Aurore *et al.* (2009)
Calcium	10.1–132.4[3,4,5]	[3]Deshmukh *et al.* (2009)
Sodium	0.1 – 23.9[2,6]	[4]Hardisson *et al.* (2001)
Iron	0.3 – 12.2[3,4]	[5]Haslinda *et al.* (2009)
Zinc	0.7 – 2.8[1,6]	[6]Suntharalingam and Ravindran (1993)
Copper	0.1 – 2.1[2,4,5]	

The carbohydrate content, the protein fractions, the mineral concentration, vitamins and other functional potentials of the under-privileged cooking banana varieties like *Gonja*, *Kimalindi*, *Ekitoke*, *Ingumba*, *Insira*, *Ntotonya*, *Enkundi* and many more cultivars need further investigations. Such information might be a breakthrough in crop improvement and nutrition-sensitive agricultural activities leading to nutrients (such as vitamins, probiotics, carbohydrate and minerals) increase in bananas that are greatly solicited currently in combating hidden hunger in developing countries. It is also noted that the biochemical composition of banana peels have not adequately studied as either human food, animal feed or medicinal extracts, this may be due to their limited usages.

Physicochemical characteristics of cooking banana cultivars

Systematized study of the physicochemical characteristics of foods and food products is a relatively new scientific arena (Salih *et al.*, 2017). Physicochemical properties are of great interest to food scientists and farmers because of their close connection with the quality of the produce or product, not to mention their influence on the sensory and processing characteristics of foods (Baiyeri *et al.*, 2011; Belayneh *et al.*, 2014).

Since cooking bananas are inherently perishable, it is expected that substantial quality losses ranging from a slight loss of quality to total spoilage may occur at any point in the marketing process from the initial harvest to distribution to the final consumer, (Affognon *et al.*, 2015). According to Prusky (2011), quality of cooking banana changes rapidly after harvest and thus substantially affects the acceptability by the consumers. Firstly, fruit selection is based on physical appearance, colour, gloss size and then by texture, pH, total soluble solids (TSS) content and titratable acidity (TA). These parameters supply important information to the consumers in recognizing fruits with attractive sensory quality and draw special attention to researchers (Drogoudi *et al.*, 2008). The presence of various oxo-acids identified as malic and oxalic, contribute to the acidity and pH hence influence the taste of the cooked banana. The TSS concentration of the fruit, on the other hand, is commonly obtained by measuring the degree Brix of the fruit pulp, table 4 shows the average ranges of TSS of cooking banana. Brix offers a clue of how much sugar is concentrated in the pulp (Alkarkhi *et al.*, 2011), and it is influenced by minerals, fats, proteins, carbohydrates and organic acids present in the pulp (Jayasena and Cameron, 2008). It represents at least 10% of the unripe fresh banana weight and increases as fruit mature and ripen to produce less acidic and sweeter pulps (Sardá *et al.*, 2016). While zinc, magnesium and iron all increase TSS substantially, nitrogen and potassium have a negligible effect on TSS (Hasani *et al.*, 2012). However, it is reported that Molybdenum induces a decrease in TSS and may also help improve the ascorbic acid content of the fruit (Kazi *et al.*, 2012). Fruit properties like pH, TSS and titratable acidity among others are also of utmost interest for researchers in studying behaviours of fruits under different experimental settings (Belayneh *et al.*, 2014). The presence of various oxo-acids identified as malic and oxalic, contribute to the acidity and pH hence influence the taste of the cooked banana. Table 4 summarizes the average ranges of physicochemical properties of cooking banana varieties.

Table 4. Ranges of physicochemical properties of unripe banana genotypes.

Parameter	Quantity	Unit	References
pH	4.7-6.5[3,4,5]		[1]Alkarkhi *et al.* (2011)
TSS	0.5-2.7[3,4,5]	%	[2]Arvanitoyannis and Mavromatis (2009)
Viscosity	35.7-47.5[1]	*mPa s*	
TA	1.9-2.2[3]	%	[3]Belayneh *et al.* (2014)
Ascorbic acid	1.4 – 33.5[1,3]	mg/100g	[4]Bugaud *et al.* (2009)
			[5]Savlak *et al.* (2016)

The TSS concentration of the fruit, on the other hand, is commonly obtained by measuring the degree Brix of the fruit pulp, Table 4 shows the average ranges of TSS of cooking banana. Brix offers a clue of how much sugar is concentrated in the pulp (Alkarkhi *et al.*, 2011), and it is influenced by minerals, fats, proteins, carbohydrates and organic acids present in the pulp (Jayasena and Cameron, 2008). It represents at least 10% of the unripe fresh banana weight and increases as fruit mature and ripen to produce less acidic and sweeter pulps (Hoffmann Sardá *et al.*, 2016). While zinc, magnesium and iron all increase TSS substantially, nitrogen and potassium have a negligible effect on TSS (Hasani *et al.*, 2012). However, it is reported that molybdenum induces a decrease in TSS and may also help improve the ascorbic acid content of the fruit (Kazi *et al.*, 2012).

Thorough understanding of the inherent properties of cooking banana is essential for the development of better hybrids and novel food products that meet consumers' expectation. Important developments about these properties might include significant efforts in determining them as well as their prediction based on composition to meet dietary and sensory demands. Fruit properties like pH, TSS and titratable acidity among others are of utmost interest for researchers in studying behaviours of fruits under different experimental settings. Future studies on the current topic are therefore recommended.

Sensory Characteristics and Consumers' Preferences Banana Cultivars

Sensory quality is a superficially clear but elusive concept and sensory evaluation is necessary to acquire information on claimed facets of food quality to which no other objective technique can be employed (Lawless and Heymann, 2010; Meilgaard *et al.*, 2006).

Sensory attributes play an important part in how consumers discern the quality and preferences of a produce or food product (Green-Petersen, 2010). Certainly, colour and taste are some of the central parts of the human regular sensory practice. For example, a particular food should have a specific colour and taste feature to be appealing and palatable to the consumer (Caballero *et al.*, 2003). Like any other food, cooked banana stimulates biological and emotional responses accustomed to knowledge, environment, education, and traditional practices (Lawless and Heymann, 2010). The impression of dullness of food is related habitually and involuntarily with sub-standard or inferiority. In contrast, natural and bright colours give the sensory feeling of nutritious, high-quality, beneficial foodstuff (Costell *et al.*, 2010). For this reason, banana consumers are not only concerned with the nutritional value of the food, but also the amount of inherent ingredients that improve the consumers' sensory demand like colour and flavour (Callaghan *et al.*, 2012), not to mention their ability to show outstanding health effects (Grashorn, 2005). The appearance and inherent flavours of cooked banana, therefore, serves as one of the leading criteria on which consumers base their choices while purchasing the produce. Caballero *et al.* (2003) noted that sensory attributes of food may cause a reduction in the contentment of the given food after it is consumed on regular basis and an increase to a substantial food intake if that property is changed by successive presentation of different foods. In light of this, sensory evaluation plays a significant role in the quality control of not only developed banana hybrids but also banana food products (Wang *et al.*, 2017).

A range of factors, along with sensory attributes and beliefs about the nutritional and socio-economic value of the foods also influences food choice. Nevertheless, it is even more challenging to conclude the relative importance of beliefs about sensory aspects to foods (Nestle *et al.*, 1998). Consumer food preference is considered as a function of the interactive combination of the individual, person's culture and beliefs, sensory characteristics of the food, previous exposure to it and subsequent expectations or the situation in which the food is consumed (Caballero *et al.*, 2003; Vabø and Hansen, 2014).

Furthermore, East African banana producers grow cultivars preferred by local communities in terms of sensory attributes, a phenomenon known as varietal compartmentalization (Kilimo-Trust, 2012). However, such compartmentalized varieties are not appropriate for sale to communities with different banana varietal alternatives. Kilimo-Trust (2012) reported that this has hindered the growth of the banana trade with urbanization, not all types of bananas have won popularity in East Africa's major urban centres. However, some of cooking bananas gained their tremendous popularity in East African region probably due to their appealing sensory properties (Onyango *et al.*, 2009).

These properties are attributed by several inherent compounds that have a significant effect on the consumer sensory quality. Among other bioactive components in cooking banana, the most prominent ones are phenolic compounds which show numerous and notorious health benefits such as high antioxidant activity and useful physiological functionalities (Bujor *et al.*, 2018; Carocho and Ferreira, 2013). However, these compounds may reduce the palatability of cooked bananas, largely due to the noticeable bitter and astringent taste (Pu *et al.*, 2018). It is claimed that higher-molecular-weight (> 430) polymers appear to be astringent and phenolic polymers of lower molecular weight are more likely to be bitter (Drewnowski and Gomez-Carneros, 2000). As the molecular weight increases to approximately ten units, tannins gradually become more astringent and less bitter (Bravo, 1998). It has been reported that the sensation of astringency increases significantly with the increase of tannin concentration with a tendency to mask perceived bitterness (Villamor, 2012). These particular components are commonly linked to reduced preferences of unripe banana (Muñoz-González *et al.*, 2018), and can influence the taste of cooked bananas hence lower eating quality (Suárez-Estrella *et al.*, 2018).

Sensory properties, mainly colour, aroma and taste, are major factors affecting quality perception and consumer's acceptance of any food.

Appearance and colour form initial quality features attracting consumers; nonetheless, the flavour (the overall blend of both nasal and oral stimulation) may have the largest impact on acceptability and desire to consume it again. As outlined above, cooking bananas contain compounds that are in some cases not appealing to the consumers. Because of limited information resources available so far, this review emphasizes more palatability studies focusing on the analysis of flavour compounds and carrying out a sensory evaluation of under-utilized banana cultivars. This is necessary to identify inherent compounds responsible for un-appealing flavours and reveal the consumer acceptability of cooked banana. In addition, sensory information on under-utilized bananas may be useful for improvement of these cultivars to more palatable sensory attributes that may help in reducing the compartmentalized banana cultivars and diversify their usage. Further work is required to establish this.

The role of breeding in improving the quality of cooking bananas

Crop plants have been bio-engineered in order to have different but desired characteristics. Thanks to plant breeding technologies which developed from the artificial selection methods based on phenotypes over decades. To meet the needs of the fast-growing population in East Africa and elsewhere, yield improvement has been a key emphasis in breeding and some other genetic manipulation of food crops (Opara *et al.*, 2010; Rowe and Rosales, 1993; Smale and Tushemereirwe, 2007). The demand for better quality crops and fruits that are rich in nutrients and which can endure the needs of the regional and global supply chain is growing quickly (Gordon *et al.*, 2017). Although food production has expanded over the recent decades, nutrient deficiency poses a new challenge to people that lack physical and/or economical access to a balanced diet and rely on staple food crops with low levels of micronutrients and essential amino acids (Dwyer and Drewnowski, 2017). For examples, recently, considerable researches by International Institute of Tropical Agriculture (IITA) in Tanzania and Uganda and

Bioversity International across East Africa have focused their programs on improvement of banana cultivars with respect to agronomic traits e.g., high yielding and disease- or pest-resistant traits through breeding and other biotechnological techniques (Karamura *et al.*, 2012). These are some of the remarkable efforts in addressing food security and hunger in the region, however, due to public awareness to nutrition quality parameters such as nutritional value, taste, colour, texture, to mention a few, are becoming increasingly important in current banana consumers in the region (Christinck and Weltzien, 2013; Fan and Pandya-Lorch, 2012).

From the short review above, this suggests that it is very important to include both nutritional and sensory quality aspects in future banana breeding programs. Advances in biotechnology make it possible to study these complex, multifactorial traits and come up with possible solutions. The breeding for nutrition and sensory quality should aim to make more nutritious and appealing food, readily available and accessible; and increase food production and diversity. Studies have shown the potential to exploit the genetic variation and breeding in fruit concentration of iron, zinc and other trace minerals without the general negative effect on yield of adding new traits (Kumssa *et al.*, 2017; Moreira *et al.*, 2018). The use of biotechnological techniques, such as molecular marker-aided selection, will notably increase the speed and prospects of realization for breeding to improve not only the agronomic features but also the nutritional value and sensory quality of cooking bananas. Apart from the development of hybrids that are resistant to pests and diseases, fruit sensorial evaluations are imperative in the course of selecting new cultivars. Banana fruits must have flavour, shape, texture, colour, size and aroma that meet consumers' requirements (Dadzie and Orchard, 1996). Evaluations provide valuable information that may help the future improvement of food crop through breeding or genetic programs.

Therefore, we suggest that the future attention to banana breeding should be geared towards designing genetic strategies and developing breeding materials to meet the following requirements: to sustain banana nutritional value and sensory quality throughout the post-harvest supply chain as a means to preclude or reduce nutrient deficiency and food loss; to maintain quality at increased production and yield; and to achieve desirable quality banana under sub-optimal growing conditions. These are important issues for future research.

Conclusion

Banana cultivars for cooking are of great importance in East Africa's food security affairs, making this crop an object of common interest. Full characterization of its nutrient and sensory parameters and concentrations of useful bioactive compounds especially from under-exploited cultivars is necessary. The banana family has a wide range, with many accessions and cultivars grown, nevertheless, in future the genetic engineering and breeding technologies has to help improve nutritional and sensory qualities from this banana diversity whenever possible. Thus, banana cultivars that contain genes specific for desirable and useful characteristics may be considered for developing targeted nutritional, sensory and agronomic qualities for bananas. It is therefore essential that researchers, donors, farmers, consumers and traders are made aware of the importance of this crop in the region in order to ensure that the level of resources commensurate with its importance and directed towards its improvement in the future for public nutritional welfare.

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