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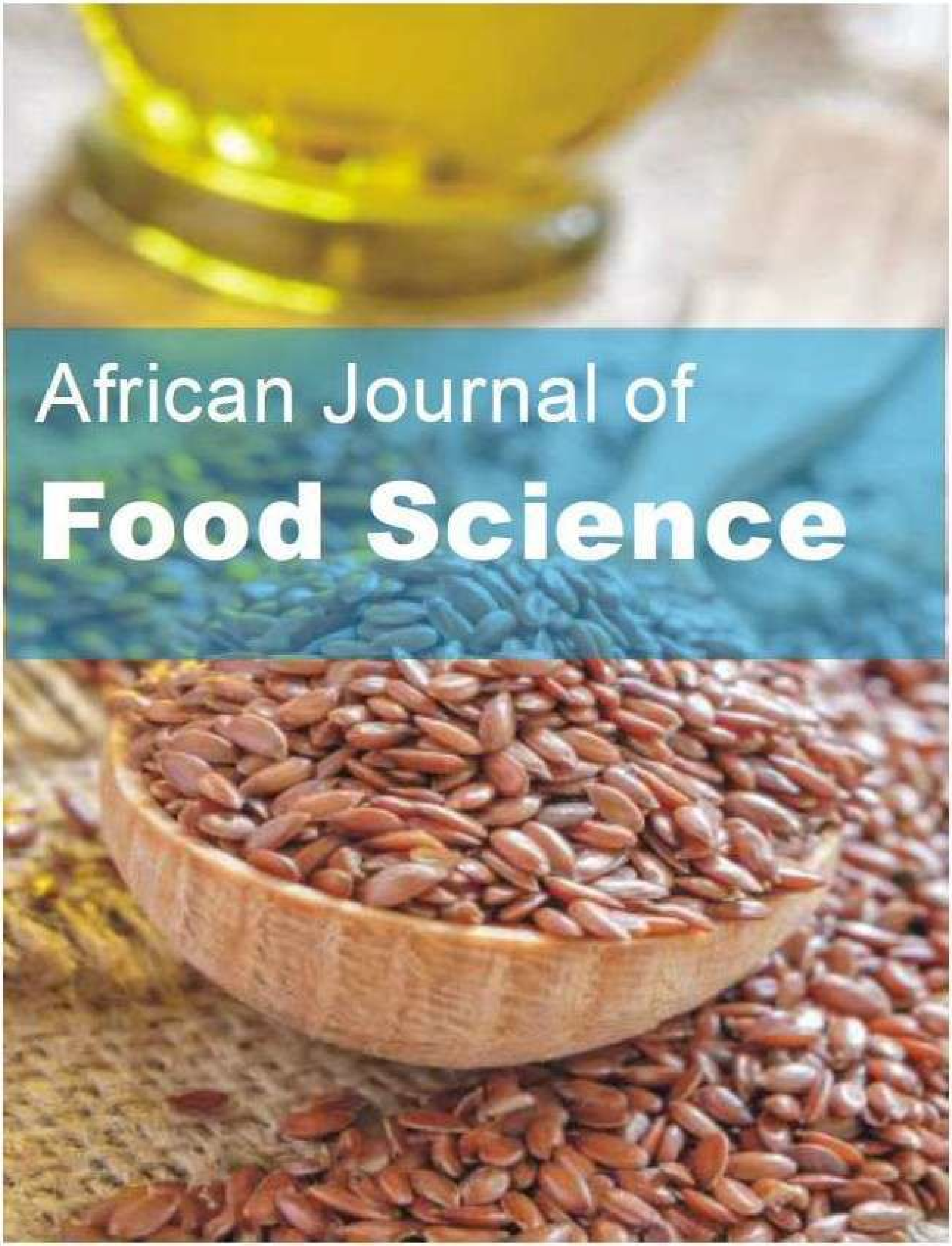

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Full Length Research Paper

Production practices of table salt by small-scale miners in Tanzania: A case study of Nkonkilangi, Singida, Tanzania

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In Tanzania, a small-scale salt enterprise supplies salt which is mainly consumed within the country. However, the producers often lack appropriate production knowledge. The purpose of this study was to assess salt processing and handling practices at Nkonkilangi village in Singida region, Tanzania. A cross-sectional study design was used to collect data. Scheduled interviews with 63 out of 100 producers were conducted using semi-structured questions. The producers were exclusively women (100%) with primary school education (98%) and aged from 20 to 60 years (90.5%). Although 33.3% of the producers attended food processing and hygiene training, none used improved methods. The traditional method used involved mixing three soil types locally known as *Nkuluse, Mbuga and Sepa*, or *Nkoko* in the ratio of 1:1:1 (v/v/v). Brine is obtained by leaching the soil with water in perforated clay pots. Majority (63.5%) of the producers boil brine for 1 - 2 h for salt recovery, up to 5 batches per day. Three buckets of brine yield 1 bucket of salt. Two-thirds of the producers clean equipment and containers without detergents. More than 84% of the salt producers identified sand as major contaminant, whereas 47.6% of the processers use pieces of plastics and broken guards to stir salt during cooking. The salt is conditioned and packed for delivery. Despite the fact that salt fortification is mandatory in the country, none of the processers fortified the salt with iodine. Majority were neither aware of the nutritional benefits of fortification (90.5%) nor of the legal implications of selling non-iodized salt (79.4%). Therefore, proper control and monitoring of small-scale mining in Tanzania is essential for assuring quality and safety of salt.

Key words: Salt, salt quality, iodized, salt mining, contaminants, soil, plastic, Nkonkilangi.

INTRODUCTION

Salt is an important commodity for public health. Universally salt has been used as a vehicle to facilitate access of consumers to iodine (Etesin et al., 2017; Ba et al., 2020). Salt is used as flavour enhancer, food

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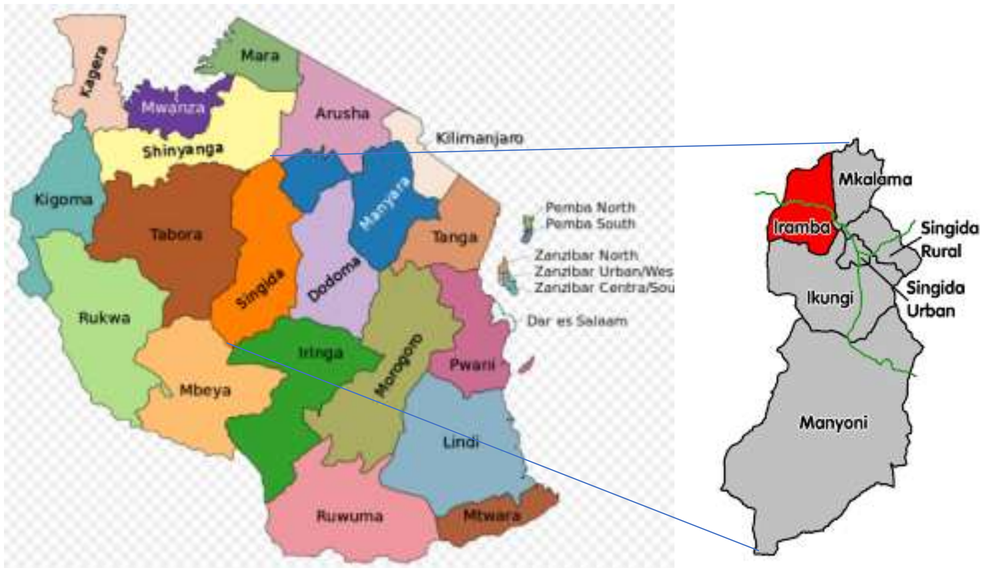

Figure 1. Location of Iramba district in Tanzania.
Source: Authors

preservative, colour maintainer, and medicine (Duerst, 2019; Weremfo, 2019). Salt production across the world varies from place to place.

While in the developed countries, salt producers are likely to be medium and large-scale companies, in developing countries the majority are micro and small-scale producers without right knowledge and equipment. The micro-scale producers use traditional techniques (Kam, 2017; Muhandhis et al., 2020) which are inefficient and may compromise the quality and safety of salt.

Salt is distinguished according to its colour from white, pink, and red to black (Helmi and Sasoka, 2018). Variation of salt chemical compositions gives different salt colour and tastes (Carapeto et al., 2018). There are three methods (that is, conventional, solar evaporation and solution mining) of salt production categories based on the method of salt recovery. Conventional underground or rock salt mining is carried out by drilling and blasting to remove solid salt. Solar evaporation is the use of the sun to evaporate saline water (sea or lake) in special ponds to produce salt crystals that will be harvested mechanically. Solution mining involves underground brine pumping filtration, mechanical evaporation by steam-powered multiple effects or an electric-powered vapor compressor to form salt crystals (Syafii et al., 2019; Muhandhis et al., 2020).

Due to the fact that majority of salt producers in developing countries including Tanzania are micro-scale, salt production has been practiced seasonally as it is weather dependent. Societies living around the salt mines are eventually engaged in salt production (Ba et al., 2020). However, women are the key players in salt processing at micro- and small-scale levels (Iwuchukwu et al., 2021).

As compared to medium and large-scale companies, small and micro-scale companies receive inadequate control and monitoring by the food control authorities (Kussaga, 2015). Inadequate control and monitoring indicate such production units produce inconsistent quality and safe salt (Assey et al., 2009; Syafii et al., 2019). Although salt iodization/fortification with potassium iodate (KIO3) or iodide (KI) is mandatory in Tanzania (URT, 2014; TFNC, 2015; EAS, 2019), majority of micro and small-scale companies do not fortify their salt. This indicates that the public is most probably exposed to non-iodate salts.

Therefore, this study aims to assess the processing and handling practices of salt by small-scale producers at Nkonkilangi.

MATERIALS AND METHODS

The study location

The study was conducted in Nkonkilangi village, Iramba District in Singida Region, Tanzania. The village hosts several micro-and small-scale salt producers in the region, which meets the needs for this study. Iramba District (Figure 1) lies between latitudes 4º to 4º.3º South and longitudes 34º to 35° east. The district covers 4,549.40 square km with a population of 255,373 (URT, 2012). It is bordered by Shinyanga Rural and Meatu districts in the north, Ikungi District in the south, Igunga district in the west and Mkalama district in the east. The district is semi-arid with an extended dry season of seven to eight months (i.e., April to early November) and an annual rainfall of 600 mm to 800 mm (URT, 2012).

Study population (small-scale salt producers) and sample size

The study location had a total of 100 small-scale salt producers.

However, due to financial and time constraints, it was not possible to assess all producers. Therefore, a convenient sample was constituted. The sample size was calculated according to Morris (2004) equation as follows:

$$n = \frac{NZ^2pq}{(E^2(N-1) + Z^2pq)}$$

Where, n is required sample size, population size (N)=100, confidence level (z) =2.58, error (E) = 0.01, population proportions (p and q) each = 0.05 was applied for unknown population proportion. By substituting values of each parameter in the equation:

The sample size $n = \frac{100x\,2.58^2x0.05x0.05}{(0.01^2x(100-1)+2.58^2x0.05x0.05)} = 63$

Sampling

The simple random sampling technique was used to select 63 participants from the study population of 100 small-scale salt producers. This was simply done by tacking a hundred pieces of paper, out of which 63 pieces were written OK and 27 were labelled NO. The pieces of paper were properly folded, mixed up and put in a bowl. Then, each producer was requested to pick one of the folded papers from the bowl. Producers who picked a folded paper labelled OK were included in the study, whereas those who picked NO were excluded.

Assessment of salt processing and handling method

Scheduled interviews using a questionnaire uploaded in a mobile-phone with help of KoBo Collect software were conducted to assess processing method, soil and water ratios used, filtration, evaporation, drying, production batches, daily production capacity, packaging, storage, type of water used, equipment cleanliness, quality assessment, processing knowledge and skills and availability of toilets. The face-to-face interviews took at least 30 min. The questionnaires were anonymously coded from number 1 to 63.

Statistical analysis

Data collected were downloaded in computer Microsoft excel form and analysed by statistical software International Business Machine (IBM) SPSS statistics ver. 20. Descriptive statistics were performed to obtain frequency, mean, range and percentages.

RESULTS AND DISCUSSION

Characteristics of small-scale salt producers

The salt producers at Nkonkilangi village were all women (100%), whose majority were married (77.8%), primary education holders (63.5%) and aged between 20 and 60 years (90.5%, Table 1). Previous studies in Tanzania and Nigeria also observed women as dominant in small-scale salt production (Assey et al., 2009; Iwuchukwu et al., 2021).

The nature of salt production activities which is mainly cooking could be a limiting factor for men. In most African societies, cooking activities are commonly done by women (Iwuchukwu et al., 2021).

Despite the fact that salt production is a laborious job which would be best suited for young people, 9.5% of processors were over the age of 60 (Table 1). Likewise, study in Guinea also found that salt production was dominated by the younger generation (Balde et al., 2013). Involvement of old people in salt production facilitated the transfer of the traditional processing technology to younger generation.

Although, majority (63.5%, Table 1) of producers had primary level education more than one-third (34.9%) had informal education). The salt production activity in the study area used traditional knowledge that does not require any further training. Old age salt producers conduct the on-job training to younger ones. Long-time schooling could be among the reasons people in Nkonkilangi forego school for salt production. A study in India also observed that majority of salt producers have limited skills with low or no formal education (Bhattacharya et al., 2018). Moreover, a significant number (66.7%) have never attended any training on food processing or food hygiene.

Likewise, Amadu (2019) reported lack of formal training of salt producers in Ghana. Lack of food hygiene training suggests that salt could be inappropriately handled and compromises its quality. It may further limit the adoption of new and improved production technologies. This study also observed that salt production at Nkonkilangi is weather dependent. During the rainy season, producers shift to other economic activities like farming (92.1%) business (3.2%) and mineral mining (4.7%). Unavailability of cooking shelters and storage facilities limit salt production capacity during the rainy season. This does not only affect availability but also price of salt.

Salt production process

All producers (100%) at Nkonkilangi use traditional salt processing method. The method involves several steps namely, mobilisation of raw materials, blending of raw materials, addition of water, filtration, concentration, conditioning, packaging and storage (Figure 2). The next sub-sections provide description of each process step.

Raw materials

The major raw materials used to produce salt are soils and water (Figure 2). Physical observation and explanation by salt producers revealed that traditionally Nyiramba tribe assigned different names to soil used for salt production. The traditional names given to soil include; *Nkuluse* (red silt soil), *mbuga* (dark pack soil) and *sepa* (stacked soil filter residues), or *nkoko* (top soil crust)]. According to experienced salt processors, each soil has different properties and serves a specific function in salt production. Both *nkoko and sepa* aid salt particle

Table 1. Characteristics of salt producers at Nkonkilangi.

Parameter	Frequency (n=63)	(%)
What is your sex?		
Male	0	0.0
Female	63	100.0
What is your marital status?		
Divorced	2	3.2
Married	49	77.8
Single	2	3.2
Widow	10	15.9
What is your age group?		
20-30	13	20.6
31-40	19	30.2
41-50	16	25.4
51-60	9	14.3
Above 60	6	9.5
What is your level of education?		
Informal	22	34.9
Primary	40	63.5
Secondary	1	1.6
Besides salt processing, what other economic activities are you involved		
Business	2	3.2
Farmer	58	92.1
Others	3	4.8
Have you attended any food/salt processing training?		
No	42	66.7
Yes	21	33.3

Source: Authors

size reduction when any one of them is used at the recommended quantity. The ratios used are 1 volume (33.3%) for *nkoko* or *sepa* by 66.6% of mixture of 1 volume of *Nkuluse* and 1 volume of *mbuga.* However, when used in excess could increase foam formation during boiling. *Sepa* is the residue soil after the salt filtration process; it is heaped up to make a protective wall against the wind at the salt production site. A quarter volume of the soil mixture used is *Mbuga* which whitens the final produced salt. Excessive use of *Mbuga* reduces the quantity of salt. *Nkuluse* is used to increase salt quantity. If one of the soil material types is missed, it limits salt production quantity and quality. The chemical reactions occur when Na_2SO_4-rich soil is mixed with $CaCl_2$-rich soil in the presence of water to form NaCl (Li et al., 2021).

The quantity of NaCl formation is determined by proper soil mixing ratios (Li et al., 2021). Although soil has several mineral matters that can contaminate the salt and render it unsafe for human consumption, the soil colour at dry moisture content predicts the potential contaminants (Vodyanitskii and Savichev, 2017). For instance; *Mbuga* (dark pack soil) is associated with high levels of organic compounds while *nkoko (top soil crust)* has high levels of binding agents such as organih c matter, liming materials (calcium carbonate). *Nkuluse* (red soil) is rich in non-soluble materials (iron, aluminium, organic matter, Magnesium, lime, potash, phosphorus and nitrogen (Tamfuh et al., 2018; Li et al., 2021). *Sepa* (*stacked soil filter residue*) *is* residue soil mix of *nkoko, nkuluse, and mbuga,* henceforth has what the three soils have.

Water is used as dissolution medium of soil mixture to make salt. The salt production area has two types of water sources; hot spring and open stream water. As compared to hot spring water, stream water is susceptible to physical contamination. The hot spring water is preferred by the majority of producers (87.5%) as it is regarded as clean and has been used traditionally to make salt.

However, despite such a belief, the readily available water in production areas would be more preferred and used. Therefore, salt miners along the sea would use sea water, whereas those along the lakes would go for lake water to produce salt (Iñiguez et al., 2017).

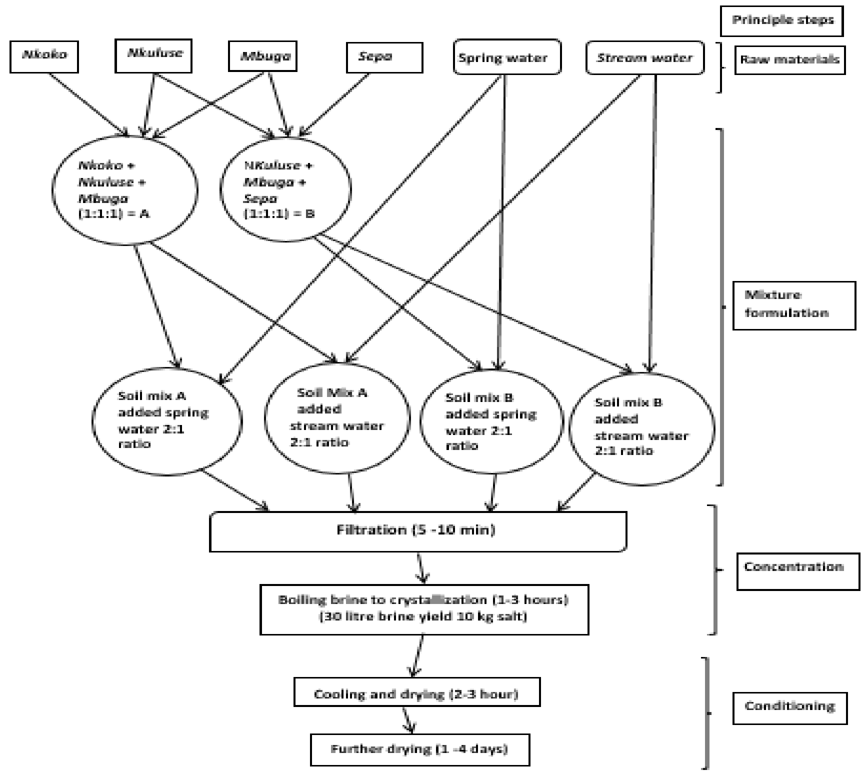

Figure 2. Flow diagram of salt production.
Source: Authors

Preparation of soil mixture

Producers mix at least three types of soils (*nkuluse, mbuga and sepa,* or *nkoko*) in a ratio of 1:1:1(v/v/v) to formulate soil mix A or B (Table 2; Figure 2). However, some slight differences in soil ratios used are likely, as the ratio determines quality of salt (Li et al., 2021). The ratios used are sometimes kept confidential. Some slight differences in soil ratios used are likely to cause salt quality discrepancy among producers.

Dissolution of salt components from the soil (Leaching)

Salt components are dissolved from the soil mixture by using hot spring or stream water. Normally, water enables soil elements to react to different compounds including NaCl (Li et al., 2021). The soil-water ratios commonly used by salt producers are either 2:1 (55.6%) or 1:1 (28.6%, Table 2). Normally water is poured on the mixture of soil placed in perforated clay pots and allowed to percolate. As it percolates, it dissolves water-soluble materials from the soil mixture. The amount of water used determines the concentration of the leach (that is, the brine). Before, the soil mix is poured into pots, a net at the bottom of the pots is properly laid out and clean river sand is put on top of the laid net. Then, the soil mixture in 20 litres bucket is placed on top of that river sand and about 10 litre water is discharged from the top of soil through the leaching pot. The sand and nets aid the filtration process.

Brine filtration

Filtration of the soil leach aims to remove impurities from the brine. As the brine percolates through the soil and sand in the perforated leaching clay pots filtration occurs. The soil and sand provide the same filtration mechanism as observed in sand water filters (Ji et al., 2022).

Majority (65.1%) do filtration more than one round; after the first round the filtrate is poured back on the perforated pot to remove further the contaminants and get a clear filtrate (Table 2). The filtration process conducted in the study area resembled the Benue trough in Nigeria; which also uses perforated clay pots to filter saline (Tijani and Loehnert, 2004). The colour of the salt reflects the efficiency of the filtration process; the whiter the salt the lesser is its impurities.

Salt concentration

Salt concentration involves boiling of the brine to make crystals. It is done through the process known as

Table 2. Salt production.

Parameter	Frequency (n=63)	(%)
What soil and water ratios do you use?		
1:1	18	28.6
1:2	2	3.2
2:1	35	55.6
Others	8	12.7
What type of water is used in salt processing?		
Any water	2	3.2
Hot spring water	54	85.7
stream water	7	11.1
How many times filtration is done?		
Once	22	34.9
Twice	41	65.1
Do you know any loses occurring in the processing		
No	54	85.7
Yes	9	14.3
With what material do you use in stirring salt during boiling?		
Piece of gourd	31	49.2
Plastic	30	47.6
Wood	2	3.2
How long do you evaporate brine for salt recovery?		
< 1 h	8	12.7
1 -2 h	40	63.5
2-3 h	14	22.2
> 3 h	1	1.6
How long do your drying salt before selling?		
One day	3	4.8
Two days	1	1.6
Three days	52	82.5
Four days	7	11.1
How many brine batches do you process per day?		
Three	2	3.2
Four	22	34.9
Five	39	61.9
How many kilogrammes of salt do you produce day?		
180	1	1.6
120	4	6.3
100	30	47.6
80	19	30.2
60	9	14.3
Do you think losses occur in the process?		
No	54	85.7
Yes	9	14.3

Source: Authors

crystallisation. Crystallisation is the formation of salt crystals from the brine. The crystallisation process involves boiling of salt to evaporate water. It was observed that majority of the producers (63.5%) boil the

Table 3. Salt iodization.

Parameter	Frequency (n=63)	(%)
Do you know the salt iodization process or KI?		
Don't know the process	51	81.0
Knows the process	12	19.0
Do you fortify salt with iodate (KI)?		
No	63	100
Yes	0	0
Why don't you fortify the salt?		
Belief that inhered salt from ancestral spirits has enough iodine.	2	3.2
Customers don't prefer off flavour and yellow colour of iodized salt taste foods	1	1.6
Both customers dislike fortified salt off flavour and yellow colour in food and belief that iodine is naturally present in Nkonkilangi's salt	1	1.6
I don't know	17	27.0
KI is not available to fortify salt	14	22.2
Naturally present in salt	27	42.9
Salt loses its white colour	1	1.6
Do you know that selling unfortified salt is criminal?		
No	50	79.4
Yes	13	20.6
What is the importance of KI?		
I don't know	57	90.5
Prevent goitre	1	1.6
To add value	1	1.6
Improve child's brain prevent goitre	1	1.6
Improve child's brain prevent goitre to add value	3	4.8

Source: Authors

brine for 1-2 h (Table 2). Although heating could be done by electricity, solar energy or biogas, all producers at the study site use firewood stoves. Prolonged use of firewood as source of energy may affect salt producers' health (blindness, red-eyes and coughing) and cause environment pollution and degradation (Mhache, 2021). Boiling is normally done in batches (1-5 batches/day); usually, three buckets of brine may produce 1 bucket (20 kg) of salt. Previous studies also observed that brine boiling can take about 1½ to 2 h (Connah et al., 1990). Traditional processing method (filtration and boiling) limits the salt production quantity and quality. The introduction of solar dryers reduces firewood consumption thus giving environment protection and minimizes salt iodine volatility.

Salt conditioning

Salt conditioning involves cooling, drying and/or fortification with iodine to produce salt of the recommended standard. In Nkonkilangi salt cooling is followed just after salt concentration (Figure 2). Cooling and preliminary drying are done for 2-3 h by transferring salt to a net sheet placed on top of the inclined ground. The cooled salt is transported to the producers' households. Then, secondary drying is done for up to four days outside the producers' home, under the sun. This is a critical step for salt safety, as inadequate and long drying periods may introduce various health hazards to salt. Moreover, sun drying has some limitations particularly during rainy and cloudy days and may result in iodine loss (Etesin et al., 2017). Iodine is heat labile (Assey et al., 2009), hence, the significant amount of natural occurring iodine is vulnerable to boiling for salt recovery and conditioning by sun drying. Iodine fortification is necessary to compensate for the processing losses and top up to Tanzanian standards for the health of consumers.

Salt fortification

Despite the fact that salt iodisation has been mandatory for a long time in Tanzania (URT, 1994), none of the salt producers at Nkonkilangi did fortification (Table 3).

Table 4. Packaging storage and marketing.

Parameter	Frequency (n=63)	Percent
What type of packaging material do you use?		
woven polyethylene	63	100.0
Bottle	0	0.0
Paper bags	0	0.0
Jute sucks	0	0.0
Where do you store the produced salt?		
Dedicated store inside the houses	5	8.0
Outside without shade	58	92.0
Where do you sell salt?		
Singida, Shinyanga, Tabora, Simiyu and Mwanza	1	1.6
Singida, Shinyanga, Tabora	62	98.4
What do you do with salt rejected/ returned by the customer?		
Receive and keep for sale	44	69.9
Refuse to receive it	19	30.1
Receive and destroy	0	0.0
What is the price of salt?		
Dry season 500/tin	63	100.0
Wet season 1000/tin	63	100.0

Source: Authors

Majority (81%) of salt producers have never heard of salt fortification. They do not know whether selling of non-iodised salt is illegal (79.4%) and know nothing about the nutritional importance of iodised salt (90.5%, Table 3). On the contrary, previous studies in other countries like Ghana reported that the salt producers iodize salt before selling (Amadu, 2019). Besides lack of awareness, some salt producers (42.9%) at Nkonkilangi village believed that the salt produced at their area has enough natural iodine (Table 3). Others claim that some consumers dislike the flavour of food prepared with iodized salt. Moreover, some say the loss of natural colour of foods prepared with iodized salt is the stumbling blocks to adaptation of salt iodisation. The outcome of such claims and beliefs is the continuation of consumption of non-iodised salt within the area and beyond. As compared to urban areas, people in rural areas have limited opportunities to eat out of their homes. So, if a family depends on such salts, they may consume non-iodised salts throughout their lives which increase chance of health implications (Ba et al., 2020). However, previous studies did not find any sensory obstacle to food products processed using iodized table salt in Finland (Greis et al., 2018). Contrary to the above 22% of producers reported the major limiting factors to salt fortification (Table 3).

A similar study in Ethiopia identified lack of KI as among the influencing factors of salt iodine fortification (Desta et al., 2019). Furthermore, majority (79.4%) of salt producers at Nkonkilangi do not know that it is illegal to sell non-iodized salt in Tanzanian and know nothing about the importance of using iodised salt to the human body (90.5%). These results show inadequate promotion campaign regarding the utilisation of iodised salt in Tanzania. Strategies to increase awareness and adoption of salt fortification by salt producers at Nkonkilangi and other areas are therefore very essential.

Packaging, storage and marketing of salt

All (100%) salt producers observed in this study package salt in woven polyethylene bags (Table 4). Likewise, a study in Ghana found that polyethylene bags were the major packaging materials for the small-scale producers (Amadu, 2019).

Woven polythene bags used were porous and allowed entrance of dust and other contaminants. The drying methods used by producers are inadequate to properly dry the salt. So woven bags may allow water to squeeze out the salt even during storage. The producers have no proper stores for their salt; it is often stored outside their houses without shade (92%).

Likewise, salt producers in Ghana store salt under inadequate conditions (Amadu, 2019). Improper storage of salt may expose salt to sunlight, allow pickup of moisture and contaminate it with other hazards. According to CAC (2001) salt should not be exposed to rain, excessive humidity or direct sunlight at any stage of

Table 5. Quality assessment parameters.

Parameter	Frequency (n=63)	Percent
With what means do you clean equipment?		
Washing with water, brush and detergent	1	1.6
Washing with water and brush	7	11.1
Washing water only	43	68.3
Others	12	19.0
How many times do you clean the equipment?		
After two days	1	1.6
Daily (before and after use)	41	65.1
Don't wash	7	11.1
Monthly	1	1.6
Weekly	13	20.6
What of the following contaminants do you find in salt?		
Animal dropping(dung), Soil, plastic, Petrol/Diesel	3	4.8
Not aware of salt contaminants	1	1.6
Plastics only	3	4.8
Plastics, Sand only	2	3.2
Plastics, Sand, Animal dropping(dung)	1	1.6
Sand only	53	84.1
With what material do you use in stirring salt during boiling?		
Piece of gourd	31	49.2
Plastic	30	47.6
Wood	2	3.2

Source: Authors

storage.

The study also observed that salt was sold within the region (i.e., Singida) and neighbouring regions of Shinyanga and Tabora. Salt producers (69.9%) receive and compensate the customers when they return unfit salt for human consumption. The price of salt ranges from TZS 500 during the dry season to TZS 1000/l tin (≈ Kilogram) in the rainy season. Likewise, in Indonesia, it is reported that the price of salt is higher during the rainy season (Rochwulaningsih, 2018).

Hygiene/ sanitation/ cleanliness of equipment

More than 68.3% of salt producers do not use detergents to clean and wash their processing equipment daily (65.1%). Some producers (11.1%) do not clean their equipment at all. Although salt is a preservative that inhibits the growth of microorganisms, if the equipment is not properly cleaned it may corrode and contaminate salt with other foreign matters leading to salt colour changes. Studies in Italy and Croatia reported changes in salt colour due to mud, clay macro plastics, micro-plastic and litter contaminants (Helmi and Sasoka, 2018; Renzi and Blašković, 2018). This was contributed by low quality small-scale salt products due to poor equipment and less effective purification process as well as occurrence of floods. Table 5 shows the quality assessment parameters.

The use of woven polyethylene bags by all (100%) small-scale salt producers for packing salt did not restrict contamination and loss of iodine. High-density polyethylene bags or paper with plastic lining are better in iodine retention than woven polyethylene bags (Sarkar and Aparna, 2020). A practice of storing salt outside without any shade by the majority (92%) of small-scale salt producers accelerates the loss of iodine and exposes the salt to contamination. This has implications to salt iodine content and accessibility for consumption to be low.

Furthermore, the contaminants of salt identified by the producers were mainly sand (84.1%). Other contaminants like animal dropping, plastic, petrol or diesel were observed by very few producers. It also indicates that the producers are not aware of the sources of some hazards like microplastics. A significant proportion of producers (47.6%) use plastic and broken pieces of guard to steer salt during cooking. Grazing animals were observed in the salt production areas. Most likely, microplastics and organic compounds were among the salt contaminants. Previous studies observed microplastics in table salts produced from sea, lake and well water as well as rock (Iñiguez et al., 2017). The occurrence of microplastics in rock/well salts implied the introduction of microplastics during the production stages.

CONCLUSIONS AND RECOMMENDATIONS

Small-scale salt production in Tanzania is generally dominated by people with inadequate knowledge of food handling which makes the quality of salt to be questionable. Small-scale processors use traditional techniques to produce salt. The use of traditional techniques, and lack of proper packaging materials associated with inadequate storage conditions indicate that cross-contamination is inevitable. Although salt fortification is mandatory, small-scale producers are not aware. There is also a lack of control and monitoring of such smaller processing units to ensure the quality and safety of salt. Taking into account the importance of universal salt iodisation, deliberate efforts are required to control and monitor small-scale salt producers across the country. Salt fortification should be equally regulated/ implemented regardless of the size of production. Training is recommended to all actors along the salt value chain to ensure the quality and safety salt.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Production, consumption, processing and marketing of the baobab fruit (*Adansonia digitata* L.) in Kenya

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Parts of the baobab tree (*Adansonia digitata* L.) have been considered vital in addressing various nutritional needs and augmenting household incomes. However, limited utilization, processing, and marketing exist in developing countries like Kenya, despite the fruit pulp gaining mass interest overseas as a natural ingredient in various formulations. This study therefore aimed at assessing the status of production, consumption, processing, and marketing of baobab fruit pulp by small holder farmers in selected growing regions. A cross-sectional design was used to carry out the study and purposive sampling was done to identify 250 study cohorts in addition to five focus group discussions and ten key informant interviews. Data was expressed in frequency, percentages and cross tabulation. The findings of the study indicated that the fruit pulp was abundantly consumed by 72% of the respondents while all other parts were consumed to a limited extent. Pulp/seed sweets (*mabuyu*) were largely known and vended by women in the study area. Despite marketing and processing activities being limited, multiple uses of baobab during lean season at the household level were reported. Training on value addition and promotion of value-added baobab products, is necessary for income diversification and increased utilization of the baobab products.

Key words: Baobab products, utilization, superfood, food security, supplement.

INTRODUCTION

Non timber forest products play a significant role in fulfilling several requirements of rural livelihoods, ultimately resulting in reduced vulnerability during lean seasons (Meinhold et al., 2022; Shackleton et al., 2011). Non timber forest products are often vital sources of nutrition and capable of improving dietary diversity in vulnerable poor households (Meinhold and Darr, 2019). Various communities living in dryer parts of Africa rely on such products as alternative sources of food, during lean seasons often characterized by crop failures and livestock losses (Wanjeri et al., 2020). The baobab tree (*Adansonia digitata L*.), endemic to the semi-arid regions of Africa is a non-timber forest products often depended upon to supplement local diets, nutrition, and a buffer

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during such times of scarcity (Muriungi et al., 2021; Venter and Witkowski, 2013). Further, the baobab tree (*A. digitata L.*) has long been revered for its multiple applications and traditionally considered essential as a source of food, fodder, medicine, shelter, and commercial handicrafts (Buchmann et al., 2010; Gebauer et al., 2016). The nutritional profile of parts of the baobab tree in the supply of essential nutrients is reportedly better than staple food crops (Stadlmayr et al., 2020). This has resulted to appreciation of the baobab tree in international markets thereby putting pressure on baobab pulp exportation to European Union and United States (USA) markets (Fischer et al., 2020). Rapid development of the baobab fruit pulp market has been triggered by the declaration of the fruit pulp as a novel food, by the European Commission (Meinhold et al., 2022), consequently resulting to its promotion as a superfood and its application as a natural ingredient in over 300 formulations (Gebauer et al., 2014). The baobab tree is well appreciated in West African countries, whereby the fruit pulp is incorporated traditionally into diverse cereal gruels or consumed in its fresh state as a snack (Buchmann et al., 2010). Despite the baobab tree gaining mass interest in other countries, there is limited utilization of baobab products in countries such as Kenya. This is largely attributed to increased attention towards the production of staple foods with minimum efforts being directed towards high ecological tolerance indigenous foods (Mc Mullin and Kehlenbeck, 2015) resulting in limited production of innovative high value nutritious products from baobab. When consumed, baobab fruit pulp can provide 54 to 100% of the recommended dietary intake of vitamin C (Asogwa et al., 2021) while consumption of dry or fresh baobab leaves contributes to high calcium and protein intake (Wanjeri et al., 2020). This is a clear indication that baobab products can boost the nutrient uptake and prevent nutritional deficiencies (Momanyi et al., 2019) in rural communities where malnutrition is prevalent. Baobab products are particularly useful during lean seasons in the rural poor communities where they reportedly act as hunger survival strategies (Darr et al., 2020; Legwaila et al., 2011). Formal processing of baobab products is rare in Kenya, with most of the existing baobab products being informally processed and sold on a limited scale (Kaimba et al., 2020; Muriungi et al., 2021). The product largely processed and vended is pulp/seed sweets (*mabuyu*), a candy prepared from the seeds embedded in the pulp (McMullin and Kehlenbeck, 2015) often perceived as food for kids (Kinuthia, 2018). Scarcity in research and innovation on superior processing techniques has largely resulted to a gap in development and commercialization of substantial high quality baobab products for consumption by the general population (Omotayo and Aremu, 2020). Considering minimal employment in the rural areas, commercialization activities of baobab fruit is a worthwhile venture in ensuring the improvement of rural livelihoods (Meinhold et al., 2022). Parts of the baobab tree (*A. digitata L.*) offer an array of economic benefits as they can be utilized as raw materials for many useful items (Kamatou et al., 2011). The bark of the tree possesses robust fibers that have been successfully exploited in the manufacture of ropes, baskets, and clothing (Chadare, 2010). Such commercial value offers an opportunity for income diversification which contributes to household sustenance since in countries like Sudan, baobab trading activities generates more than half of the annual income of small holder farmers (Adam et al., 2013). However limited knowledge in marketing of baobab products in Kenya due to weak entrepreneurial spirits among the rural communities has impeded successful realization of the full potential of the baobab sector in Kenya (Kaimba et al., 2020). This could be attributed to, inferior processing techniques resulting in poor quality products and socio-cultural factors which contribute to negative consumer attitudes (Jäckering et al., 2019), whereas well-developed baobab products can foster economic prosperity while promoting better nutrition among the rural poor. Hence, there is a need to determine the contribution of baobab products to the diet and in the overall household income towards poverty alleviation (Wanjeri et al., 2020). This study was therefore conducted among different rural communities in Makueni county, Kenya to assess the status of production, consumption, processing, and marketing of the baobab fruit pulp.

MATERIALS AND METHODS

Study design

The study involved a cross-sectional survey of randomly selected small holder farmers, traders, Micro Small Medium Enterprises, and households that were actively involved in utilization of the baobab fruit since in the baobab sector there are interlinkages between and within the value chain (Figure 1).

Study area

The study was conducted in Makueni County located in the southeastern part of Kenya in October 2021, during which a lot of baobab fruit had been harvested for sale or processing purposes. The county lies between a latitude of 1° 35’ and 32° 0’ South, and longitude of 37° 10’ and 38° 30’ East (CGM, 2018) and covers an area of 8008.7 km^2 (CGM, 2018). The county is largely arid and semi- arid with the lower regions receiving rainfall ranging from 250 to 400 mm, while high regions receive 800 to 900 mm (CGM, 2018). Most residents rely on rain-fed farming (Gevera et al., 2020). The county is characterized by a rapidly growing population, water scarcity, falling food production, and low resilience to climatic changes and with all these factors combined result to increased food insecurity, environmental degradation, and high poverty levels (Gevera et al., 2020). The county is divided into six sub-counties which are further subdivided into 30 wards and 60 sub-wards (CGM, 2018). Two sub-counties that is Kibwezi East and Kibwezi West were purposively selected from which two wards from each sub-county were randomly selected as study sites. Authority to

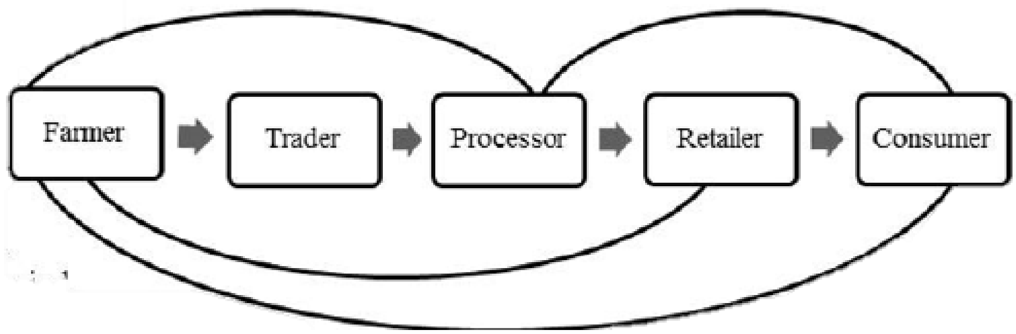

Figure 1. Value chain network of baobab products.
Source: Jäckering et al. (2019).

conduct the survey was obtained from the respective sub-county Agricultural Officers and Head of Wards. The enumerators who participated in data collection process were selected by sub-county agricultural officers.

Sample size

A sample size of 250 respondents was involved in the study to which the semi-structured questionnaire was administered. The sample size was calculated using the method described by Anderson et al. (2016).

$n = p\ (1-p)\ Z^2 / E^2$

where n is the sample size, p is the proportion of the population involved in the utilization of the baobab fruit, Z is the confidence interval, and E is the marginal error.

Since the proportion of the population involved in the utilization of the baobab fruit was unknown in the study site, the values were then set as $p = 0.5$, $Z = 1.96$, and $E = 0.062$.

Sampling procedure

Purposive sampling was used in getting the sample units in this study. Data was collected from two sub-counties namely Kibwezi East and Kibwezi West, and respondents were further selected from four wards namely Makindu, Mtito Andei, Kambu, and Ivingoni/Nzambani. These sub-counties were purposively selected as they represented baobab consumption and processing areas in Kenya since a variety of processed products are known to be available and sold in these areas.

Data collection

A semi-structured questionnaire was validated and used for surveys. Key informant interviews and focus group discussions were also used. The questionnaire was developed by the researchers and loaded in the Open Data Kit (ODK) mobile application to gather information.

Household survey

The survey was carried out in October 2020. Face to face interviews were used to gather information on the socio-demographic and socio-economic characteristics of the study population as well as the production, consumption patterns, processing, and marketing activities. The questionnaire was written in English, but questions were interpreted into the local dialects of the respondents for ease of communication. Written consents of the respondents were sought once the study objective was fully explained to them before their participation in the study. During the survey, geographical coordinates of the households visited were recorded. The semi-structured questionnaire was validated by pretesting with ten small holder farmers that were not included in the actual study. The necessary adjustments were made and additional questions that arose during the Focus Group Discussion were included in the tool. The questionnaires were administered with the help of field enumerators who were first trained on the operation of the Open Data Kit application, administration of the questionnaire as well as data collection ethics, with each question being explained to the enumerators to ensure that they familiarized themselves with the survey tool.

Focus group discussion

Focus group discussion was used to collect information on the utilization of parts of the baobab tree, processing and marketing of baobab products, and challenges experienced by small holder farmers and small-scale processors and traders. The intention was to bring together small holder farmers, traders, and processors to understand the various ways which parts of the tree are included in the local delicacies, perceptions around the baobab tree and various products processed from the baobab. Five focus group discussions were conducted in Kinyambu and Muuo wa Sombe in Kibwezi West sub-county with each focus group discussion consisting of 11 to 15 participants. The areas were chosen since they were easily accessible by farmers and were part of the baobab processing sites for some women group associations. Key questions were used to guide the focus group discussion, with the facilitator ensuring even participation from all members. Neutrality was maintained while the diverse opinions that were expressed and agreed by all members of the focus group discussions noted.

Key informant interviews

Ten face to face key informant interviews were conducted using formulated key guide questions. The interviews consisted of sub-county agricultural officers, women group leaders in small scale baobab processing facilities, middlemen involved in the sale of baobab fruits and one large scale baobab fruit processor located in Kibwezi. The key informant interviews were conducted in order to provide in depth qualitative information from community experts

Table 1. Socio-demographic characteristics in selected wards of Makueni county.

Variable		Ivingoni Nzambani	Kambu	Makindu	Mtito Andei	Combined (Pooled)
		Percentage				
Gender	Female	43.5	61.9	56.9	44.4	58.3
	Male	56.5	38.1	43.1	55.6	41.7
Marital status	Divorced		1.3	1.5		1.2
	Married	87.0	78.7	70.8	88.9	77.8
	Separated		1.3			0.8
	Single	8.7	8.4	24.6		12.3
	Widowed	4.3	10.3	3.1	11.1	7.9
Level of education	No education	4.3	3.9	7.7		4.8
	Primary	39.1	44.5	23.1	22.2	37.7
	Secondary	56.5	47.1	47.7	44.4	48.0
	Tertiary		3.9	21.5	33.3	9.1

*N = 252, P values = 0.325, 0.123, 0.004, respectively.
Source: Authors

who had knowledge and understanding of the baobab tree, while providing insights on the nature of the problems experienced in processing and other utilization activities.

Statistical data analysis

Data analysis was performed using statistical package for Social Sciences Software (IBM SPSS Statistics for Windows, version 25 (IBM Corp., Armonk, N.Y., USA)). Descriptive statistics for mean, frequency and percentages were used to analyze data for consumption and processing of the baobab fruit while cross tabulations were used to determine the relationship between the different study sites and demographic, socioeconomic characteristics, and the marketing aspect of the baobab fruit and products.

RESULTS

Sociodemographic and economic characteristics of baobab utilizing households in Makueni county

From the study, more females (58.3%) were involved in baobab production and processing activities compared to males (41.7%) (Table 1).

The main income generating activity reported by 29% of the households was crop farming with small holder farmers largely depending on rain-fed agriculture. As a supplement to monthly incomes, at least 13% of the respondents were involved in income generation from baobab. However, majority of these reported to derive low income from sale of the fruit and other products (Figure 2).

The study area was characterized by rising levels of poverty with majority of the respondents (81.7%) earning a monthly income of less than 20000 KES, while 18.3% reportedly earned a monthly income of 20000 KES and above as shown in Figure 3.

Majority of the respondents (49.6%), reported low supplementary income generation from the baobab fruit and high income reported in only 4.4% of the respondents (Figure 4).

Production of baobab products

All the respondents in the study area reported to know the baobab tree with 84.1% of respondents growing at least one tree in their farms. On average each household had at least 1.02 ± 0.166 baobab tree growing in their farm. These households reported that the baobab trees existed in their farms naturally and had not been cultivated. However, negative effect on crop farming in the presence of baobab trees was reported, which claimed that the roots of the tree suck all the water, allowing no food crop to grow around it. Some respondents had no ownership of baobab trees but reportedly accessed them from either surrounding neighborhood or community lands (Figure 5).

Consumption of baobab plant products

Majority of the respondents (98.4%) reportedly use the baobab tree parts in one way or another in their local diets. Baobab fruit pulp was the most consumed part in the study area (Figure 6) while consumption of all other parts was to a limited extent.

Consumption of baobab fruit pulp

In all interviewed households, 87.3% of the respondents

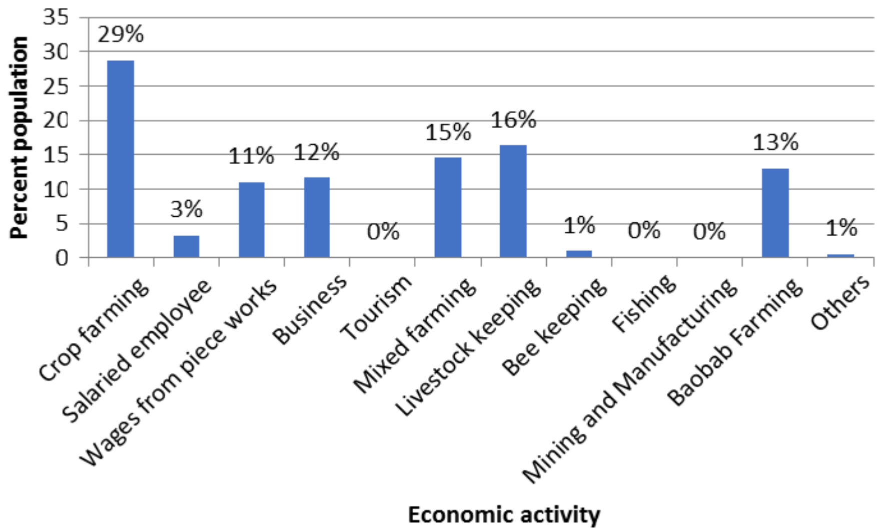

Figure 2. Main economic activities among baobab utilizing households in Makueni county.
Source: Authors

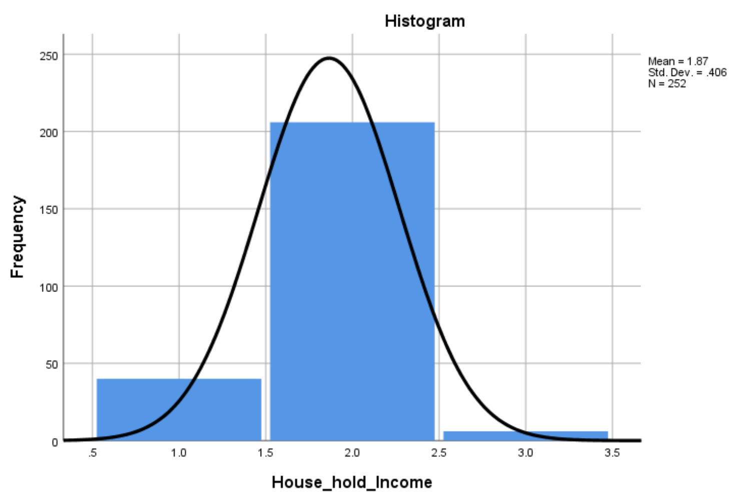

Figure 3. Average household incomes of respondents in Makueni county.
Source: Authors

reported the consumption of the fruit pulp by all family members, 11.1% reported consumption of the fruit pulp by only children (5-12 years) while 1.6% reported consumption by only adults. The frequency of consumption of the baobab fruit pulp is as indicated in Figure 7.

Consumption of baobab leaves

Consumption of the leaves was quite unknown to most of the respondents with 98% considering them as livestock fodder with only 2% of the respondents reporting the use of the baobab leaves as substitutes for regularly consumed vegetables.

Consumption of baobab seeds

Baobab seeds consumption was also reported, with majority of respondents (56%) reporting that after sucking the pulp covering the seed, the outer shell of the seed is cracked and the inner part (kernel) that has a nutty flavor consumed. Other diverse consumption practices of the

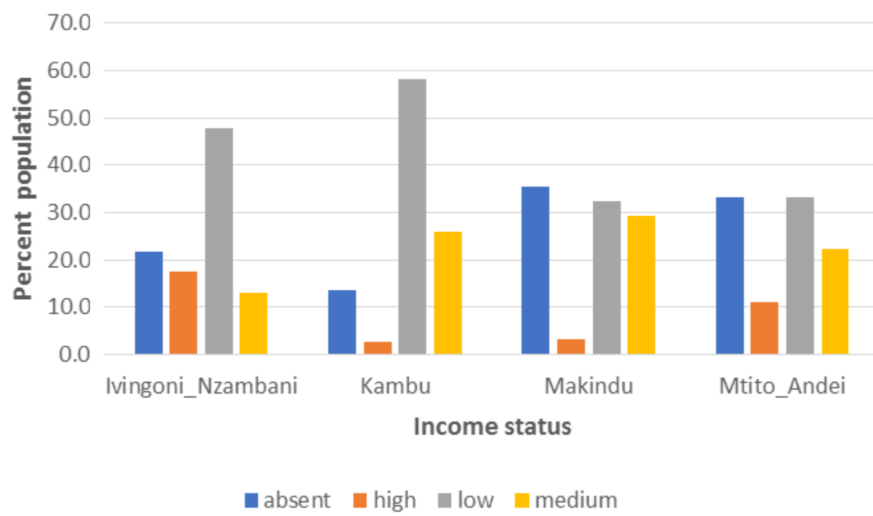

Figure 4. Income generation from baobab products in Makueni county.
Source: Authors

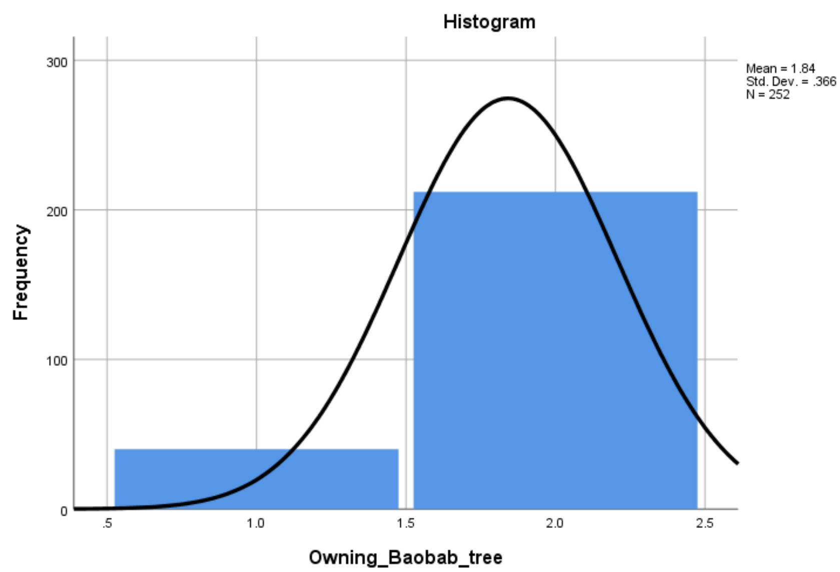

Figure 5. Ownership of baobab trees in Makueni county.
Source: Authors

baobab seeds were also reported among the respondents (Figure 8).

Processing of baobab-based products

In the current study, only a small percent (28.2%) were involved in processing products from baobab while the rest were not involved in any form of processing (Figure 9). Baobab seed processing activities are as illustrated in Figure 10.

The baobab fruit pulp was the most processed part in the study area proving useful in manufacture of local brews, baobab jam, baobab juice, pulp/seed sweet (*mabuyu*) and baobab fruit powder as illustrated in Figure 11.

On an annual basis it was established that pulp/seed (*mabuyu)* sweets recorded the highest volume of production (8875 KGS) annually as illustrated in Figure 12, followed by baobab fruit powder (3598 KGS) and the least processed product reported was baobab seed oil since most of the processors lacked the oil pressing equipment and facility.

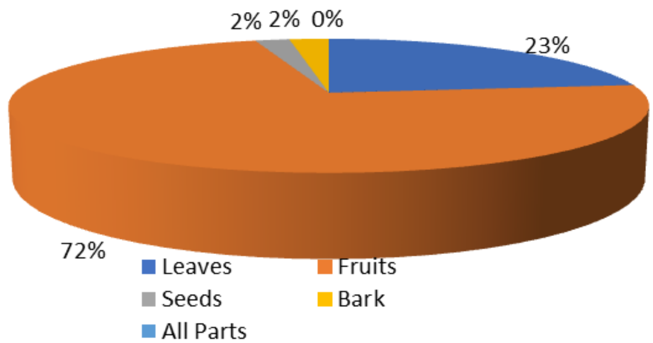

Figure 6. Consumption of baobab tree parts in Makueni county.
Source: Authors

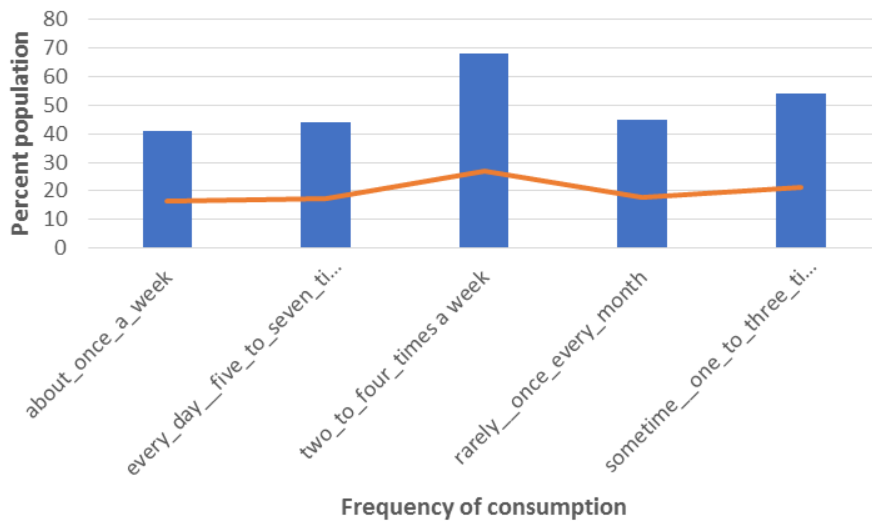

Figure 7. Frequency of consumption of baobab fruit pulp in Makueni county.
Source: Authors

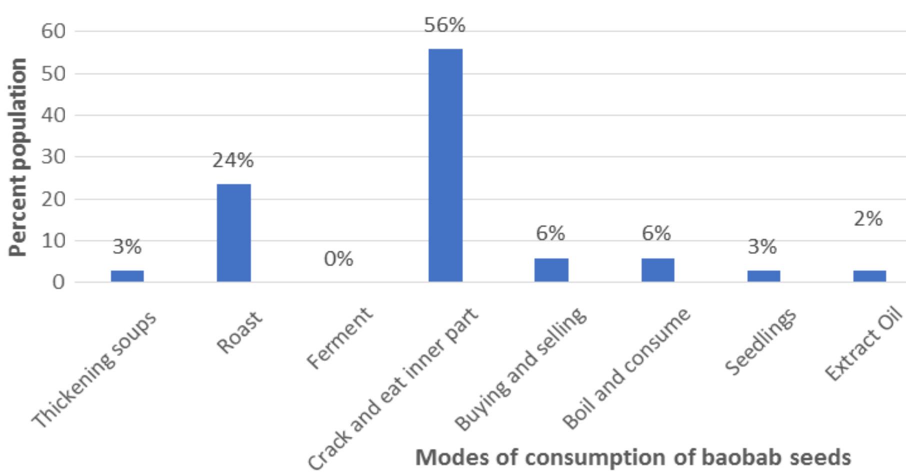

Figure 8. Modes of baobab seeds consumption in Makueni county.
Source: Authors

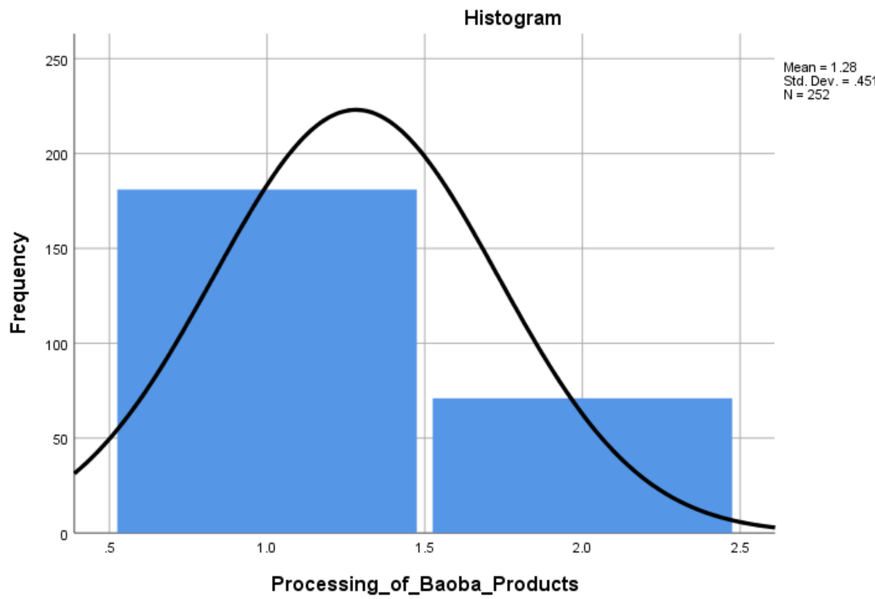

Figure 9. Status of processing of baobab products in Makueni county.
Source: Authors

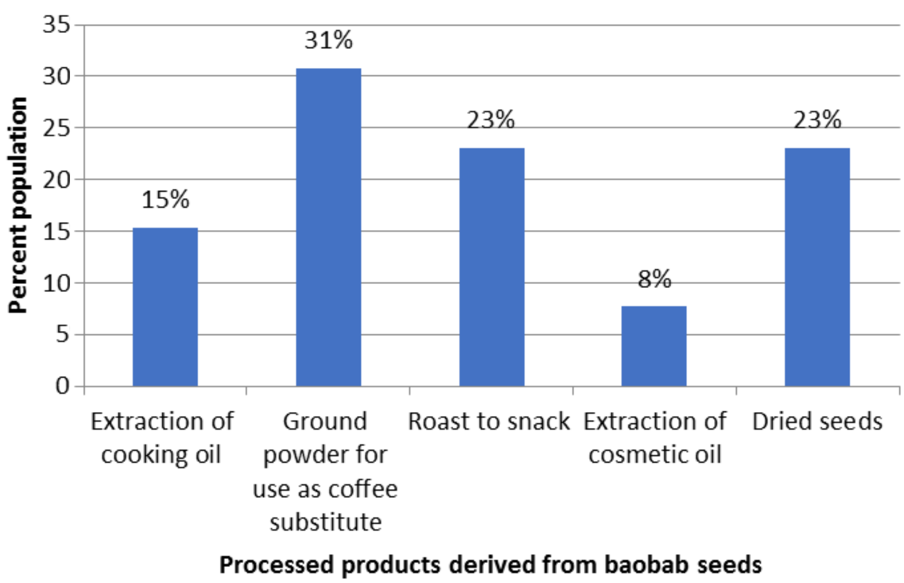

Figure 10. Processing of baobab seeds in Makueni county.
Source: Authors

Marketing potential of the baobab fruit

Income generation from the baobab processed products in various study sites within Makueni county is as indicated in Figure 13.

In the current survey, 29.8% of the respondents reported involvement in marketing baobab products with pulp/seed (*mabuyu*) sweets being the most vended product in packages that cost KES 20. The study area consisted of organized community women groups who besides the sale of pulp/seed (*mabuyu*) sweets were also involved in the sale of baobab jam sold at KES 400/50 g and baobab fruit powder sold at KES 1000/1 kg. The sale of baobab processed products was quite a new venture among majority of the respondents who were reportedly involved in the business for less than five years with an

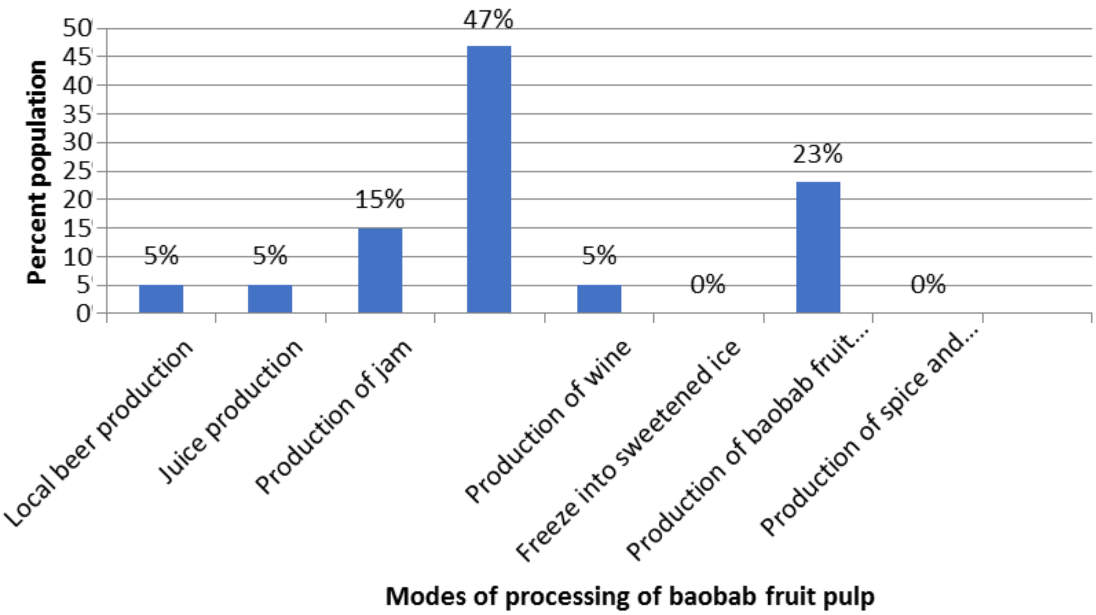

Figure 11. Various products processed from the baobab fruit pulp in Makueni county.
Source: Authors

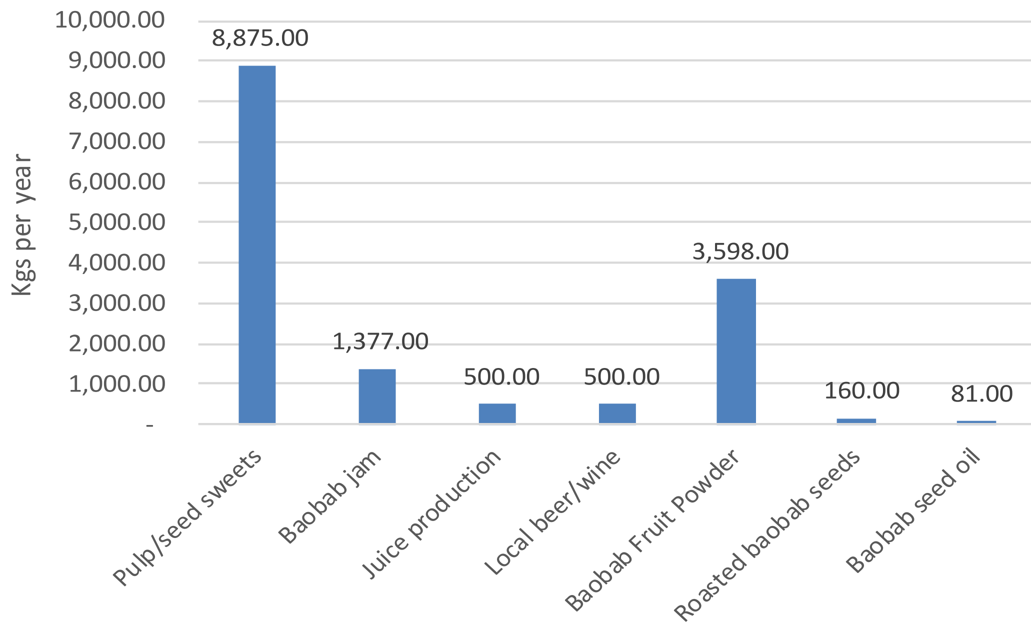

Figure 12. Volume of production in KGS per year of various baobab processed products in Makueni county.
Source: Authors

aim of generating supplementary income. Majority of the respondents (52%) derived meagre profits of less than KES 5000 from the sale of baobab processed while only 5% of the respondents earned profits more than KES 10000 (Table 2).

Various sale avenues of baobab processed products were also reported as illustrated in Figure 14. The importance of the sales of baobab products in the contribution of the overall household income was reported to be less than 20% in 58% of the respondents,

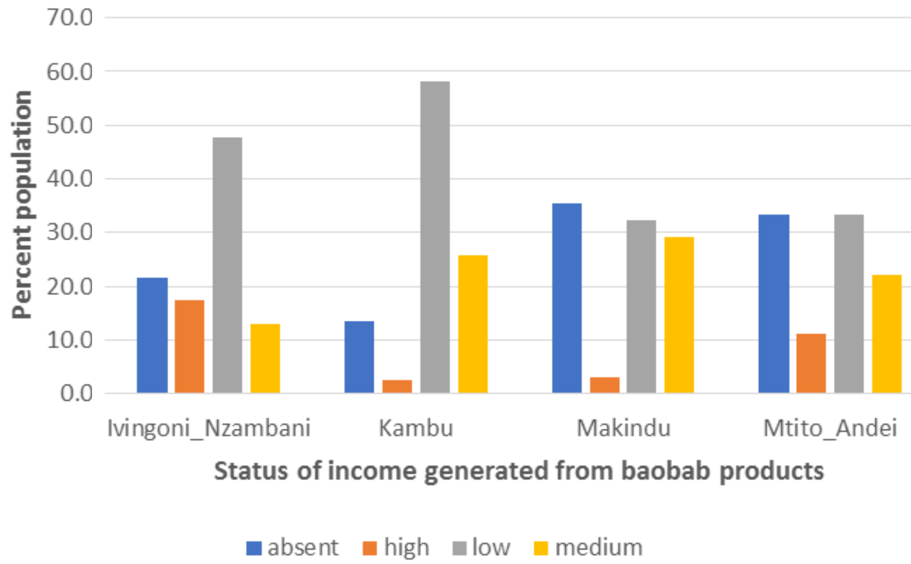

Figure 13. Income generation from the baobab products in Makueni county.
Source: Authors

between 40 to 49% in 28%, between 60 to 79% in 10% and more than 80% in 4% of the respondents.

Challenges faced by baobab processors in the study area

Rural marketers of baobab products face several challenges with 40% of the small holders encountering financial constraints in running their enterprises, 25% reported few customers, 12% reported limited market space while 23% reported limited market returns. Minimum substantial capital developments acquired from the sale of baobab products was reported whereby 70% utilized profits in expansion of businesses, 2% built houses while 28% bought livestock.

DISCUSSION

Production of baobab products

Makueni county has a high density of mature baobab trees (Musyoki et al., 2022). The trees are easily accessible facilitating consumption among the rural poor and encouraging business ventures into various baobab products (Vinceti et al., 2013). However, felling of baobab trees is common since it is believed where the tree exists crop cultivation cannot prevail (Musyoki et al., 2022). Notwithstanding indigenous foods are often considered inferior, they can be exploited in the production of premium specialty products vended in urban markets therefore improving income generation among these vulnerable populations (Darr et al., 2020) consequently promoting domestication of the trees.

Consumption of baobab products (leaves, pulp, and seeds)

This study corroborates with findings of Wanjeri et al. (2020) who established that households in Kilifi and Kitui counties often consume baobab fruit pulp in its fresh state. Besides baobab fruit pulp being consumed in fresh state, the pulp is incorporated into cereal gruels, soups, ice cream and used in the manufacture of *mabuyu* sweets. Consumption of the pulp comes in handy in the provision of nutrients when the rural poor cannot afford the acquisition of fruits from markets/farms or during pre-harvest periods of the rural staples (Wanjeri et al., 2020). This study and another conducted in Taita Taveta and Kitui counties indicate that consumption of leaves is unknown to people living along Kenyan baobab growing regions (Fischer et al., 2020). This reveals that there is a need for sensitization of communities living along the baobab growing regions on the utilization of baobab leaves as an alternative source of food during periods of food scarcity (Wanjeri et al., 2020) as well as their engagement in baobab leaves value addition activities as part of income generation. Consumption of baobab leaves is a common practice in West African countries, preferably used in local soups and stews to impart a desirable slimy like consistency (Zahra'u et al., 2014). A review by Asogwa et al. (2021) indicates that baobab kernels can be roasted or eaten raw agreeing with the findings of this study. Similar to findings of this study other communities, roast the seeds, grind and utilize the powder as a coffee substitute (Tembo, 2016) or used in,

Table 2. Sales and marketing of baobab processed products in Makueni county.

Characteristic	Response	Ivingoni Nzambani	Kambu	Makindu	Mtito andei	Pooled
		Percent (%)				
Involvement in processed baobab products marketing	No	73.9	83.9	35.4	77.8	70.2
	Yes	26.1	16.1	64.6	22.2	29.8
Frequency of sale of baobab products	2-3 times a week	8.7	13.5	12.3	11.1	12.7
	Everyday	39.1	12.3	36.9	11.1	21.0
	Not involved	26.1	34.2	35.4	44.4	34.1
	Once a week	26.1	40.0	15.4	33.3	32.1
Period involved in income generation	>20 years	0.0	6.5	0.0	0.0	4.0
	<5 years	47.8	24.5	53.8	33.3	34.5
	10-20 years	8.7	6.5		11.1	5.2
	5-9 years	17.4	27.7	10.8		21.4
	Not involved	26.1	34.8	35.4	55.6	34.9
Main reason for engaging in sale of baobab products	Generate major source of income	47.8	12.9	3.1	0.0	13.1
	Generate supplementary income	26.1	52.3	61.5	55.6	52.4
	Not involved	26.1	34.8	35.4	44.4	34.5
Demand of baobab products	Decreasing	4.3	2.6	1.5	0.0	2.4
	Fluctuating	13.0	20.6	27.7	22.2	21.8
	Not changed	4.3	8.4	27.7	22.2	13.5
	Increasing	56.5	34.8	7.7	11.1	29.0
	Not involved	21.7	33.5	35.4	44.4	33.3
Ability to meet demand	No	52.2	85.8	89.2	88.9	83.7
	Yes	47.8	14.2	10.8	11.1	16.3
Profits	5000-10000 kshs	34.8	38.1	16.9	33.3	32.1
	<5000 kshs	39.1	23.9	47.7	22.2	31.3
	>10000 kshs	4.3	3.2	0.0	0.0	2.4
	Not involved	21.7	34.8	35.4	44.4	34.1

*N = 252; P value = 0.004.
Source: Authors

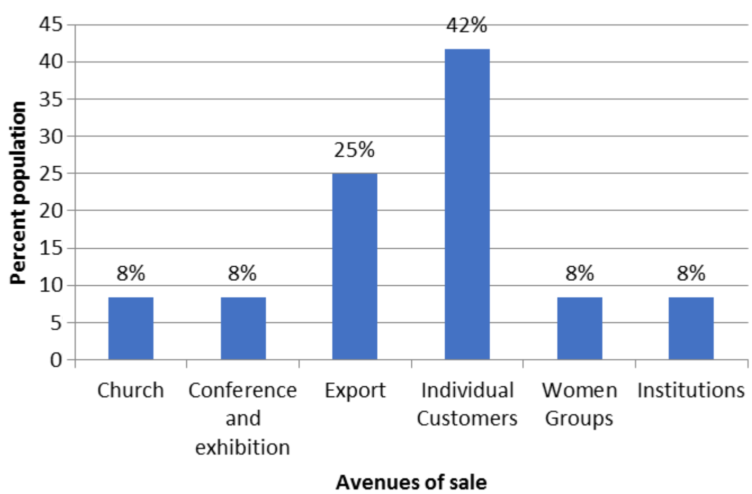

Figure 14. Various sale avenues of baobab products in Makueni county.
Source: Authors

thickening soups (Braca et al., 2018). The kind of utilization of baobab seeds revealed in the study was an indicator of a coping mechanism among the rural poor when calamities strike or during food shortages (Fanzo et al., 2013; Wanjeri et al., 2020).

Processing baobab products

With regards to processing of baobab products, there is a clear indication of how underutilized the baobab tree is in Kenya. Products processed from the baobab leaves were not available in the study area yet, in other countries like Mali and Benin the fresh leaves are sundried and ground into leaf powder for sale (Venter and Witkowski, 2013). Extraction of cooking oil from the baobab seeds was however reported. Baobab seed oil contains a high fatty acid composition with a low degree of unsaturation making it a promising source of vegetable oils (Abubakar et al., 2015). Baobab fruit pulp was the prevalent raw material in majority of processed products. The most actively commercialized products included pulp/seed sweets and baobab jam. The pulp/seed sweets were produced by covering the pulp powder embedded on the baobab seed with sugar and artificial food grade coloring (Jäckering et al., 2019). All these products were being processed by women group associations, confirming the findings of a study conducted by Jäckering et al. (2019) on the main value chain actors being predominantly women. Other additional baobab processed products from the fruit reported in Key Informant Interviews included baobab toffees and biscuits enriched with baobab fruit pulp. Processing of pulp/seed (*mabuyu*) sweets was reported to be done by first cracking the outer shell of the fruit with a hammer or stone, separating the fibers from the pulp covering the seed after which artificial coloring and sugar is boiled in water to form a thick paste in which the seed containing the pulp is added. A small amount of the pulp powder is added, allowed to cool, and packaged in polythene bags or plastic containers in small quantities. The current findings on the processing of *mabuyu* sweets agree with a similar study by Jäckering et al. (2019). Baobab jam on the other hand involved soaking of the fruit pulp for approximately 1 h in water to form a thick paste and sieving to separate the fibers. Afterwards, sugar in the ratio of three quarters the amount of baobab fruit pulp is dissolved in approximately 1 L of warm water. The mixture is then put over high heat while stirring to prevent caramelization and a golden-brown color change serves as an indication of achievement of the correct brix. The high level of pectin in baobab imparts a high gelling capacity in jam and has been utilized as a substitute for commercial pectin (Ndabikunze et al., 2011) forming part of the reason why it is possible to produce jam using the baobab fruit. All these baobab fruit products were processed informally on a small-scale basis using informal equipment such as sufurias, cooking sticks, energy generated from firewood and measurement estimation using cups and spoons. The least processed product was baobab seed oil due to the lack of proper facilities for carrying out subsequent extraction processes.

Marketing of baobab products

Marketing of baobab-based products is considered to provide an opportune buffer during times of scarcity (Venter and Witkowski, 2013) and serve to alleviate poverty (Venter and Witkowski, 2013). Further to that, since constant drought in the arid and semi-arid lands leads to livestock losses and crop failures, households have delved in alternative sources of food and income (Mwema et al., 2013) such as the sale of non-timber forest foods like the baobab fruit. However, the baobab fruit pulp market in Kenya is still at an infancy stage (Meinhold and Darr, 2019) with most of the baobab products occupying a small market share and being traded by a small number of actors compared to tropical fruits (Kiprotich et al., 2019). The successful commercialization of underutilized indigenous fruits is impeded by the lack of financial resources and lack of entrepreneurial capabilities by the rural processors (Meinhold and Darr, 2019) resulting to minimum returns. Further to that, the lack of interest and acceptance of indigenous fruits plays a big part in derailing the successful innovation and commercialization of indigenous based products (Bvenura and Sivakumar, 2017). This explains why majority of the respondents reported no increase in demand of baobab fruit products with most of the products being sold to individual customers than retailers. The demand for *mabuyu* sweets in particular, is high during school events such as sports or during county events such as agricultural shown as earlier stated by the respondents. In a study conducted by Jäckering et al. (2019), the demand for *mabuyu* sweets is reportedly high during festive seasons such as Ramadan. In the same study rural processors were involved in transportation of *mabuyu* sweets to urban centers like Nairobi (Eastleigh) and Mombasa (Kongowea market) with consumption being largely appreciated by the Muslim population. Some respondents reported an increase in demand of baobab fruit products, particularly the fruit powder as it was considered by most of their clients important in boosting immunity following the rising COVID-19 cases. This is attributed to the substantial Vitamin C levels in the baobab fruit pulp. Vitamin C is an essential micronutrient that contributes to the immune defense and its supplementation can prevent and treat various respiratory and systemic infections (Carr and Maggini, 2017).

Challenges faced in the baobab processing sector

Limited knowledge on the potential health benefits of the baobab fruit due to inadequate research, thwarts baobab commercialization activities in East African countries such as Kenya (Gebauer et al., 2016). Furthermore, baobab fruit pulp is regarded as a snack or poor man food and not an essential part of the diet (Jäckering et al., 2019), thereby impeding its success in the market. Owing to the fact that local value chains provide low incomes to traders compared to global value chains (Mwema et al., 2013; Shackleton et al., 2007), minimum capital developments are derived from the sale of baobab products. Regulatory frameworks in sub Saharan Africa do not actively promote development of small enterprises as laws are bureaucratically or weakly enforced (Meinhold and Darr, 2019). In addition, small processors face various challenges in their small-scale manufacture of products such as: lack of proper processing facilities, lack of proper equipment which has consequently derailed the certification of their products and lack of proper training on processing of diverse baobab products that would enable them to earn more income. The lack of financial muscle to facilitate all these activities results in limited value addition and low economic impact (Meinhold and Darr, 2019).

Conclusion

Consumption of the baobab fruit pulp was well appreciated in the area with multiple uses being reported particularly during the recurrent drought seasons. However, compared to West African countries baobab utilization in Kenya is limited, since parts of the tree are not regarded important in the daily diets of the local communities. Processing and marketing activities of various baobab processed products was carried out to a limited scale, but it cannot be ignored that women in the study area have actively taken part in the processing and trading activities of baobab products. Through the conglomeration of women into community groups, they can earn additional income while others depend solely on the baobab processing activities. Finally, action is needed to expand markets for the rural baobab processors since most of them are not able to access the right markets for their products causing them not to reap immense benefits from the baobab products.

RECOMMENDATION

Research organizations should consider creating awareness on the nutritional benefits of various parts of the tree to promote incorporation of parts of the baobab tree (leaves, seeds, and fruit pulp) into the local diets of communities living along baobab growing regions. For instance, sensitization of such communities on consumption of the baobab leaves will lead to appreciation of the leaves as an alternative source of food and income when all other crops have failed and subsequently promoting food security. Empowerment of community groups through adequate training will serve to improve their knowledge on baobab processing operations. Capacity building through equipping small holders with sufficient resources necessary for production of high-quality products with a higher market value will ultimately result to better income. In return, this will result to improved standards of living among them noting that in the rural areas women have a role in supplementing household incomes and even being bread winners. Provision of credit services, market space and empowering the women associations involved in processing will serve as a major driver towards promoting the consumption, processing, and marketing of baobab products.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

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Influence of processing methods on the sensory acceptability of products from selected hybrid plantains (*Musa* species *AAB*) cultivars

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High-yielding and disease-resistant hybrid plant cultivars recently developed by breeders need evaluation for end-use. This study evaluated the influence of processing methods on the sensory acceptability of products (plantain chips, fried ripe plantains called “dodo” in Nigeria, boiled unripe and ripe plantains, and "amala," a dough, as it is called in Nigeria when unripe and ripe plantain flour is reconstituted in hot water) from selected hybrid plantain cultivars. Pita 26, Pita 27, Mbi egome, and Agbagba landrace cultivars were studied. Plantain pulps were subjected to frying (170°C for 2 min), boiling (100°C for 15 min), and drying (65°C for 48 h) at unripe and ripe stages before analyses. These food items were subjected to sensory evaluation. The panel of 20 people evaluated samples for texture, taste, flavor, appearance, color, stretchability, moldability, mouthfeel, and overall preference on a 9-point hedonic scale. The sensory studies showed statistically significant differences (P<0.05) between products and processing methods significantly affected the cultivars' sensory parameters and essential minerals and vitamins. Products from the Mbi egome cultivar were adjudged acceptable in terms of overall quality, followed by the Agbagba local landrace cultivar. The data in this study have shown that hybrid plantains have the potential to be used industrially.

Key words: Consumers acceptability, value added products, hybrid plantain, organoleptic.

INTRODUCTION

Plantains are staple food crops in the tropics especially in West and Central Africa (Adenitan et al., 2022). Nigeria produces over 2.11 million metric tons of plantain annually and consumed as a staple food (Anajekwu et al., 2020). Most plantain producers are small-scale farmers from developing countries who grow them mainly

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for consumption and sale in local markets. But as more people in developing countries move to cities, plantains are becoming a cash crop. This means that farmers in rural areas will be able to profit from them, which will aid in reducing poverty in developing countries (Oluwagbenga et al., 2020). Nigerian food processors have been able to make more money from adding value to plantains (Ubi et al., 2016).

In the unripe stage, the nutritional composition of plantain showed that starch is the predominant carbohydrate in the crop which makes it an important source of energy (Ogechi et al., 2017). Additionally, plantains are a good source of vital nutrients like carotene (pro-vitamin A), vitamin C, and other nutrients that should be consumed daily according to the National Research Council's Food and Nutrition Board. Plantains are high in potassium and low in sodium (17 mg/100 g) and fat (0.1%) making it recommended to control blood pressure and suitable for persons who are salt intolerant (Borges et al., 2020). All stages of the fruit (green to ripe) are used as a source of food in one form or the other. The mature unripe and ripe fruits are consumed boiled, steamed, baked, pounded, roasted, or sliced and fried into chips.

Plantains are highly perishable, and significant post-harvest losses are unavoidable from farm gate to market, resulting in food insecurity. Post-harvest losses are caused by poor handling, insufficient storage and transportation, and pest and disease infestation of fresh fruits (Lamptey et al., 2019). Postharvest losses are also exacerbated by a lack of postharvest and marketing infrastructure, such as packaging, cold storage, prepackage and distribution, postharvest treatment and washing facilities. Processing unripe plantains into chips and flour, and ripe plantains into fried snacks like 'dodo' are two common indigenous methods of reducing post-harvest losses and increasing income for processors (Oluwagbenga et al., 2020).

To reduce post-harvest losses of plantain and improve on food security, the International Institute of Tropical Agriculture, IITA have developed new hybrid plantain varieties which have been reported to have a high yield and disease resistant ability (Eriksson et al., 2018; Tenkouano et al., 2019). The adoption rate of the new hybrids plantain by farmers is limited and literature is scarce on their utilization for the production of value-added products.

Processing methods are an excellent way to extend the shelf life of foods, change their structure, appearance, and nutritional composition, and make them more appealing to consumers. Consumers expect foods to have a longer shelf life while also improving in quality and naturalness (Du et al., 2019). However, nutritional and bioactive ingredients are lost in food during processing such as drying, frying, and boiling. It is necessary to investigate the impact of processing methods on plantains to improve their quality and sensory properties while preserving their natural values as much as possible. Furthermore, these new hybrid plantains must be evaluated for their suitability for acceptable traditional plantain products in terms of sensory characteristics and quality. The sensory quality and acceptability of the products made from the new hybrid plantain will determine their adoption. There is a scarcity of data on the sensory and acceptability of traditional plantain-based products using these new hybrids with superior agronomic traits. The objective of this study focuses on the influence of processing methods on utilization of new hybrid plantains and organoleptic characterization of the value-added products made from them.

MATERIALS AND METHODS

Study area

The study was conducted in Nigeria. The selected hybrid plantain cultivars were harvested from the International Institute of Tropical Agriculture (IITA) research farm, in Ibadan, Oyo State.

Four plantain varieties were evaluated in this study which are PITA 26 and PITA 27, Mbi egome and Agbagba landrace (control) (Figure 1). The cultivars used in this study was selected based on their availability in the period of study, morphological difference and also due to limited literature on their utilization. Table 1 presents the morphological differences that exist between the plantain cultivars used in this study. The selected plantain cultivars were divided into two batches; a batch was processed at the matured green (stage 1) and the other at ripe yellow (allowed to ripen after harvesting to stage 5). The ripening stages of the fruits were determined following (Bhuiyan et al., 2020) ripening chart. The food products evaluated are fried unripe plantain (plantain chips), fried ripe (“dodo”), boiled unripe plantain, boiled ripe plantain and plantain flour (“amala”) produced from both unripe and ripe plantain cultivars. The sensory evaluation room of the food and nutrition science laboratory of IITA was used for this study. The sensory room was well illuminated, and the booths were well-partitioned to avoid distraction or interference by other panelists. All other analyses were carried out in duplicates at the Food and Nutrition Sciences Laboratory of IITA, Ibadan, Oyo State.

Frying of plantain fingers

Unripe and ripe plantain bunches were separated into individual fingers, washed, peeled, and then sliced longitudinally into small round slices (2 mm thickness) with the aid of a sterile stainless-steel kitchen knife and fried in vegetable oil (specific gravity of 0.92 g/cm^3) for 2 min at 170°C. After frying, it was cooled and packaged in a polyethylene bag for further analysis at 30±2°C (Adeyanju et al., 2016).

Boiling of plantain fingers

Fingers of plantain were selected randomly from each set (unripe and ripe) and cut into a cooking pot containing 2 L of water each and then cooked for 15 min at 100°C. The peel of the plantain was not removed to prevent the leaching of nutrients into the boiling water during cooking. After the boiling, each set of plantain was drained out of hot water and cooled for 10 min before the peels were removed (Ajiboye and Shodehinde, 2022).

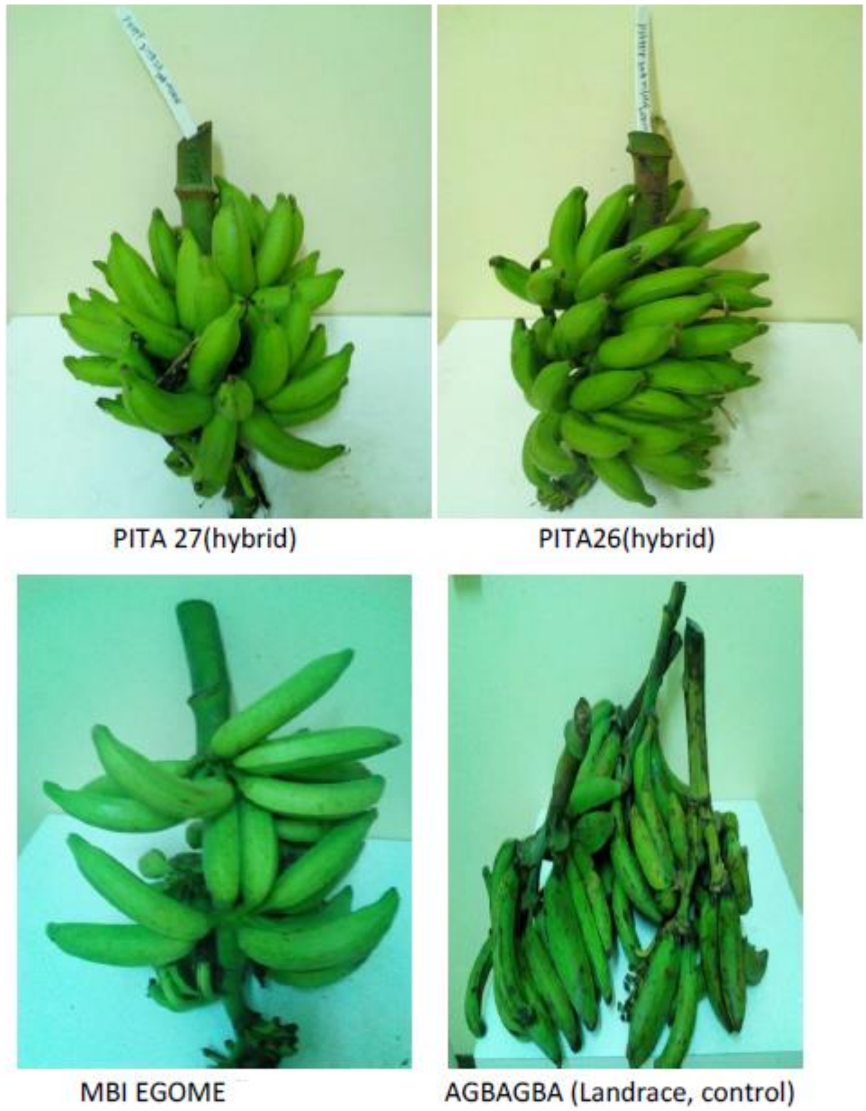

Figure 1. Four plantain varieties used for the study
Source: Authors

Table 1. Morphological differences between the cultivars used for the study.

Cultivars	Bunch type/family grouping	Stature type	Source	Response to black sigatoka disease
Pita 26	Hybrid	Small	Nigeria	Resistant
Pita 27	Hybrid	Small	Nigeria	Resistant
Mbi Egome	French horn	Medium	Nigeria	Less susceptible
Agbagba	False horn	Medium	Nigeria	Susceptible

Source: Brown et al. (2017).

Production of plantain flour by drying

Anajekwu et al. (2020) described the processing steps for making plantain flour. Plantain fruits (unripe and ripe) were removed from bunches, washed, and peeled by hand before being sliced (2 mm thickness) with a stainless-steel kitchen slicer, blanched at 80°C for 5 min, and dried in a cabinet drier at 65°C for 48 h. The dried slices were milled, sieved, sealed, and stored in a low-density polyethylene bag for later use.

Moisture content determination

Moisture content was determined by the method described by AOAC (2005) method.

Mineral analyses

Five grams of each sample were gently heated over a Bunsen burner flame until the majority of the organic matter was destroyed. This was then heated in a muffle furnace for 5 h at 550°C until white-grey ash was obtained. The ash material was cooled. The ash material was treated with 20 mL of distilled water and 10 mL of dilute hydrochloric acid. This mixture was boiled, filtered into a 250-ml volumetric flask, thoroughly washed with hot water, cooled, and made up to volume. The mineral content of each sample was determined using an Atomic Absorption Spectrophotometer (PYE Unicon, UK, model SP9) (Adegunwa et al., 2017).

Ascorbic acid (Vitamin C)

Ascorbic acid was determined by dyestuff titration method as described by Adegunwa et al. (2017). 0.4/100 g oxalic acid was used to digest the sample (5 g). The aliquot was titrated against dyestuff that had previously been standardized by standard ascorbic acid solution, and the ascorbic acid content was calculated using the formula:

$$\text{Vitamin C (mg/100 g)} = \text{Titre value} \times 0.606 \times 100 / \text{Weight of sample}$$

Total carotenes

Total carotenoid was determined by method described by Adegunwa et al. (2017). 5 g of plantain flour was mixed with 2 ml of distilled water. It was then moved to mortar. A pestle was used to crush 50 ml of cold acetone and 2 g of cellite. Suction was used to filter the mixture through a Buchner funnel using filter paper (Watmann 90 mm). Small amounts of acetone were used to clean the mortar, pestle, and residue, and the washings were collected in the funnel. The crushing and filtration processes were repeated twice (until the residue is colorless). The total carotenoid content was extracted with petroleum ether and measured at 450 nm with a UV-VIS spectrophotometer. Total carotenoid content (TC spec) was calculated as follows:

$$\text{TC } (\mu g/g) = A \times \text{volume (ml)} \times DF \times 10^4 / A^{1\%}_{1cm} \times \text{sample weight (g)}$$

Where A= absorbance; DF= dilution factor, volume = total volume of extract (25 ml), and $A^{1\%}_{1cm}$ = absorption co-efficient of carotene in PE.

Sensory evaluation of value-added products

A 9-point hedonic scale with the ratings of: 9 = like extremely; 8 = like very much; 7 = Like moderately; 6 = Like slightly; 5 = Neither like nor dislike; 4 = Dislike slightly; 3 = Dislike moderately; 2 = Dislike very much and 1 = Dislike extremely, as described by Nina et al. (2020) was used to compare the acceptability of plantain products. Twenty panelist composed of 10 males and 10 females were selected from the staff and graduate students at the International Institute of Tropical Agriculture (IITA), Ibadan and screened with respect to their interest and ability to different food sensory properties as described by Nina et al. (2020). Plantain chips, 'dodo', boiled unripe and boiled ripe plantain were evaluated for texture, taste, color, appearance, flavor, overall acceptability while 'amala' made from unripe and ripe flour was evaluated for texture, color, stretchability, mouldability, flavor, mouth feel and overall acceptability. The samples were served to panelist in a randomized manner with different codes. The means of the scores by the panelists were analyzed for significant differences between the respective samples.

Statistical analysis

The data obtained in the laboratory were subjected to analysis of variance (ANOVA) using the Statistical Analytical System (SAS) package (SAS 9.3 version) (2008), and the means were separated using Least Significant Difference (LSD). The significance test was done at the 5% probability level ($p < 0.05$).

RESULTS AND DISCUSSION

Moisture, minerals and vitamins content of the plantain cultivars at unripe and ripe stages

The moisture content, essential minerals and vitamins are presented in Figure 2. The moisture content of the unripe and ripe plantain of the different cultivars ranged from 56.69 to 69.38%. Moisture provides a measure of the water content and index of storage stability (Adegunwa et al., 2017). The vitamin C content varied between 5.49 and 10.25 mg/100 g. At the ripe and unripe stages, Pita 26 had the lowest and highest value, respectively. Carotene (pro-vitamin A) levels ranged between 1.71 and 19.77 g/g. At the unripe stage, Pita 26 had the lowest value, whereas Mbi egome had the highest value. The calcium content varied between 7.48 and 99 mg/kg. The ripe Agbagba cultivar had the highest calcium content, while the unripe Pita 27 cultivar had the lowest calcium content. Magnesium content ranged from 10.06 to 14.37 mg/kg, with ripe Mbi egome having the lowest value and unripe Agbagba having the highest. The potassium content varied between 94.37 and 184.45 mg/kg. At the ripe stage, Mbi egome had the lowest value, while Pita 26 had the highest value. Sodium content varied between 4.72 and 6.15 mg/kg. Mbi egome at ripe stage had the lowest value, while Agbagba at unripe stage had the highest value.

Analysis of variance showed that processing methods had a significant effect on the value-added products with regards to moisture, essential minerals and vitamins as shown in Figure 3. The moisture content that ranged from 4.06 to 69.28% where dried products recorded the least value (4.06%) followed by fried products (15.82%) and boiled products had the highest values (69.28%). The calcium content ranged from 6.51 to 9.66 mg/kg where dried product recorded the least value (6.51 mg/kg), followed by boiled products (8.37 mg/kg) and fried products recorded the highest value (9.66 mg/kg). Fried product recorded the highest value (22.93 mg/kg) for magnesium content, followed by dried products (16.94

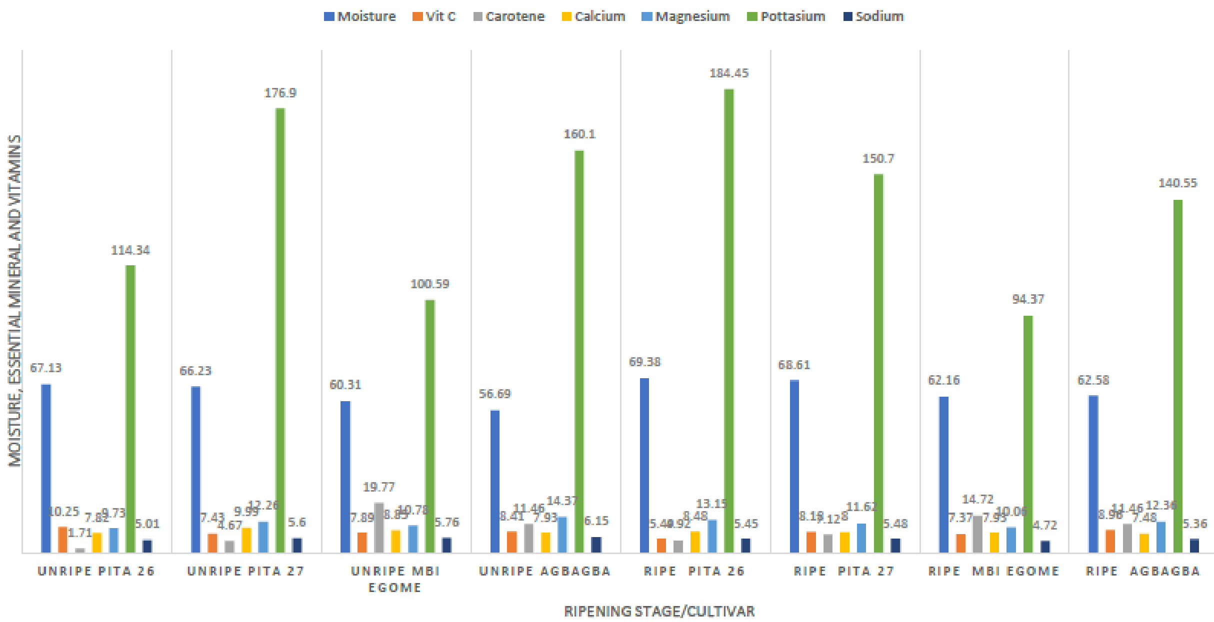

Figure 2. Graphical representation of the moisture (%), minerals (mg/kg), vitamin C (mg/100 g) and carotene (µg/g) of the raw plantain cultivars at different ripening stages.
Source: Authors

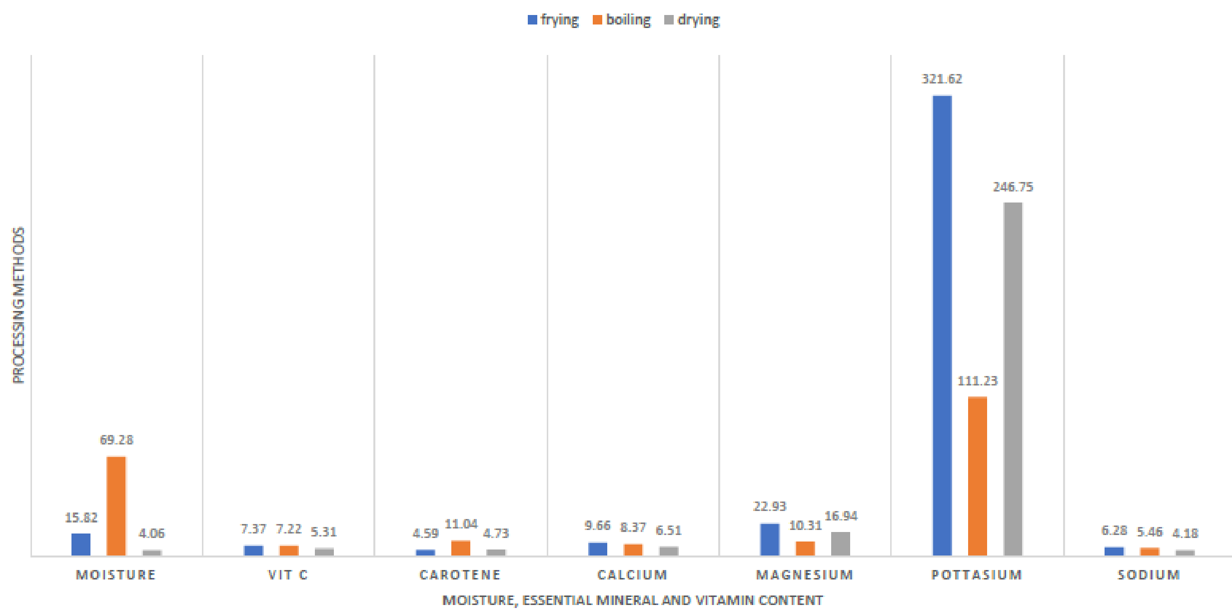

Figure 3. Graphical representation of effect of processing methods on the moisture (%), minerals (mg/kg), vitamin C (mg/100 g) and carotene (µg/g) of the plantain cultivars.
Source: Authors

mg/kg) and boiled products (10.31 mg/kg). Fried products showed highest value (321.62 mg/kg) for potassium content, boiled products (111.23 mg/kg) and dried products recorded the least value. Sodium content showed high value (6.28 mg/kg) in fried products, 5.46 mg/kg for boiled products and least value (4.18 mg/kg) for dried products. Generally, fried products recorded the highest values for essential minerals, and this may be due to the composition of the frying oil. Vitamin C showed high value for (7.37 mg/100 g) for fried products, 7.22

Table 2. Sensory evaluation of plantain chips and "dodo" from hybrid plantain cultivars.

Sample	Cultivar	Texture	Taste	Colour	Appearance	Flavor	Overall acceptability
Fried unripe (Plantain chips)	PITA 26	6.09^b	5.38^b	5.76^b	5.67^a	5.57^b	5.67^b
	PITA 27	4.19^a	3.52^a	5.00^a	5.14^a	4.38^a	4.43^a
	MBI EGOME	7.86^d	7.43^c	7.76^c	7.86^b	7.05^c	7.76^c
	AGBAGBA	7.00^c	7.29^c	7.62^c	7.67^b	6.86^c	7.38^c
Fried ripe plantain ('Dodo')	PITA 26	5.25^a	5.50^a	5.15^b	5.40^c	5.15^a	5.40^a
	PITA 27	5.85^c	7.00^d	5.10^a	4.70^a	6.70^d	6.10^c
	MBI EGOME	6.25^d	6.50^b	6.60^d	6.25^d	6.30^c	6.50^d
	AGBAGBA	5.30^b	6.70^c	5.75^c	5.15^b	6.15^b	5.85^b

Means followed by different superscript within a column indicate a significant difference ($p<0.05$).
Source: Authors

mg/100 g for boiled products and least value (5.31 mg/100 g) for dried products. Carotene (Pro-vitamin A) content was high in boiled product with 11.04 µg/g, followed by 4.73 µg/g for dried products and 4.59 µg/g for fried products. Boiling retains the carotene of plantain in a study by Adegunwa et al. (2017).

Plantain chips (fried unripe plantain)

The results of the effect of processing method on sensory evaluation of plantain chips are presented in Table 2. There was a significant difference ($P<0.05$) for all sensory parameters. Frying as a processing method showed a significant effect on the sensory parameters of the cultivars at different ripening stages.

The response of the panelist on texture ranged from 4.19 to 7.89. Mbi egome recorded the highest texture and Pita 27 had the least texture. Generally, the panelists scores indicated that the plantains chips from Mbi egome had a very hard to good texture. Textural attribute denotes the freshness and high quality of a food product (Ajani et al., 2020). Nina et al. (2020) reported similar score for texture (6.20-6.55) for plantain chips while Onwudiwe and Obue (2019) reported higher score for texture (8.4) for fried plantain chips.

Taste ranged from 3.52 to 7.43. Mbi egome had the highest taste value while Pita 27 recorded the least taste. The significant difference ($P<0.05$) in taste quality of the plantain chips can be linked to the total soluble solids and pH difference of the plantain cultivars. However, taste is mainly a balance between sugar and acid content. Nina et al. (2020) reported similar score for taste (6.30-6.45) while Onwudiwe and Obue (2019) reported 8.4 score for taste of fried chips which is higher compared to this study.

Color of the chips is important in the assessment of consumer acceptability and a quality parameter of fried snacks which is related to the perception of consumers (Ajani et al., 2020). There was color variation among the evaluated plantains chips which ranged from 5.00 to 7.76 where Mbi egome had the highest score and Pita 27 had the least value. Agbagba plantain chips (control) also had a high value for color while Pita 27 and Pita 26 showed least value for color, which may be due to the slice sticking problem observed in the fruit pulps. Slices sticking together during frying had a great influence on homogeneous product processing efficiency. Generally, all the samples in this study had a golden yellow color which is the characteristics color of plantain chips (Ajani et al., 2020). Control of the frying temperature and time is important to the color of plantain chips because increase in these parameters will reduce the color intensity of the plantain chips (Adeyanju et al., 2016). Onwudiwe and Obue (2019) reported 8.1 score for color for fried chips compared to this study.

Appearance is considered as one of the attributes critically assessed by consumers and often forms the basis for their selection or rejection of products. Appearance ranged from 5.14 to 7.86. Mbi egome had the highest appearance value while Pita 27 had the least. Panelists also scored high value of 7.67 for Agbagba plantain chips. Appearance affects the visual perception of consumers. The primary reason for the popularity of fried foods may be the characteristics like soft, juicy interior as well as thick and crispy outer crust. Nina et al. (2020) reported similar result range for appearance (6.25-7.40) for plantain chips.

Flavor is an important sensory quality that affects smell perception of consumers. It ranged from 4.38 to 7.05 where Mbi egome had the highest value and Pita 27 had least. Onwudiwe and Obue (2019) reported 8.4 score for flavor for plantain chips which is a higher value compared to that in this study. Nina et al. (2020) also reported similar result for flavor (6.20-6.55) for plantain chips. The overall acceptability ranged from 4.43 to 7.76. Mbi egome had the highest overall acceptability, followed by Agbagba while Pita 27 had the least value. Similar score (6.20-6.55) was reported by Nina et al. (2020). Plantain chips processed from Mbi egome cultivar had the highest

Table 3. Sensory evaluation of boiled unripe and ripe hybrid plantain cultivars.

Sample	Cultivar	Texture	Taste	Colour	Appearance	Flavour	Overall acceptability
Boiled Unripe Plantain	PITA 26	6.02^{b}	5.22^{b}	5.82^{b}	5.27^{b}	5.52^{b}	5.63^{b}
	PITA 27	4.20^{a}	4.07^{a}	5.02^{a}	5.04^{a}	4.48^{a}	4.32^{a}
	MBI EGOME	7.82^{d}	7.54^{d}	7.92^{d}	7.96^{d}	7.35^{d}	7.82^{d}
	AGBAGBA	7.20^{c}	7.21^{c}	7.73^{c}	7.22^{c}	6.90^{c}	7.20^{c}
Boiled Ripe Plantain	PITA 26	5.20^{a}	5.51^{a}	5.16^{b}	5.42^{c}	5.06^{a}	5.56^{a}
	PITA 27	5.80^{c}	6.60^{b}	5.12^{a}	4.72^{a}	6.02^{b}	6.12^{c}
	MBI EGOME	6.95^{d}	6.65^{c}	6.68^{d}	6.75^{d}	6.38^{d}	6.75^{d}
	AGBAGBA	5.52^{b}	6.72^{d}	5.70c	5.07^{b}	6.25^{c}	5.80^{b}

Means followed by different superscript within a column indicate a significant difference ($p<0.05$).
Source: Authors.

acceptability, indicating that the cultivar was the best for value addition into plantain chips.

Plantain chips made from Pita 26 and Pita 27 cultivars showed significantly low overall acceptability for value addition as plantain chips and as such are not recommended for value addition as plantain chips. In Nigeria, the production and marketing of plantain chips was formally done by females. Recently, it has been overtaken by many jobless male youths who now venture in this as real time agribusiness since plantain chips are generally eaten as snack food at any time (Ubi et al., 2016).

"Dodo" (fried ripe plantain)

The result showed a significant difference ($P<0.05$) in the sensory parameter as presented in Table 2. Frying as a processing method showed a significant effect on the sensory parameters considered for 'dodo'. 'Dodo' is a high demand value added product for customers in social events, restaurants and fast food services (Oluwagbenga et al., 2020). The texture ranged from 5.25 to 6.25 where Mbi egome had the highest value while Pita 26 had least value. Pita 27 also scores a high value of 5.85 for texture compared to Agbagba which is the control. Texture, color and oil content are the main quality parameters of fried products (Oyedeji et al., 2017).

Taste is a very important sensory parameter that influence consumer acceptability. Taste ranged from 5.50 to 7.00. Pita 27 had the highest value and Pita 26 recorded the least value.

Color ranged from 5.10 to 6.60. Mbi egome had the highest while Pita 27 had the least value.

Appearance ranged from 4.70 to 6.25 where Mbi egome had the highest value while Pita 27 recorded the least value.

Flavor ranged from 5.15 to 6.70. Pita 27 scored the highest value while Pita 26 has the least value. Frying is one of the major value addition processes for plantain which results in products with a unique flavor-texture combination (Oyedeji et al., 2017).

The overall acceptability ranged from 5.40 to 6.50. Panelists scored Mbi egome the highest value for overall acceptability, thus is the best for 'Dodo' value addition which is always in high demand in this agro-ecology in the mornings and evenings in homes (Ubi et al., 2016). A high proportion of the cultivars scored significantly high acceptability for this value added product and thus were also best for 'Dodo' value addition which is always on a high demand in all parts of Nigeria and can be eaten with porridge beans and meat (Ubi et al., 2016). More income is derived from the value-added plantain as dodo by fast food restaurants and food catering services.

Boiled unripe plantain

Table 3 shows the effect of processing method on sensory evaluation of boiled unripe plantain of the selected cultivars. There was a significant difference ($P<0.05$) for all parameters studied. Boiling as a processing method showed a significant effect on the sensory parameters of the cultivars at different ripening stages.

The texture ranged from 4.20 to 7.82, taste 4.07 to 7.54, color 5.02 to 7.92, appearance 5.04 to 7.96, flavor 4.48 to 7.35, and overall acceptability 4.32 to 7.82. Mbi egome scored the highest value while Pita 27 recorded the lease value for all sensory parameters studied. Agbagba (control) also scored high values for the sensory qualities. Onwudiwe and Obue (2019) reported similar sensory quality results of texture 7.6, taste 7.5, color 7.1, flavor 7.1 and overall acceptability score of 7.4 for boiled unripe plantain. The panelists accepted boiled unripe plantain from Mbi egome cultivar as best compared to other cultivars. Gunasekaran et al. (2020) reported that boiled unripe plantain contributed to the

Table 4. Sensory evaluation of unripe plantain flour (“amala”) from hybrid plantain cultivars.

Sample	Cultivar	Texture	Colour	Stretch ability	Mould ability	Flavour	Mouth feel	Overall acceptability
Unripe plantain flour	PITA 26	6.52[b]	5.52[b]	5.67[b]	4.78[a]	5.63[b]	4.27[a]	5.77[b]
	PITA 27	5.07[a]	4.68[a]	5.05[a]	5.27[b]	4.42[a]	4.52[b]	4.32[a]
	MBI EGOME	8.60[d]	8.06[d]	7.62[d]	7.82[d]	7.38[d]	7.88[d]	7.80[d]
	AGBAGBA	7.53[c]	7.20[c]	6.88[c]	6.75[c]	6.95[c]	7.27[c]	7.07[c]
Ripe plantain flour	PITA 26	3.44[a]	3.68[a]	3.90[a]	3.56[a]	3.21[a]	3.82[a]	3.17[a]
	PITA 27	3.22[a]	3.50[a]	3.77[a]	3.40[a]	3.02[a]	3.33[a]	3.01[a]
	MBI EGOME	5.09[c]	5.12[c]	5.65[c]	5.21[c]	6.52[c]	5.23[b]	5.35[c]
	AGBAGBA	4.06[b]	4.50[b]	4.86[b]	4.63[b]	4.28[b]	4.54[c]	4.16[b]

Means followed by different superscript within a column indicate a significant difference (p<0.05).
Source: Authors.

recovery in children with acute watery diarrhoea. Resistant starch played a major role in prevention or cure of diarrhoea.

Resistant starch constitute about 83.7% of unripe plantain which is refractory to enzyme hydrolysis in the small intestine, and passes to the colon unaltered where it is acted upon by the normal commensals to produce short chain fatty acids, which are the primary mediators of the beneficial activity (Gunasekaran et al., 2020). Boiled unripe plantain is used for the preparation of unripe plantain porridge which an important delicacy in Nigeria and West Africa.

Unripe plantain porridge is used to control diarrhoea in Nigeria (Ayinde et al., 2017). Ayinde et al. (2017) reported in a study that most people living in urban areas regularly consume boiled ripe plantain compared to rural dwellers.

Boiled ripe plantain

Effect of processing method on sensory evaluation of boiled ripe plantain is represented in Table 3. There was a significant difference (P<0.05) for all parameters studied. Processing method showed a significant effect on the texture, taste, color, appearance and overall acceptability of boiled ripe plantain. Texture ranged from 6.20 to 6.95 and flavor ranged from 5.06 to 6.38. Mbi egome had the highest value while Pita 26 had the lease value for both texture and flavor qualities. Taste ranged from 5.51 to 6.72 where Agbagba had the highest value and Pita 26 recorded the least. Color ranged from 5.12 to 6.68 and appearance ranged from 4.72 to 6.75. Mbi egome had the highest value while Pita 27 recorded the least value for color and appearance qualities. Mbi egome recorded the highest value 6.75 for the overall acceptability while Pita 26 recorded least value of 5.56. Ayinde et al. (2017) reported that most people living in rural areas regularly consume boiled ripe plantain compared to urban dwellers.

Unripe plantain flour reconstituted dough (‘Amala”)

Table 4 shows the sensory evaluation results of the ‘amala’ samples from selected hybrid plantain cultivars. There was a significant difference (P<0.05) for all the sensory parameters. Drying as a processing method showed a significant effect (p<0.05) on the sensory parameters of the cultivars at different ripening stages.

The ‘amala’ samples made from Pita 27 and to some extent Pita 26 were rated lowly by the test panelists. The panelists on the other hand, seemed to have rated the ‘amala’ samples from Mbi egome and Agbagba highly in combined scoring for texture, color, stretchability, mouldability, flavor, mouthfeel, and overall acceptability. Texture ranged from 5.07 to 8.60, color 4.68 to 8.06, stretchability 5.05 to 7.62, mouldability 4.78 to 7.82, flavor 4.42 to 7.38, mouthfeel 4.27 to 7.88 and overall acceptability 4.32 to 7.80. The panelist score ‘amala’ made from Mbi egome highest overall acceptability for all sensory quality. The ‘amala’ sample from Agbagba cultivar (local landrace) was rated higher than the hybrid plantain cultivars except Mbi egome for all sensory parameters. Babalola and Taiwo (2019) reported appearance (4.47-6.93), texture (4.33-7.13), taste (4.60-6.93) and flavor (4.93-6.80) for reconstituted dough of cardaba banana and plantain flour which is like the results recorded in this study. Texture is first important factor before ‘mouth feeling’ in consumers’ acceptability of “fufu” like pounded yam and ‘amala’ in Nigeria. From this study, the panelist scored high for texture than mouthfeel for all the cultivars. Generally, the cultivars used for this study (from the scores of the panelists) could also be used in the production and preparation of ‘amala’ in Nigeria. The food called ‘amala’ in Nigeria, is always eaten with a source which is considered rich in protein (Ubi et al., 2016). It is a staple food in certain regions in Nigeria.

Ripe plantain flour reconstituted dough (‘Amala”)

The results of the sensory evaluation of dough reconstituted from ripe plantain flours from selected hybrid plantain cultivars are presented in Table 4.

The texture of ‘amala’ from ripe Pita 26 and Pita 27 flour was less preferred (3.44 and 3.22) to the texture of ‘amala’ from ripe Mbi egome and Agbagba flour (5.09 and 4.06), respectively. Pita 26 and Pita 27 samples scored lower marks (3.68 and 3.50, respectively) in color compared to Mbi egome and Agbagba that scored higher marks (5.12 and 4.50) from the panelist. Stretchability ranged from 3.77 to 5.65, mouldability 3.40 to 5.21 and mouthfeel 3.33 to 5.23. Mbi egome sample recorded the highest mark while Pita 27 had the least score for stretchability, mouldability and mouthfeel. It was observed that ‘amala’ produced from flours of Mbi egome and Agbagba samples had better flavor than those from Pita 26 and Pita 27 flour samples. The overall acceptability ranged from 3.01 to 5.35. The panelists score Mbi egome the highest for overall acceptability percentage while Pita 27 has the least mark.

Conclusion

The sensory properties of the value-added products (plantain chips, "dodo," boiled unripe and ripe plantains, unripe and ripe plantain flour reconstituted dough "amala") demonstrated that hybrid plantains cultivars have the potential to be processed into value-added products, thereby providing food security, enhancing livelihoods, improving nutritional status, and social well-being of the populace. The sensory parameters studied were significantly affected by processing methods such as frying, boiling, and drying. Mbi egome cultivar products were deemed acceptable in terms of overall quality, followed by Agbagba local landrace cultivar products. The findings of this study show that hybrid plantains (Mbi egome cultivar) have the potential for industrial exploitation through processing into snacks and food items suitable for consumption at home and in fast food service systems.

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CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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