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PROFILING CULINARY PROPERTIES OF EAST AFRICAN HIGHLAND COOKING BANANAS TO ENHANCE HYBRID SELECTION EFFICIENCY

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ABSTRACT

In many tropical households, the East African Highland Cooking Bananas (EAHCB) referred to as "Matooke" in Uganda are a staple food. Despite its importance, the crop is faced with numerous challenges such as drought, soil fertility, pests, and diseases that threaten its production and productivity. To curb this, banana breeding was developed as one of the strategies to avert the depletion of these bananas through the development of not only pests and disease resistant cultivars but also drought tolerant and high yielding cultivars. The pressure to satisfy the growing global population is also mounting, hence the need to increase production for food security. Breeding has proven to be an approach by which food production is boosted through the development of high yielding and fast-growing varieties. Unfortunately, not so many cooking banana hybrids that have been developed and released are cultivated by farmers as most are rejected as a result of consumer perception of them. The hybrids sometimes possess culinary properties considered inferior. Consumer demands are pertinent in any product development. This review aimed to determine the key factors that influenced consumer perception and acceptability of improved cooking banana hybrids. The data sources used for this study were Google Scholar, PubMed, AgEcon, Sciencedirect.com, CABI Abstracts, and organizational websites (FAO, RTBFoods, and CGIAR). The keywords and search terms used were "East African Highland cooking bananas", "consumer acceptability", "sensory attributes", "culinary properties," "hybrid selection", and "banana breeding". This article presents a summary of banana production and its challenges, banana breeding and its successes, consumer perception, and acceptability of banana hybrids, and profiles the consumer traits responsible for the acceptance or rejection of new hybrids. Overall, the most important culinary properties for both preference and acceptance of new hybrids were the perceived deep yellow color of the cooked matooke, soft texture, smooth mouthfeel, "matooke" aroma, and non-astringent taste, all summed up as "tookeness". Attributes for rejection included possession of mixed colors of the cooked matooke, absence of deep yellow color, lack of "matooke" aroma, hard placentas, and hard texture. Knowledge of product attributes that lead to the acceptance of new products is vital for breeders and this information could guide them during the development and selection of hybrids for release.

Key words: Consumer acceptability, improved traits, new varieties, perception, quality, sensory attributes

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INTRODUCTION

Bananas (Musa *spp*.) are considered one of the most important crops in the world [1]. Close to 145 million tonnes of plantains and bananas are harvested globally [2]. Bananas' contribution to food security, nutrition, and livelihoods of the global population cannot, therefore, be underestimated. In sub-Saharan Africa alone, it is a major staple feeding for over 100 million people, and in Uganda, more than 7 million people depend on bananas [1, 3].

Banana cultivar diversity constitutes cooking type, dessert type, and juice/beer types, which are all classified according to their uses. Most common are the cooking type, which are consumed for food at their green mature stage, and after being cooked. Dessert bananas are consumed when ripe, roasted bananas are roasted at their ripe stage, and juice/beer bananas are used for making local brews at the ripe stage too [4].

In Uganda, the cooking type is locally known as "Matooke" and is consumed in all parts of the country. Cooking bananas are divided into two main groups; the East African Highland Bananas (EAHB) and plantains. The former belongs to the AAA genome and is grown mainly in the highlands of East Africa hence its name [4]. Plantains belong to the AAB genome and are common in West Africa [5].

Much as bananas are harvested all year round, their production is faced with several challenges ranging from low soil fertility, pests, diseases, and drought which threaten yield and eventually food security [1, 4, 6, 7]. To address these challenges, the Banana Research Programme at the National Agricultural Research Organisation (NARO) together with the International Institute of Tropical Agriculture (IITA) launched a program in 1995 to breed for resistance and productivity through conventional methods and genetic engineering [8]. Banana breeding generally involves controlled hybridizations between indigenous varieties and wild genotypes possessing robust resistance attributes [6]. Indigenous varieties are low-yielding compared to hybrids and susceptible to diseases and pests that include Sigatoka, xanthomonas, fusarium wilt, nematodes, and weevils [6]. In one on-farm study by Ssali *et al.* [9], a local check "Mbwazirume had an average bunch weight of 15.5 Kg and the hybrids weighed between 18.8 to 23.3 Kg, which implies that hybrids yielded more than landraces.

Unfortunately, cross-breeding between varieties introduces unpreferred traits into the hybrids and as a result of the ploidy and sterile nature possessed by many common varieties these traits cannot be selected [2]. Most improved bananas are characterized by an unpreferred color, hard and enlarged placentas, the presence of seeds, an astringent taste, and the hard texture of the cooked product, which contribute to minimal acceptance and sometimes rejection of the hybrids [10].

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The sensory quality of food is pertinent because it contributes to acceptance. Previous studies indicated that the primary components of cooking banana quality influencing consumer acceptability were appearance, texture, taste, and aroma [10, 11, 12]. However, no studies have been conducted to relate food characteristics to consumer preference characteristics to understand what influences the decisions of a consumer to accept or reject a new hybrid. A good understanding of the key factors responsible for these acceptable quality traits is required when developing practical criteria for the selection of banana hybrids with acceptable appearance, texture, taste, and aroma.

Given the increasing urgency of addressing sustainability in the production of bananas, and the imminent commercial feasibility of hybrids, it is imperative to synthesize the current knowledge about consumer perceptions of cooking banana hybrids. In addition, reviews on the culinary properties of cooking bananas to enhance breeding efficiency have not been published. As a result, the goal of this review is to discuss comprehensive and sensible responses to the question, "What is known regarding consumer acceptance of cooking banana hybrids?" This review will be useful to banana breeders because it will address the breeding challenge of selecting hybrids with undesirable consumption qualities, which has resulted in a negative perception of hybrid bananas, and low adoption.

METHODS

A critical review of quantitative data was conducted, covering the period 1994 to 2023. The data sources used for this study were Google Scholar, PubMed, AgEcon, Sciencedirect.com, CABI Abstracts, and organizational websites (e.g. FAO, RTBFoods, and CGIAR). The keywords and search terms used were “East African Highland cooking bananas”, “consumer acceptability”, “sensory attributes”, “culinary properties,” “hybrid selection”, and “banana breeding”.

A total number of 77,200 results were obtained from the search. To narrow down the results, the search strategy in the selected databases was executed using appropriate filters such as; publication date, language, and publication type. Search results were also screened by reviewing titles and abstracts to assess their relevance to the research objectives. The irrelevant records were excluded at this stage. Full texts of potentially relevant articles identified during the screening process were obtained.

The inclusion criteria for selecting relevant literature for the study depended on the relevance of the literature to the research objectives. In addition, Peer-Reviewed Sources were also considered as key. These included; academic journals, conference proceedings, and books that have undergone peer review. The research methods employed by some studies had very good methodological rigor

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and the methods, key findings and sample characteristics used were appropriate to the research questions of this study. The experimental designs, case studies, surveys, and qualitative analyses were also appropriate to this study topic.

Also, literature from reputable publishers, academic institutions, and well-known researchers was considered relevant to the study. Studies that provided a comprehensive coverage of the topic and depth of analysis relevant to the research questions were deemed fit for the study. Literature written in the language(s) understood by the researcher and their audience was also included. Readily available literature such as open access or access through institutional subscriptions was used. The literature also was of good quality based on factors such as; sample size, validity, reliability, bias, and relevance to the research questions. Overall, forty-three sources of literature were used. These were organized and managed using the EndNote reference management software to facilitate citation tracking, deduplication, and bibliography generation.

RESULTS AND DISCUSSION

Banana production and its constraints

One of the main drivers of global banana production is the escalating consumption requirements of the rising population, currently estimated at 7 billion people and envisaged to reach close to 10 billion by 2050 [13]. Banana production is reported to be at 119.83 million tonnes having moved from 116.83 million tonnes in 2019. In Uganda, it has been shown to increase gradually in the past 10 years from 4.6 to 7.4 million tonnes in 2011 and 2020, respectively as shown in Table 1 [14].

Of all staple foods grown in Uganda, banana is the most cultivated and is grown as a subsistence crop characterized by a continuous growth season and fruits throughout the year [1]. There are five clone sets in which bananas are classified; “Musakala”, “Nakitembe”, “Nfuuka”, “Nakabululu” and “Mbidde” [4].

Banana is faced with numerous production challenges as reported by several authors [1, 7]. For example, a report on *Xanthomonas campestris* pv. *Musacearum* outbreak in Uganda in 2001 noted that this disease, which had started in Mukono, mostly affected the younger leaves of bananas by causing them to yellow and wilt [7]. The disease also changes the colour of the inner vascular vessels and causes banana fruits to rot inside. This was the beginning of the outbreak in Uganda which later became disastrous by causing a tremendous decline in banana production. Between 2001 and 2004, an average of 33% of the total number of mats of Ugandan farm households was reported to be affected by Banana Xanthomonas wilt (BXW). This led to a banana yield loss estimated at 30% to 52% [15]. Further decline attributed to pests and deteriorating soil fertility were also reported [16].

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Similarly, Lorenzen *et al.* [17] conducted an overview of banana and plantain improvement in Africa and reported several biotic challenges that included bacteria, fungi, nematodes, viruses, and insects that resulted from the movement of plant material from one region to others destabilizing traditional landraces. The authors recommended the introduction of host plant resistance as the cheapest, effective, and sustainable means to manage these pests and diseases [17].

Another study alleviating biotic stress on protecting the African banana revealed that nematodes, banana weevils, Xanthomonas wilt, Fusarium wilt, and black leaf streak were the major pests and diseases that threaten banana production. These had significantly contributed to the reduction in banana yields and several methods for disease and pest control were suggested, among which included training of scientists by research institutes so that new diseases can be quickly identified, isolated, and managed through the use of disease-resistant varieties, chemical, biological and cultural control, and the use of clean planting materials was emphasized [18].

The American Samoa Community College reported that the yield losses caused by nematodes ranged from 30% to 60% in banana production systems in many countries [19], and the most important nematode species reported is *Radopholus similis* [16, 17].

Another study by Nyombi [20] looked at the opportunities and challenges of sustainable banana production in Uganda and reported that declining soil fertility, moisture stress, and pests were key production constraints. To deal with the constraints, the author recommended a systems approach that involved knowledge of the interactions of plant-soil environmental factors and their effect on banana yield. Nyombi [20] emphasized the use of both organic and mineral fertilizers for enhanced banana yields together with affordable rainwater harvesting methods [20].

Fusarium oxysporum f. sp. cubense tropical race 4 (Foc TR4), is another menace in banana production and a soil-borne fungus, which was reported to cause fusarium wilt [21]. Furthermore, drought was also noted as a very big challenge to banana production and was reported to contribute up to 65% yield loss, affecting production globally. These drought spells were said to be recurring because bananas have a comparatively long growth period [1]. Developing drought tolerant varieties is therefore one of the mitigation measures breeding programs have resorted to.

Banana breeding overview

Banana breeding is one of the strategies put in place to solve the challenges faced during production through the development of new varieties that are resistant to

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pests and diseases. Generating hybrids involves conducting crosses between landraces that are highly susceptible with varieties that have resistance. The use of resistant varieties enhances disease control [1].

Until 1994, formal banana breeding had not begun in Uganda [17]. In 1995, NARO in collaboration with IITA set up a program to address challenges of banana production including drought, pests, and diseases that led to the development of several hybrids called NARITAs [7]. The nomenclature of the hybrids was obtained from the combination of abbreviations of the participating institutions (NARO and IITA).

Research in plantain and banana improvement is conducted under different themes depending on specific breeding programs. For example, at IITA, the banana improvement program focuses on increased efficiency of on-farm production, development of improved varieties resistant to nematodes, fruit quality, and dwarfism, and enhanced capacity of staff from the National Agricultural Research System (NARS) [22].

Banana breeding aims at the enhancement of productivity, resistance to abiotic stress, resistance to biotic stress, improvement of postharvest attributes, and market-related issues [17]. Breeding of East African Highland Banana (EAHB) involves crosses between triploid landraces (3x) and diploids (2x) to obtain tetraploids (4x), which are then crossed with diploids (2x). Products of these crosses then go through several selection stages such as the Early Evaluation Trials (EET) and Preliminary Yield Trials (PYT). Here, evaluations of performance, response to black streak, and acceptability are conducted [6].

Improvement of bananas through breeding faces several challenges namely; of inability to obtain viable seeds as a result of female sterility and polyploidy; the long duration cycle of the crop, the need for large fields to conduct field trials, and the longevity of time to move from one trial phase to another [23, 24].

Early banana breeding programs mainly focused on developing varieties resistant to black sigatoka and resulted in the development of hybrids “NAROBAN1”, “NAROBAN2”, “NAROBAN3”, and “NAROBAN 4” (Table 2) [25]. Prioritizing black sigatoka resistance resulted in the release of varieties that were not acceptable to end users because their culinary attributes were lacking [26, 27, 28, 29]. The “NAROBAN” varieties which were released in 2017 by the Ministry of Agriculture Animal Industries and Fisheries (MAAIF) did not only possess multiple resistance to pests and diseases but were also found to be acceptable by consumers for fruit quality traits evaluated and these were; taste, aroma, mouthfeel, colour and overall acceptability [25].

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Breeding for improved quality traits has recently been forthcoming [24]. Much as it has not registered much attention from breeders, it is starting to take shape as an area of importance. Prioritizing fruit quality during breeding is relevant as it gives end users products that satisfy their needs. As reported by several authors, end users particularly consumers prefer matooke with yellow food colour, soft texture, smooth mouthfeel, and a distinctive "matooke" taste and aroma [10, 12, 25, 26, 28, 29].

Breeding for improved postharvest quality factors relating to fruit palatability, durability, and content should also be included in breeding programs because these attributes are crucial for the acceptability of new *Musa* hybrids [30].

Banana breeding success

On-farm participatory evaluation of East African Highland Banana 'Matooke' Hybrids (*Musa* spp.) in Kasangombe and Nakaseke districts revealed that out of the eighteen hybrids evaluated for agronomic performance, consumer acceptability, and black Sigatoka resistance, four varieties; "M2", "M9", "M14", and "M17" were the most acceptable because of their resistance to black Sigatoka, good agronomic performance and high yields. 'Matooke' hybrids produced heavier bunches ranging from 18.9 Kg to 23.2 Kg as compared to the local check "Mbwazirume" which weighed 15.5 Kg. Bunch weight variation was a result of more hands per bunch and fruit size which was characterized by fruit length and girth. The food colour produced by the hybrids was as yellow as that of "Mbwazirume", the local check. The hybrids that were perceived as astringent scored low for acceptability as this is an unwanted consumption attribute. These were "M3", "M7", "M1", "M5", "M16", "M4" and "M12". Another hybrid "M10" was disliked because of its possession of sticky placentas [9]. The authors stress that as much as most hybrids had high yields and moderate resistance to black sigatoka, the priority traits for acceptability by farmers were the sensory attributes. This suggests intrinsic quality attributes are pertinent during breeding as they influence consumer acceptability.

Similarly, a study was conducted by Tumuhimbise *et al.* [30] on the selection of cooking banana genotypes and it involved eleven cooking bananas with two checks ("Kabana 6H" and "Mbwazirume"). The authors evaluated yield and black Sigatoka resistance in different locations in Uganda and their results showed that four genotypes were stable for resistance to Sigatoka, agronomic traits, and bunch yield, besides the possession of a soft texture and yellow food color. The research was conducted in diverse ecological zones to ensure wider adaptability of successful cultivars [30].

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In another study conducted by Kubiriba *et al.* [6] where the performance of three banana hybrids ("M9", "M19", and "M20") and one local check, "Mbwazirume" were studied, hybrids showed better resistance to black leaf streaks and high tolerance to pests than checks, and their acceptability by consumers was not significantly different from the checks. The acceptability scores for the hybrids were found to be above 3.5 and considered acceptable by consumers who rated them on a scale of 1 to 6, where 1=extreme disapproval and 6=extreme approval [6].

Tumuhimbise *et al.* [12] evaluated the acceptance of the banana hybrid 'NABIO808' (Syn. 'NAROBAN5'), which was released in April 2019. The study was conducted in seven multi-location preliminary trial sites in the country which represented key banana growing areas. These sites were in Mbarara, Bushenyi, Fortportal, Hoima, Jinja, Kamuli and Kawanda. The aim of developing 'NABIO808' was to improve bunch yield, and resistance to nematodes, black sigatoka, and weevils [12]. Tumuhimbise *et al.* [12] reported that the cultivar was not only high-yielding and resistant to nematodes, weevils, and black sigatoka, but it was also tasty, soft, and produced yellow food, like most acceptable local varieties [12]. This implies significant promise for agricultural productivity and food security. The cultivar not only demonstrates resilience against common pests and diseases such as weevils, nematodes, and black sigatoka but also demonstrates preferred fruit qualities, including taste, texture, and color important of widely accepted local varieties. This complicated profile implies potential for widespread adoption among farmers and consumers alike, contributing to enhanced yields, improved food quality, and overall agricultural sustainability.

In summary, the literature has shown that resistance to diseases and pests together with increased yield continues to be leading factors for the selection of banana hybrids during breeding [12, 25]. In addition, hybrid varieties are perceived by farmers to be superior to local varieties in terms of resistance to disease and production characteristics but inferior in terms of consumption traits (taste, colour of cooked food, aroma, and texture) [31]. This criterion has resulted in several major drawbacks that include, rejection of the hybrids and low adoption of the same. This was confirmed in a study aimed at establishing the role of variety attributes in the uptake of new hybrid bananas among smallholder rural farmers in central Uganda [11]. The authors found that out of the 242 randomly selected smallholder households from Luwero and Nakaseke districts, 36% were adopters of hybrid banana varieties and 64% were non-adopters. The study further established the proportion of households using different categories of cooking banana varieties and found that the majority which was 51% had only local cultivars, 27% had both local and hybrid banana varieties, 13% had both local and FHIA hybrids, and only 9% had all the variety types. No household was found with

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only hybrid banana varieties. Although a number of attributes such as; size of household and farmland, access to hybrid banana varieties, education level, age and gender of the farmer were reported as influencers of adoption, processing and consumption, related attributes such as; shelf-life after harvest, ease of peeling, colour of food when cooked, softness, flavour and taste were also noted as important [11].

To enhance the selection efficiency of cooking banana hybrids, a more reliable method that combines breeders' priority traits with fruit quality is needed. This would save a lot of time and resources spent on long breeding procedures yet help breeders generate consumer-acceptable genotypes. Previous studies have not addressed this and none has demonstrated how the combination of resistance, yield, and quality attributes might be used for selection, hence necessitating this study.

CONSUMER PERCEPTION AND SENSORY ACCEPTABILITY OF BANANA HYBRIDS IN UGANDA

Consumer perception is defined as the overall opinion of a consumer regarding product attributes, whereas preference is the tendency to like or favor something over other alternatives. Product demand is greatly affected by changes in preferences. This is why it is always good to know and understand consumer preferences before developing any product for consumers. Efforts to understand consumer attitudes and preferences have been explored widely in the recent past, although few studies on cooking bananas exist [30, 32].

Consumer attitudes and perceptions are very vital for new product development, rendering sensory evaluation a critical component in banana breeding. Sensory evaluation induces, measures, evaluates, and interprets responses perceived by taste, smell, touch, taste, hearing, and sight to a food product [33].

Organoleptic properties are the overriding factors contributing to the acceptance and preference of new genotypes, and sensory perception is the leading factor for new hybrid acceptability [32]. A few consumer acceptability studies involving EAHB hybrids have been done to understand consumer preference in Uganda [10, 32]. Texture and appearance have been reported to be essential qualities of cooking bananas [34]. Soft and sticky attributes are mentioned as acceptable textural traits that drive acceptability, which is confirmed by some studies (Table 3).

Consumer acceptability of fourteen introduced banana and plantain varieties in Uganda was investigated [27]. Findings from this study showed that although the introduced varieties had big fingers and bunches, their cooking attributes

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characterized by high tannins, hard texture, and poor taste were unacceptable to consumers (Table 3).

Similarly, another study by Ssemwanga *et al.* [28] evaluated the acceptability and quality of FHIA 3 as a cooking banana. Results indicated the unacceptability of the hybrid was attributed to its high level of astringency, poor food color, and firm and lumpy texture (Table 3). The study further showed that eating characteristics influenced preference as much as yield characteristics were also important to consumers. These results were following the study by Nowakunda and Tushemereirwe [10].

Product characteristics and cultivar preferences of bananas among males and females of Uganda and Tanzania were investigated by Marimo *et al.* [35]. Results showed that what farmers preferred was consumption characteristics like texture, mouthfeel, color, and taste (Table 3). The authors further noted that for color, both men and women preferred food that had an attractive yellow color. For texture, both men and women preferred smooth and soft, non-sticky food although the women wanted it slippery on their fingers, whereas men wanted it stretchy like chewing gum. A nice smell, good taste, and flavor were also pointed out as important by both genders. Consideration of consumer-preferred traits in breeding was reported as imperative for the effective development of new banana hybrids and their subsequent adoption [34, 36].

Furthermore, the importance of product attributes in the uptake of hybrids among banana farmers in rural households was evaluated [11]. Decisions on adoption and intensity from 242 randomly selected smallholder banana farmers in Nakaseke and Luwero districts were examined. Results indicated that local varieties were preferred over the hybrids because they possessed desirable consumer characteristics such as; yellowness of the food, softness, smoothness, and possession of a unique “matooke aroma”.

The consumer acceptability study of NARITA hybrids was conducted in Uganda and Tanzania by Marimo *et al.* [37]. The study was conducted in five sites; Maruku, Mitatula, and Moshi in Tanzania, and Kawanda and Mbarara in Uganda. Two forms of presentation of cooking bananas were evaluated for each country. Boiled fingers were evaluated for Tanzania and steamed matooke for Uganda. The results showed that the attributes of interest to the consumer were colour, aroma, texture in hand, taste, mouthfeel, and overall acceptability [37]. Acceptability was assessed on a 5-point hedonic scale where 5= very good, 4= good, 3=fair, 2= bad, 1=very bad. NARITAs that had an overall acceptability score of >3.3 were considered fit for advancement on-farm. At Kawanda, three varieties were recommended for on-farm trials; “N14”, “N7” and “N24”, whereas in Mbarara,

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"N17", "N7", "N24", "N23", "N4", "N18", "N12", "N14" were recommended. "Mbwazirume", characterized by its yellow food colour, aroma, and soft texture was used as a local check and had scores between 4.29 and 4.48.

The preferences of 'Matooke' farmers and traders were studied and it was found that agronomic traits such as big bunches and fruits as well as quality traits such as soft texture, taste, aroma, and color were the main characteristics that influenced variety preferences [32]. In that study, the authors recommended that physicochemical properties should be used to describe quality so that they are incorporated into breeding programs to enhance efficiency.

Overall, these studies showed that from the consumer point of view, the main quality parameters of cooked bananas were reported as soft texture, yellow food, good taste, and matooke aroma when cooked, which was summed up as "tookenness".

Banana preferences in Uganda

There are so many banana varieties grown and consumed in Uganda some of which are specific to the geographical locations. Uganda has several agro-ecological zones but the ones that grow bananas are the South West (Kabale, Bushenyi, Mbarara, and Kabarole), Central North (Mubende, Mpigi, Kibale, and Kiboga), Central (Luwero, Mukono, and Iganga), Eastern (Mbale and Kapchorwa) and some parts of the Central South (Rakai, Mubende, Masaka, and Mpigi) [38].

A study on the "diversity, distribution, and farmer preference of Musa Cultivars in Uganda" was conducted by Gold *et al.* [38] reporting that several cultivars were consumed in the different agroecological zones of the Country. The zones for this study were the south west (Kabale, Mbarara, Bushenyi, and Kabarole), central south (Rakai, Masaka, Mubende and Mpigi), central north (Mubende, Kibale, Mpigi and, Kiboga), central (Luwero, Mukono and Iganga) and east (Mbale, Kapchorwa). "Nakabululu", "Enyeru", "Nakitembe", "Mbwazirume", "Nakyetengu", "Kibuzi", "Nfuuka", "Musakala", "Nandigobe", "Kisansa", "Kafuba", "Nassaba", "Salalugazi", "Enzirabahima", "Ndiibwabalangira", "Enyamaizi", "Siira", "Muvubo", "Namwezi", "Ituntu", "Ntika" were some of the Musa varieties reported [38]. Some cultivars were specific to some regions whereas others were spread over the regions. "Nakitembe" and "Nakabululu" were said to be important in all the regions, although "Nakabululu" was most common in the east and "Nakitembe" in the central south and east. "Mbwazirume" was mostly grown in the east, south west, and central. "Enyeru" was mostly grown in the south west and central south, "Nassaba" was only in the central north, "Nakyetengu" was in the south west and central north, and "Nandigobe" was mostly in the southwest. The most cultivated varieties were "Mbwazirume", "Nakitembe", "Nakabululu" and "Enyeru" and this was attributed to

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their being quick-maturing, tasty, and having soft-textured and yellow food which made them very liked by farmers [38].

Usually, banana varieties are liked or disliked based on end-user preference and this varies from one region to another [36, 39]. The relevance of knowing why some varieties were preferred over others is very important for breeders in understanding product quality. The most common usage was the local dish that is prepared through steaming but there are also other uses such as 'katogo', a mixture of full fingers with either beans, beef, offals, or groundnuts; 'empogola', roasted over the fire with their peels and mainly eaten with roasted meat [35].

In Mbarara district of western Uganda, both men and women preferred similar landrace varieties for the preparation of steamed matooke [35]. The varieties included, "Kibuzi", "Butobe", "Muvubo", "Enjagata", "Nakabululu", "Enyeru", "Mbwazirume", and "Nakitembe" ("Entaragaza"), and the characteristics in consideration were both morphological and consumption. The consumption attributes reported included the acceptable yellow food colour, soft texture, and a distinctive aroma. Big bunches with well-filled straight fingers were mentioned as important traits for making good matooke on top of a soft peel that aided the easy movement of the knife during preparation. These traits were similar to what was reported by Akankwasa *et al.* [32].

The preferred varieties in the Luwero District of central Uganda were a little different from those in Western Uganda. Both male and women preferred "Mbwazirume", "Kisansa", "Kibuzi", "Muvubo", "Mpologoma", "Nfuuka", "Nakabululu", "Musakala", "Nakinyika", "Mukubakonde", "Nakamali", and "Nakitembe" [35]. In addition, men also included "Enzirabahima", "Nakabinyi", and "Nakyetengu" in their preference list which was precluded by the women. Similarly, women preferred "Katwala" variety which was excluded from the men's preference category. Most of these varieties were preferred because of their possession of quality traits such as soft texture, aroma, taste, and yellow colour. "Nakabululu" and "Mukubakonde" were reported to have negative traits such as having a too compact bunch and being difficult to dehand [35]. It was noted that both inward and outward product characteristics of bananas influence sensory perception, response to food products, and consequently food choice [33].

CONCLUSION, AND RECOMMENDATIONS FOR DEVELOPMENT

This review compiled the culinary consumption quality characteristics of cooking bananas that influence consumer perception and acceptance of improved hybrids. Diverse factors were identified to influence consumer perception and acceptance of hybrids. Uniformity and high intensity of the yellow colour of matooke, soft texture, and aroma were highlighted as key influencing factors determining

consumer perception and acceptance. Good taste, flavor, non-astringency, and stickiness were also pointed out as relevant determinant factors. The lack of preference for hybrids was triggered by possession of non-yellow colour, mixed colours, hard and firm texture, too soft texture, astringency, poor taste, puckering aftertaste in the mouth, and lumpiness.

Based on this review, breeders have to incorporate selection for consumption attributes during their breeding programs of new banana hybrids. Although culinary attributes are important for consumer perception and acceptability, there is inadequate knowledge and information on the biochemical constituents that contribute to their preference. In a bid to increase the acceptance and adoption of cooking banana hybrids, it is imperative to evaluate the biochemical components that are linked or determine preferred consumption quality characteristics and to develop new hybrids with similar perceived colour, texture, taste, and aroma with the acceptable landraces.

Competing Interest Statement

The authors declare no conflicts of interest in this work.

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Table 1: Banana Production (Plantain and others) in Uganda in the last 10 years

Year	Production (million tonnes/year)
2011	4.6
2012	4.5
2013	4.4
2014	4.6
2015	4.6
2016	3.4
2017	4.7
2018	3.5
2019	8.3
2020	7.4

Source: FAOSTAT [40]

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Table 2: Banana hybrids released in Uganda since 1990, their agronomic and consumption attributes

Cultivar Name	Type	Synonyms	Agronomic attributes and Resistance	Consumption Attributes	Year of release	Reference
NAROBAN1	Cooking	M19	High yielding, Resistant to sigatoka, banana weevil and nematodes	Soft, Tasty, yellow food color	2017	[25, 41]
NAROBAN2	Cooking	M20	High yielding, Resistant to sigatoka, banana weevil and nematodes	Soft, Tasty, near yellow food color	2017	[25, 41]
NAROBAN3	Cooking	M25	High yielding, Resistant to sigatoka, banana weevil and nematodes	Soft, Tasty, near yellow food color	2017	[25, 41]
NAROBAN4	Cooking	M27	High yielding, Resistant to sigatoka, banana weevil and nematodes	Soft, Tasty, yellow food color	2017	[25, 41]
NAROBAN5	Cooking	NABIO808	High yielding, Resistant to sigatoka, banana weevil and nematodes	Soft, Tasty, yellow food color	2018	[12, 41]
KABANA 6H	Cooking	Kiwangaazi/M9	High yielding, Resistant to sigatoka, banana weevil and nematodes	Soft, Tasty, yellow food color	2010	[26, 41]
KABANA 7H	Cooking	M2	High yielding, Resistant to sigatoka, banana weevil and nematodes	Soft, Tasty, yellow food color	2010	[41]

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Table 3: Acceptance and Rejection factors for steamed cooking banana (Matooke)

Study S/No.	Sample size	Banana varieties used	Good eating quality attributes	Poor eating quality attributes	References
1	N.G	N.G	Texture: Softness, stickiness; Appearance: uniform colour, high intensity yellow colour. Flavour: sweetness, astringency and aroma	Texture: lumpiness, solidity, crumbliness. Colour: Red-brown with patches of yellow and cream	[29]
2	N.G	N.G	N.G	Texture, Appearance	[34]
3	16 untrained, 9 trained panelists	FHIA 3, Nakabululu, Nakyetengu, Mukazi-alanda	Soft matooke, not astringent, good aroma, very yellow colour, uniform colour	Firm texture, Hard texture, lumpy, mixed colours (red-brown	[28]
4	N.G	Mbwazirume, Kisansa, Ndizi, Musa-Kayinja, Entundu, Kisubi, Pisang-Awak, Yangambi Km5, Saba, Pisang Ceylan, TMPx7002/1, TMPx548/4, PV 03-44, TMPx548/9, TMPx5511/2, TMPx582/4, FHIA-23, FHIA-17, FHIA-03, FHIA-02, FHIA-01	N.G	with patches of yellow and cream)	[27]

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5	(Min. of 30 people/site)120	Bita-2, Bita-3, Pita-8, Pita-14, Pita 17, FHIA 01, FHIA 03, FHIA 17, FHIA 21 FHIA 23, Yangambi KM5, Kisansa	Taste, Texture and appearance	Astringent, puckering after taste in the mouth, hard texture, too soft texture, dark brown colour, grey colour,	[10]
6	908	M2, M9, M14, M17, Mbwazirume	Good taste, texture and colour	N.G	[42]
7	454	M2, M9, M14, M17	Good taste, soft food	N.G	[39]
8	40	M2, M14, 17, KABANA 6, Mbwazirume	Taste, Flavour, Texture and colour of the food	Astringent taste, hard texture, unacceptable colour, poor taste, puckering sensation, poor flavour	[26]
9	21 key informant interviews and 5 focus group discussions	N.G	food colour, texture, flavour and taste	N.G	[39]
10	N.G	N.G	Golden yellow, yellow colour, attractive appearance, soft, non-sticky, smooth in the hands, not too soft, stretchy like chewing gum	N.G	[35]

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11	123 farmers, 14 FGDs, 14 traders		Soft texture, Good smell, Yellow colour, Good Matooke taste, compact, elastic, uniform texture, smooth mouthfeel, moldable, non-sticky, uniform colour, does not harden fast	Hard, watery, pale yellow colour, easily separates when mashed, flat taste, no steamed banana smell, non-homogenous texture, non-homogenous colour, brownish colour, cools fast, contains threadlike materials	[43]
12	N.G	N.G	9058K-2, 8099K-16, 9019K-3, 6880K-2, 10072K-10, 10054K-1, Kabana 6H, Mbwazirume	taste, aroma, soft mouthfeel, and colour	[36]

*N.G = Not given

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