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Pitout JDD, Church DL, Gregson DB, Chow BL, McCracken M, Mulvey M, Laupland KB (2007). Molecular epidemiology of CTXM-producing Escherichia coli in the Calgary Health Region: emergence of CTX-M-15-producing isolates. Antimicrob. Agents Chemother. 51: 1281-1286.

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Full Length Research Paper

Chemical and functional properties of complementary food blends from malted and unmalted acha *(Digitaria exilis*), soybean *(Glycine max)* and defatted sesame (*Sesamun indicum L*.) flours

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Complementary foods of high nutrient qualities are expected to be given to infants in order to maintain their healthy status as they gradually transit from breastfeeding to family food. This study was aimed at producing high quality complementary food from locally available crops. Acha (*Digitaria exilis*), soybean (*Glycine max*) and sesame (*Sesamun indicum* L.) seeds were cleaned separately of dirt and extraneous materials. The acha grains were malted by steeping, germinating (72 h), drying (60°C, 20 h), desprouting, dehulling, milling and sieving. Soybean was soaked, dehulled, boiled, dried and milled while sesame seeds were soaked, acetic acid treated, rinsed, dehulled, dried, defatted, re-dried and milled. Complementary food blends were formulated at various ratios from malted and unmalted acha, full fat soybean and defatted sesame flours. The formulations produced were assessed for chemical composition and functional properties. The results showed that protein of the malted blends ranged from 7.68 – 21.68%, the energy ranged between 358.45- 433.30 kcal. The bulk density, water absorption and swelling capacities were lower in the malted blends. The viscosity of malted blends (< 2,550 Cps) was significantly lower ($p<0.05$) by LSD test than the values for unmalted blends (> 6,000 Cps). The supplementation with both soybean and sesame flours increased the protein, fat and ash contents of the blends while malting improved the consistency of the diet. The malted blends formed free flowing gruels which will aid consumption in infants.

Key words: Infants, malting, milling, protein, viscosity, water absorption.

INTRODUCTION

The use of traditional staples such as cereal as a source of complementary food for infants that are weaned from breast milk is well recognized (Fashakin and Ogunsola, 1982; Gopaldas et al., 1988; Onofioko and Nnanyelugo,

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1998; Ikujenlola, 2004). However, there is an inherent problem associated with the utilization of these staple foods as complementary food and this lies in the inability of the staples to satisfactorily supply all the necessary nutritional requirements of the fast growing infants. Plant proteins are regarded as incomplete proteins because it is deficient in one or two essential amino acids. Such limiting amino acids are required for optimum growth and healthy living. Cereals like maize, wheat, barley, acha (hungry rice), millet and sorghum lack lysine as the first limiting amino acid and in some cases tryptophan as the second limiting amino acids. These essential amino acids cannot be synthesized at reasonable quantity by the body (Bressani and Elias, 1974; FAO, 1992).

In addition to the problem of essential nutrients there are also the problems of bulkiness and processing of the traditional weaning food which often lead to leaching or depletion of protein and nutrients from the resulting gruel. Adeyemi (1989) reported that fermented maize contain less than 0.5% protein after processing to maize gruel (Ogi). Meanwhile, the problem of dietary bulk has been solved using various processing methods which include malting. Malting is controlled germination of grains during which biochemical reactions take place which leads to break down of polymers to smaller units. During the process of malting or germination an inherent enzyme is activated and this enzyme has been associated with the reduction in the high dietary bulk of malted flours. The enzyme alpha amylase which converts insoluble starch to soluble sugars, resulting in a thinning effect, is an impor-tant nutritional effect of germination (Murugkar et al., 2013; Ikujenlola et al., 2013).

Fortified nutritious commercial complementary foods are unavailable especially in the rural areas and where available, they are often too expensive and beyond the reach of most families in Nigeria. FAO/WHO/UNICEF (1971) emphasized the use of local foods formulated in the home and guided by the following principles: (i) high nutritional value to supplement breastfeeding (ii) acceptability (iii) low price (iv) use of local food items (Dewey and Brown, 2003).

Acha (*Digitaria exilis*) is in abundance in the northern part of Nigeria and scanty information is available as regards its utilization in complementary food formulations. Acha contain about 7% crude protein that is high in leucine (9.8%), methionine (5.6%) and valine (5.8%). It is believed that its methionine content is twice as high as that of egg protein (Temple and Bassa, 1991; Ballogou et al., 2013). Because of the nutritional value, Acha is highly recommended for diabetic patients by doctors (Philip and Itodo, 2006). Acha like other cereal lacks lysine.

The proteins of soy bean and sesame are considered to be rich sources of lysine and their major deficiency lies in the sulphur containing amino-acids methionine and cysteine. The amino acids profile of legumes and oil seeds placed them as natural complements to cereal based diets.

This study was aimed at producing diets that can satisfactorily meet the need of the growing infants especially in the northern part of Nigeria where Acha, soy bean and sesame are abundant. Therefore, this study was designed to produce malted and unmalted complementary foods from blends of acha, soy and sesame flours and to assess the chemical and functional characteristics of the complementary foods.

MATERIALS AND METHODS

The acha (*D. exilis*) used was purchased from the Jos Market, Jos Nigeria. Soybean and sesame seeds were bought from Owo central market, Owo, Nigeria.

Production of malted acha flour

The method described by Marero et al. (1988) was adopted in the production of malted acha. The grains were cleaned in tap water and steeped in water (1:3) for 8 h. It was spread evenly (1.5 cm depth) in a germinating chamber for 72 h with constant watering to maintain its moisture content. The resulting green malt was dried in cabinet dryer at 60°C for 20 h, this was later desprouted, conditioned, dehulled, milled and sieved (Figure 1). The unmalted acha flour was produced according to the method reported by Obayanju and Ikujenlola (2002).

Production of soybean and sesame flours

The soybean and sesame flours were produced according to the methods of Obayanju and Ikujenlola (2002) and Kulkarni et al. (1989) respectively. Figure 1 gives the flow chart of the unit operations involved in the production of the various flours.

Formulations of the blends

The flours (malted and unmalted acha, soybean and sesame) were formulated into various blends using the following ratios shown in Table 1.

Determinations of proximate composition

The proximate compositions of the blends (protein, fat, ash, crude fibre and moisture) were determined by using the standard methods of AOAC (2004). Carbohydrate was determined by difference and energy value was determined by calculation using the relationship described by Osborne and Voogt (1978) (1 g protein, 1 g carbohydrate and 1 g fat were multiplied by factors 4, 4 and 9 kcal, respectively).

Determination of functional properties

The functional properties of the blends were assessed by determining the values of these parameters - bulk density, water absorption capacity, oil absorption capacity and viscosity.

The bulk density of each of the flours was determined by the

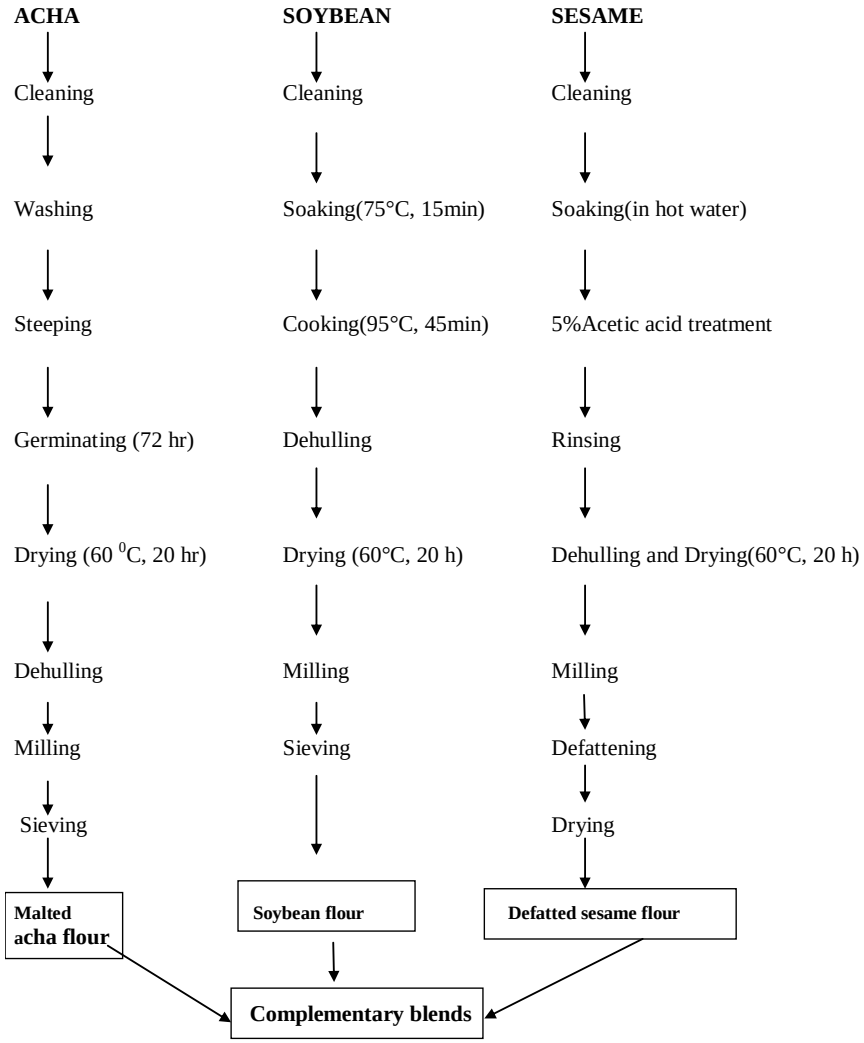

Figure 1. The production of complementary blends from acha, soybean and sesame flours.

Table 1. Various complementary blends (%).

Sample	Acha	Soybean	Sesame
Unmalted A	100	-	-
Unmalted B	70	30	-
Unmalted C	70	20	10
Malted A	100	-	-
Malted B	70	30	-
Malted C	70	20	10

method described by Okaka and Potter (1979). The water holding and oil absorption capacities were determined using the methods reported by Agrawal et al. (2013). The method described by Ikujenlola and Fashakin (2005) was used in the determination of the viscosity of the blends.

Statistical analysis

The data were expressed as means of three determinations. Data were analysed at the 0.05 level for one way analysis of variance (ANOVA) test. The level of significance test was determined using

Table 2. Proximate composition of the blends (%).

Sample	Fat	Protein	Ash	Crude fibre	Moisture	Carbohydrate	Energy (kcal)
Malted A	3.45^{e}	7.68^{d}	3.45^{b}	2.75^{c}	8.50^{b}	74.17^{a}	358.45^{e}
Malted B	13.15^{c}	16.23^{b}	4.10^{a}	2.20^{c}	7.65^{b}	56.67^{c}	409.95^{c}
Malted C	18.10^{a}	21.68^{a}	4.00^{a}	2.05^{c}	8.25^{b}	45.92^{e}	433.30^{a}
Unmalted A	3.95^{e}	7.23^{d}	4.25^{a}	2.50^{c}	9.00^{a}	73.07^{a}	356.75^{e}
Unmalted B	12.20^{c}	13.25^{c}	3.90^{ab}	2.15^{c}	8.75^{ab}	59.75^{c}	401.80^{d}
Unmalted C	15.35^{b}	17.90^{b}	4.20^{a}	3.50^{b}	7.50^{b}	51.55^{d}	415.95^{b}
Commercial diet -control	9.00^{d}	16.00^{b}	2.00^{c}	5.00^{a}	4.00^{c}	64.00^{b}	401.00^{d}

Means of the same column followed by different letters are significant ($p < 0.05$) by LSD test.

the Fisher's least significance difference (LSD) test and Duncan's multiple range test using SAS program (SAS Institute Inc., Cary NC, USA 2002-2003).

RESULTS AND DISCUSSION

Chemical compositions of the complementary blends

The chemical compositions of the formulated blends are presented in Table 2. The major nutrients of the blends are protein, fat and carbohydrate. The protein content of the products ranged between 7.23 and 21.08%. The protein contents of unmalted and malted acha were 7.23 and 7.68%, respectively. The addition of soy bean and sesame flour to both unmalted and malted acha led to increase in the protein content of the products. For malted complementary blends, the protein ranged between 16.23 - 21.08% while it was 13.25 - 17.90% for unmalted complementary blends. The protein content compared favourably with the results of Omeire (2013) and Olapade and Aworh (2012) who produced diets from acha with boiled soy and coconut; and extruded acha with cowpea respectively. Legume and oil seeds contain protein of high essential amino acids (Iwe, 2003; Kaga et al., 2002; Robellen et al., 1989). Babies and growing children require protein of high quality in order to prevent the occurrence of protein malnutrition which is responsible for stunting growth.

The fat content of the malted blends ranged between 3.45 and 18.10% while the unmalted blends ranged between 3.85 and 15.35%. The addition of both soy and sesame increased the level of fat in blends. These values were higher than the values reported by Anigo et al. (2010) for blends of guinea corn, soybean and groundnut. Flours of high fat content supply higher energy value. However, food containing high fat is susceptible to both hydrolytic and oxidative/enzymatic rancidity which are responsible for off flavour. This affects both the general acceptability and storage stability of the products. Due to the high fat content of some the products, it should be used shortly after production in order to prevent deterioration as a result of ranscidity.

The ash content of the blends ranged from 3.34 - 4.10% (malted blends) and 3.90 - 4.25% (unmalted blends). The ash content of the products is higher than the 2% ash of the control. This range is higher than the ash content of fermented popcorn-African locust bean-bambara groundnut blends (FPAB) (0.85±0.01 g/100 g) but lower than 6.07±1.24 g/100 g for fermented popcorn-African locust bean blends (FPA) reported by Ijarotimi and Keshinro (2013). The ash content is directly related to the mineral composition of the blends. The crude fibre of the blends ranged from 2.05-3.50% for the all the products. These values were lower than that of the control (5.00%) but higher than the fibre of maize gruel 'Ogi' (0.85%) reported by Ijarotimi and Keshinro (2013). World Health Organization recommends crude fibre below 5% for infants (FAO/WHO, 1991). The carbohydrate ranged between 45.92 - 74.17%. The carbohydrate content of the malted blends was lower than the unmalted samples. The energy content of the products ranged from 358.45 - 433.30 kcal (malted) and 356.75 - 415.95 kcal (unmalted). These values compared favourably with that of the control (401.00 kcal). FAO/WHO (1991) recommends a range of 400 - 435 kcal/100 g. Adequate energy is required for optimum development and growth of infants; this will promote normal growth and prevent energy malnutrition. The moisture content of malted and unmalted formulated diets were below 10%. The recommended moisture content for infant food according to FAO/WHO (1991) is less than 5%. These results compared favourably with the commercial weaning food sold in Nigeria and the results agree with the earlier reports of Obatolu and Cole (2000) and Ajanaku et al. (2012) who worked on similar complementary foods.

Functional properties of the formulated diets

The bulk densities of the malted and unmalted samples

Table 3. Functional properties of complementary blends.

Sample	Malted A	Malted B	Malted C	Unmalted A	Unmalted B	Unmalted C	Commercial diet-Control
Bulk density (g/ml)	0.65	0.50	0.51	0.75	0.70	0.65	0.60
Water absorption capacity (%)	110.00	115.00	113.00	125.00	125.00	150.00	140.00
Swelling capacity (%)	115.00	110.00	120.00	130.00	145.00	165.00	145.00
Oil absorption capacity (%)	135.00	130.00	135.00	120.00	120.00	125.00	130.00

are presented in Table 3. The bulk densities ranged between 0.51 and 0.75 g/ml. The lowest value (0.51 g/ml) was recorded for the malted sample while the highest value (0.75 g/ml) was recorded for the unmalted sample. The bulk density of the control (commercial diet) was 0.60 g/ml. According to Ikujenlola and Fashakin (2005) and Onesmo (2011) malting promotes development of hydrolytic enzymes with high activity; modifies endosperm and converts stored starch to dextrin and simple sugars. Desikarchar (1980) reported that malting process is useful in the preparation of low bulk weaning foods. Low bulk density food is desired where packaging is a serious problem.

Water absorption capacities of the samples ranged between 110.00-115.00% (malted) and 125.00 - 150.00% (unmalted) and swelling capacities ranged between 110.00 -115.00% (malted) and 130.00-165.00% (un-malted). The water absorption capacity of the control was 140.00% and the swelling capacity was 145.00%. The trend of these results agrees with the report of Agrawal et al. (2013) who worked on malted foxtail and millet.

Water absorption and swelling capacities of the malted samples were lower than the values for the unmalted samples. The water absorption capacity relate to the amount of water available for gelatinization. Malting according to the reports of Marero et al. (1988), Kulkarni et al. (1989), Mensah and Tomkins (2003) and Ikujenlola and Adurotoye (2014) lowers water absorption capacity of malted flour. Lower water absorption capacity is desirable for producing a thinner gruels or porridges for children. Gruels of low water absorption capacity will allow addition of more solid, this will invariably increase the level for increase total solid. Swelling capacity of the sample determines the ability of the sample to absorb a particular amount of water and retain same within the period under study. From this result, the process of malting led to the reduction of both water absorption and swelling capacities.

The oil absorption capacities of the sample ranged from 130.00 - 135.00% (malted) and 120.00 - 125.00% (unmalted). The oil absorption capacities (Table 3) of the malted samples were higher than the unmalted complementary blends. Germination increased the capacity of acha flour to bind oil. This observation agrees with the reports of Narayana and Narasinga (1984), Ikujenlola (2004), Agrawal et al. (2013). However, this observation is at variance with the report of Obatulo and Cole (2000).

Viscosity is the measure of the resistance of fluid to flow. Food is visco-elastic in nature. Weaning or complementary food of high viscosity is usually unaccep-table to infants, it makes feeding taskful and causes choking-/suffocation. The malted blends gave lower viscosity (<2,250 cps) than the unmalted and the control samples (>10,550cps) (Figure 2). The viscosities of malted blends were significantly lower ($p<0.05$) than those of unmalted blends. The consistencies (Table 4) of the malted blends were soft and free flowing as compared to the high viscous and thick consistency of the unmalted blends. The low hot paste viscosity of the malted samples was as a result of the activity of the amylase enzyme activated during malting which dextrinifies the starch molecule of the grain to dextrin. With low viscosity infant can easily consume as much food as possible. More solid can be added to the mixture; this will increase the nutrient density of the gruels which is highly beneficial to the infants. The reports of Desikarchar (1980), Marero et al. (1988), Kulkarni et al. (1989), Uvere et al. (2002), Sajilata et al. (2002) and Ikujenlola and Adurotoye (2014) show that malting process is valuable in reducing the viscosity of infants' gruels, increase total solid and nutrient density of such food.

Conclusion

The study successfully produced complementary foods of good chemical and functional characteristics from locally available raw materials (acha, soy and sesame). It could be concluded that malting improved the chemical composition of the products and the addition of soy and sesame further enhanced the chemical composition of the blends. Moreover, the malting reduced the viscosity and the water absorption capacity of the products which is advantageous to the infant and will make feeding easier.

Conflict of interests

The authors did not declare any conflict of interests.

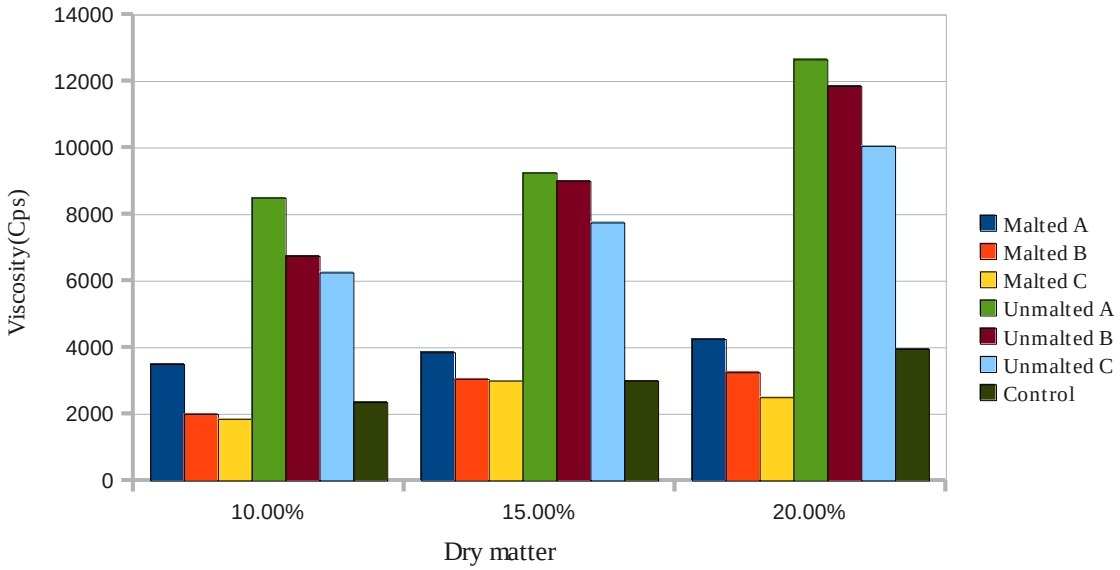

Figure 2. Viscosities of the various blends.

Table 4. Consistency of the blends.

Dry matter	Malted A	Malted B	Malted C	Unmalted A	Unmalted B	Unmalted C	Control (Nutrend)
10%	Free flowing	Free flowing	Free flowing	Free flowing	Free flowing	Free flowing	Free flowing
15%	Free flowing	Free flowing	Free flowing	Spoonful	Spoonful	Spoonful	Spoonful
20%	Free flowing	Free flowing	Free flowing	Paste like	Paste like	Paste like/ viscous	Spoonful

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Full Length Research Paper

Effect of flooding and salinity as a result of climate change on tomato production in the coastal zone of Benin

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The production of tomato in the coastal regions is affected by flooding and salinity conditions. A survey was conducted in this region to know the impact of change in climate on tomato production. Two types of flooding conditions are prevalent: flash flooding and severe flooding where water remains stagnant for weeks. The results also show that climate change is exacerbating the existing a-biotic factors (flooding and salinity) by significantly affecting tomato development, growth and yield and yield components as reported by farmers. Flooding and salinity pose a serious threat to some producers and forced them to abandon their agricultural lands in severe cases. The repeated yield losses in some other areas caused tomato producers to move from their field close to the sea to the field far away. The producers said that flooding conditions commence at the end of June till middle of August. The producers previously grew their tomato in the areas of study in May but because of repeated flooding every year they were compelled to shift their sowing calendar. A total of 16 tomato varieties were recorded in the areas of study. Gbamingbo variety was moderately resistant to flooding conditions while Aclinkonkoui and Petomèche varieties appear to be moderately tolerant to salinity due to their average performance in terms of yield and yield components.

Key words: Coastal areas, tomato production, flooding, salinity, climate change.

INTRODUCTION

In recent years, global warming and its effect on crop production has become perceptible. As a matter of fact, agriculture is highly sensitive to environmental factors and weather extremes, such as flood, salinity, temperature and drought (de la Peña and Hughes, 2007). Human activity has already changed atmospheric characteristics and such trends are expected to continue which will pose many problems to agricultural production and farmers will be faced with a lot of challenges. Ceccarelli et al. (2010) reported that climate change that are taking place at present will have – and are already having – a negative impact on food production and food quality with the poorest

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farmers and the poorest countries most at risk. Acquaah (2010) stated that a-biotic environmental stresses are responsible for about 70% of yield reduction of crops in production. In recent years, Benin Republic has been devastated by flooding. Two-thirds of the country has been affected and all the growing crops in the regions were swept off by floods.

Flooding, saline soil, drought, and heat are major environmental factors crops must endure and overcome in order to produce good yields. Farmers' worries about these occurrences are for good reason. They cause massive crop-yield losses every year even more, in fact, than losses from insects and weeds (Serrano, 1999). The increase in salinity and floods negatively affect crop yields beyond the impacts of mean climate change. Climatic changes will influence the severity of environmental stress imposed on vegetable crops (de la Pena and Hughes, 2007). It seems obvious that any significant change in climate on a global scale should impact local agriculture, and therefore affect the world's food supply (IPCC, 2007). Extreme climatic conditions will also negatively impact soil fertility and increase soil erosion (Brinkman, 1990). Global warming is predicted to lead to thermal expansion of sea water resulting in a rise of sea level which may range from 0.1 to 0.5 m (4 to 20 inches) according to present estimates of the Intergovernmental Panel on Climate Change (IPCC, 2007). The increase in the level of sea and the high irrigation of water will definitely bring about high salinity in the coastal regions in Africa and particularly in Benin Republic.

Climate change will seriously affect crop production as years go on. More erratic rainfall patterns and increased salinity caused by climate change will consequently be expected to further reduce crop productivity, and developing countries in the tropics are particularly vulnerable. In these areas, increasing salinity and flooding will be major factors limiting sustaining and increasing vegetable production. Climate change effects on Benin’s agriculture are evident in the coast, particularly in valley of Ouémé and Mono. A farm investigation conducted with producers to understand socio-economic factors related to innovation needs showed that all vegetable crops grown in coastal regions of Benin republic have been heavily impinged by salinity (Ezin et al., 2012).

A large majority of new varieties currently under cultivation have been bred for improved resistance to pest and diseases, as opposed to tolerance to abiotic conditions, the primary cause of crop loss (Wang et al., 2003). Habash et al. (2009) demonstrated that plant breeding might help in developing new cultivars with enhanced traits better suited to adapt to climate change conditions using both conventional and genomic technologies.

Climate change has started influencing greatly rainfall patterns where the suitability of land for different types of crops is affected. In the southern part of Benin rainfall water remains stagnant due to severe flooding.

Moderate water movement can reduce flood damage keeping them respiring and alive. Drainage within one to two days increases the chance of plant survival.

The objective of the present study was to evaluate the impact of flooding and salinity on tomato production in coastal zone of Benin.

MATERIALS AND METHODS

Study sites

The study was conducted in the coastal regions of Benin Republic (Figure 1). All the four departments along the coastal regions were surveyed due to the fact that they are tomato producing areas. Benin is bounded by Togo to the west, Nigeria to the east, and the Bight of Benin to the south. Benin's latitude ranges from 6°30′ N to 12°30′ N and its longitude from 1° E to 3°40′ E. The climate is of equatorial type with alternation of two rainy seasons (April-July and August end-November) and two dry seasons. Annual rainfall in the coastal area averages 1,360 mm. From December to January, there is harmattan: a dry and dusty West African trade wind.

Data source

The local governmental centers for agricultural development in the areas of study were identified and were approached to get information on tomato producers in the district. Then quantitative and qualitative data were collected through sampling method using questionnaires. Structure questionnaire was used in this study.

Sampling and data collection

During the exploratory phase, the production sites were visited. Group interviews were conducted with producers in different villages and cities visited to gather general information on the effects of flooding and salinity on tomato production. Additional information was obtained from local governmental centers for agricultural development on tomato production and the producers in each district surveyed.

Data were collected from 130 respondents of tomato producers. The respondents were selected randomly in each district. The in-depth survey was conducted based on interviews, observations, and structured questionnaires. Parameters such as gender, age groups, education level, social status, number of dependents, credit accessibility, agricultural technician’s support obtained, input use, the number and diversity of cultivated varieties, land availability, cultivated area, cost price, effects of flooding and salinity on growth, development and yield of tomato, salinity and flooding control strategies, etc were collected.

Data analysis

Data collected were processed in Microsoft Access 2003(11). Then, the entered data were verified in order to avoid errors and inconsistencies. Descriptive statistics were essentially used in analyzing the data. Standard deviation, percentage of age, sex, education level, social economic status, input use, land availability, cultivated areas in 2011, and cost price were computed through descriptive statistics. SPSS (Statistical Package for Social Science) was used for descriptive analysis, correlation of independent variable.

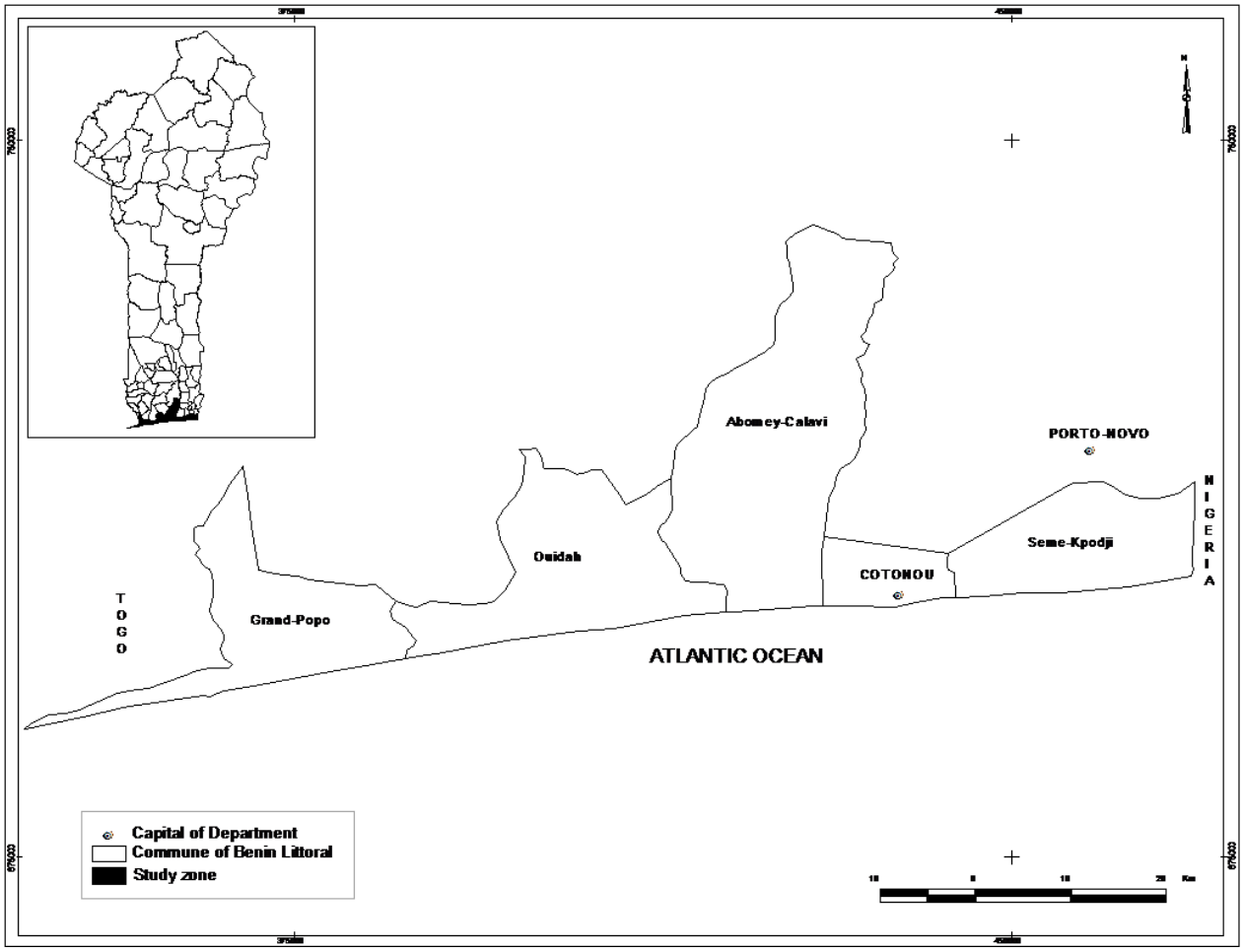

Figure 1. Benin Republic map and communes investigated.

RESULTS AND DISCUSSION

Coastal areas

The coastal regions (Figure 1) play a vital role in Benin economy. There are three main activities in the area: (1) agriculture is practiced in all the coastal areas while livestock is only practiced in Sèmè district, (2) Fishery is practiced throughout the coastal areas and has been a lucrative activity (3) the only sea port is in Cotonou city and is of huge important for Benin economy development.

Flooding and salinity have been a problem for agriculture activities. Over the last decade, many houses were lost due to flooding of sea water especially in Cotonou. Unfortunately, the protective embankment along the coastal areas that the government launched 4 years ago has failed due to lack of funding. Only 2 km out of 125 km was done. This protective embankment with big stones could help to some extent to prevent further loss of lands due to flooding of sea water.

Two types of lands characterized the areas of study: low lands and medium low lands. Most of lands encountered are low lands. Low land (75%) is higher than medium land (25%).

Characteristics of the respondents

The randomly selected respondents were tomato producers but occasionally some do the fishing. From the 130 respondents 82.5 and 17.5% were male and female, respectively. About 71.5% of producers were less than 45 years old, 24.2% from 45 to 60 years old, and 4.3% more than 60 years old.

The average cultivated lands for the production of tomato ranged from 1.3 to 0.75 ha. The production of tomato provides with the majority of farmers (59%) an annual income of less than 700000F CFA. Tomato contribution to annual income represents 1 to 65%. The average size of the household varies between 6 and 12 persons. Our results are consistent with that of Adorgloh-

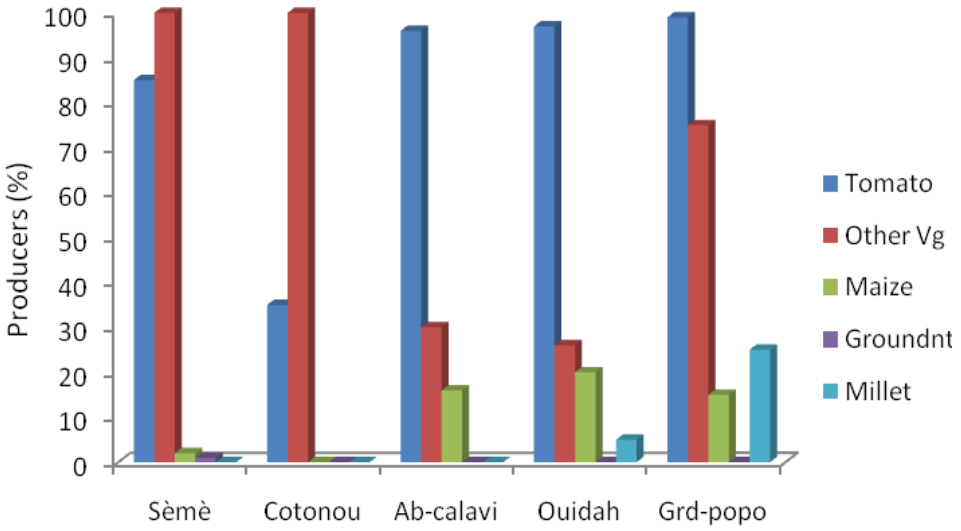

Figure 2. The main crops grown in the study sites.

Hessou (2006) who reported that tomato production plays a vital role in the economy of its producers in the South of Benin.

Crops grown in the area of study

Figure 2 shows the types of crops grown and demonstrates that tomato was grown in all the communes investigated. All the producers surveyed in Abomey-calavi, Ouidah and Grand-Popo mainly cultivated tomato while in Sèmè and Cotonou other vegetables are majorly produced when compared with tomato. Similarly, FAOSTAT (2012) reported that tomato crops are produced in urban and peri-urban areas of Benin.

Tomato varieties cultivated

Sixteen varieties were recorded in the communes investigated during our study: tounvi, gbataki, aclinkon, kekefo, pomme, adaka, gbamingbo, sonafel, ouaga, karaibo, ps royal, petomèche, mongal, tropimèche, 3fs and Brondelle. According to the respondents, ouga, ps royal, petomèche, mongal, tropimèche, 3fs, karaibo and Brondelle were imported from Ghana recently. Aclinkon, gbataki, kekefo and tropimèche were recorded in Cotonou; gbamingbo, kekefo, sonafel, adaka, tounvi in Abomey-calavi; Brondelle, tropimèche, ps royal, petomèche, 3fs, tounvi, karaibo in Ouidah, and other varieties Grand-popo, Sèmè et others.

Flood from 2010 to 2013 in Benin

The impact of climate change on abiotic stress such as flooding has been remarkable over the past five years. The flooding that has been occurring since 2010 is dramatic and devastating. In 2010, the following areas (Figure 3): Ketou, Zangnanado, Ouinhi, Adja-Ouere, Bonou, Adjohoun, Akpro-missereté, Dangbo, So-Ava, Abomey-calavi, Sèmè-Kpodji, Cotonou, Oiudah, Grand-popo, Come, Kpomassè, Athiemé, Lalo were seriously affected. More than 130,000 hectares of crops were lost due to the heavy flooding across the country. All the tomato crops produced in those areas were damaged by the flood. Severe crops losses recorded lead to food insecurity and high food price. Some farmlands in those areas are still uncultivable. Our study is consistent with that of Khan et al. (2012) who reported that recent year of flooding in Hoar areas of Bangladesh were severe and damaged agricultural crops in a large amount. They further stated that 2010 flood in this region severely damage huge amount of agricultural production. Cumhur and Malcolm (2008) reported that environmental factors such as flooding will negatively impact agricultural crops.

Municipalities and communes of Lokossa, Bopa, Athiemé and Cotonou, were most affected by flooding in 2011 leading to the destruction of farmland and crops. Our results are in agreement with that of Thomas and Prasad (2003) who reported that the modified environ-ment resulting from global warming and climate change, will drastically affect the production and productivity of food crops.

In 2012, the southern and the northern parts of the country were severely impeded by flooding causing the destruction of crops and farmlands. In each case, many lives were lost and roads and infrastructures devastated. As years go by the flooding is a serious problem in Benin causing food price to rise even in the rain season where the price of commodities is supposed to come down. The effects of flooding have significantly increased and get worsened as a result of climate change. Atkinson et al. (2008) reported that climate change will impact negatively food production, food quality and food security. Altieri and

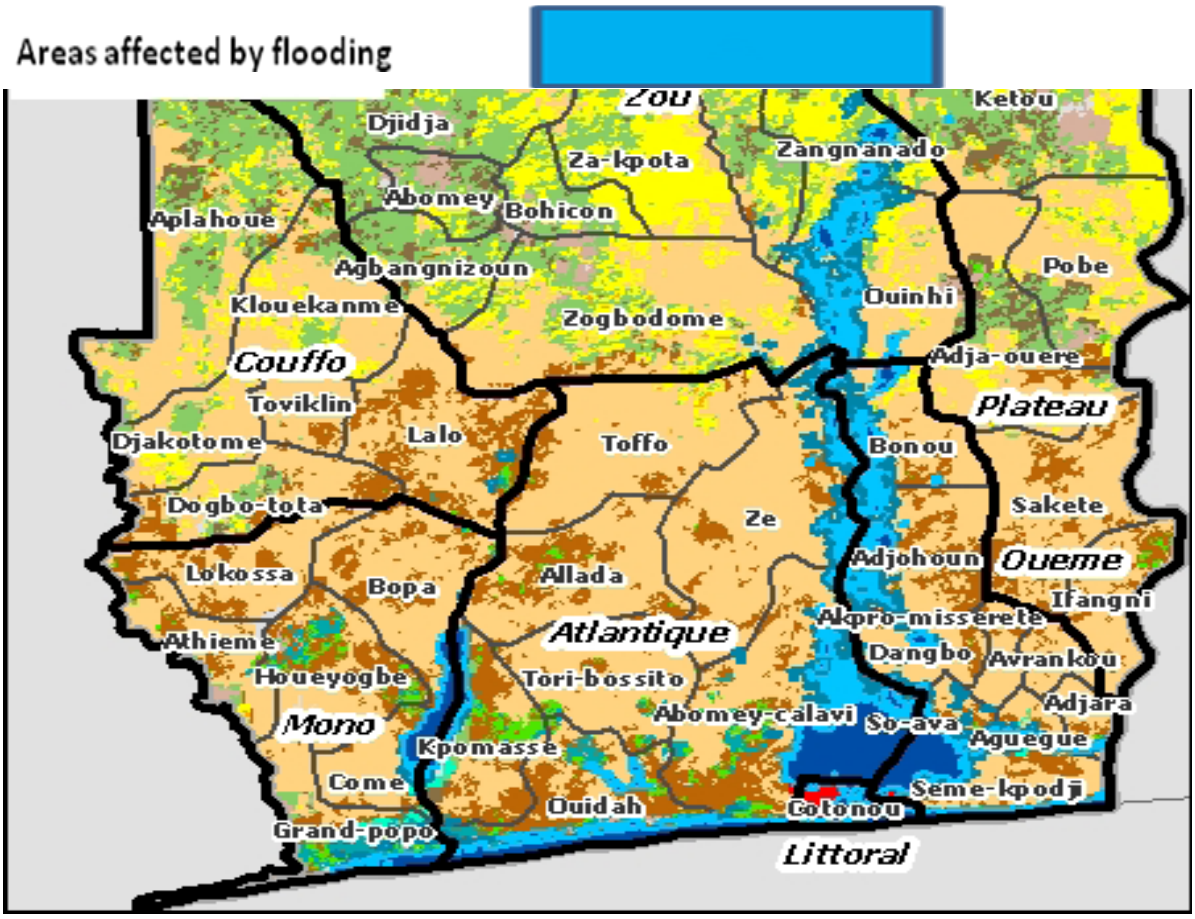

Figure 3. The villages and cities affected by flooding in 2010 and 2011.

Koohafkan (2003) also stressed that food security is potentially in danger than ever before.

Types of flooding

Most of tomato producers (87.3%) investigated said that flooding of their crops is mainly due to rainfed flood while 12.7% of respondents said it is due to ocean storm and tidal waves. They further stated that it does occur from the end of June till middle of August. The producers grew their tomato in the areas of study in May but because of repeated flooding every year they have shifted the sowing calendar. Till 2008, they still grew tomato in May but from 2011 their planting period has been August in order to avoid heavy rainfed flooding and losses of their crops. It is obvious to everybody now that climate change is occurring and the threat has become real and the question about this climate change occurrence is how to cope with it. Sidi (2012) reported that the flooding of September and October 2012 in Nigeria disrupted various sectors in the country and damaged crops like cassava, rice, yam, maize and tuber crops.

All the respondents acknowledged that due to flooding of sea water, a lot of lands were lost and the sea is progressing at alarming rate.

Flood damages tomato crops

According to tomato producers, flooding conditions caused the reduction of plant height and yield, total crop failure, yellowing of leaves, fruit rot and reduction of tomato market value and death of sensitive varieties. The same results were obtained by Kramer (1951), Kozlowski (1997), Núñnez-Elisea et al. (1999), Ashraf (2003), Walter et al. (2004) and Ezin et al. (2010) who stressed that 2 days of flooding caused reduction of plant height, wilting, leaf senescence, yield reduction and 8 days of continuous flooding lead to the death of tomato genotypes.

As shown in Figure 2, tomatoes and vegetables are the main crop grown in the areas of study. All of the tomato producers surveyed said that tomato and other vegetables were devastated by flooding. Table 1 show that only Gbamingbo is moderately tolerance to flooding amongst the 16 tomato varieties recorded. Farmers

Table 1. Evaluation of tomato varieties by farmers.

variety	**Flooding effects**	**Salinity effects**
Brondelle	Sensitive	Sensitive
Gbamingbo	Tolerant	Sensitive
Aclinkonkoui	Sensitive	Moderately tolerant
Kekefo	Sensitive	Sensitive
Touinvi	Sensitive	Sensitive
Gbataki	Sensitive	Sensitive
Sonafel	Sensitive	Moderately tolerant
Petomèche	Sensitive	Moderately tolerant
Ps royal	Sensitive	Sensitive
Mongal	Sensitive	Sensitive
tropimèche	Sensitive	Moderately tolerant
Ouaga	Sensitive	Sensitive
Adaka	Sensitive	Sensitive
3FS	Sensitive	Sensitive
Pomme	Sensitive	Sensitive
Karaibo	Sensitive	Sensitive

further said that severe flooding kill Gbamingbo variety as well. The other tomato varieties are very sensitive to flooding even 2 days of flooding are enough to damage them or render them unproductive. At 3 to 4 days of flooding, the performance of tomato varieties including Gbamingbo was poor and farmers failed to harvest tomato crops in the field, that is, there was complete crop failure.

Normally as from June the price of tomato, the most consumed vegetable, is affordable even to the poor households but unfortunately the price of tomato across the nation is still high for many reasons. On the one hand, the farmlands affected by previous flooding are yet to be available for crop production, and producers have shifted their sowing calendar due to the fact that across the country precipitation patterns have changed. On the other hand, the supply does not meet the demand due to the growing population.

In the recent survey conducted in June in the areas of study, due to the cultural practices put in place by farmers to avoid the deleterious effects of flooding on tomato, they are growing maize in the lands which were used for tomato production 4 years ago. The adjusted timing of sowing allows producers to steer clear of the flooding conditions but it is not beneficial to people who are expecting affordable tomato price. Therefore, adequate measures must be taken to avoid food insecurity now that climate change is inevitable. This study is similar to that of Sasson (2012) food security for Africa which is an urgent global challenge.

Salinity

Out of the 16 varieties recorded, only aclinkonkoui, petomèche and sonafel (Table 1) were moderately tolerant to salinity while the other varieties are sensitive. The key hindrance to the increase of crop production in the coastal areas is seasonally high content of salts in the root zone of the soil (Haque, 2006). In our study, the wet breeze from high tide and soil salinity were limiting factor to normal production and high yield as reported by farmers. For this study, soil samples were not collected and analyzed in order to determine the electrical conductivity.

Figure 4 illustrates the annual income of some tomato producers. Field 1 is the field where tomato was grown close to the sea while field 2 is where tomato was grown far away from the sea without the effect of salinity. From the graph annual incomes recorded in field 2 were significantly higher than those obtained and recorded in field 1. This indicates that salinity reduced the yield of tomato and lead to the reduction of tomato market value and consequently low income. In the last survey carried out some farmers have abandoned some fields where they produced tomato 4 years ago due to the repeat of low yield recorded. Salinity causes unfavorable environment and hydrological situation that limits normal crop production throughout the year (Haque, 2006).

Solutions used by producers to alleviate salinity effects

Farmers are still using their former methods to mitigate the deleterious effect of salinity on tomato production along the coastal regions despite the fact that climate change get more severe with time. They expressed their deception on the lack of improved varieties which could withstand the effect of climate change. Three different methods: fence with palisade (Figure 5), fence with maize/sorghum and intercropping are still employed to alleviate the effect of the tidal breeze loaded with salt which settled on tomato production in the coastal areas of the country. Most of the respondents (60%) used fence with palisade while 12 and 2% used fence with maize/sorghum and intercropping, respectively, to reduce the deleterious effect of tidal breeze which constitutes a constraint for tomato production in the regions. Only 26% of producers grew tomato in an open air without any measure of protection. Well-read people were amongst the respondents investigated and said that the rising of the sea level and waves are evident to them because the strategies of the fencing with palisade is no longer as efficient as before. They further stated that the level of the sea is higher between June and September as compared to past years. In Benin, more 10% of agricultural land in the area of study got lost due to the projection of sea and soil salinity. This is consistent with the results of Nicholls and Leatherman (1995): a 1 m sea-level rise would affect 6 million people in Egypt, with 12 to 15% of agricultural land lost, 13 million in Bangladesh, with 16% of national rice production lost, and 72 million in China and "tens of thousands" of hectares of agricultural

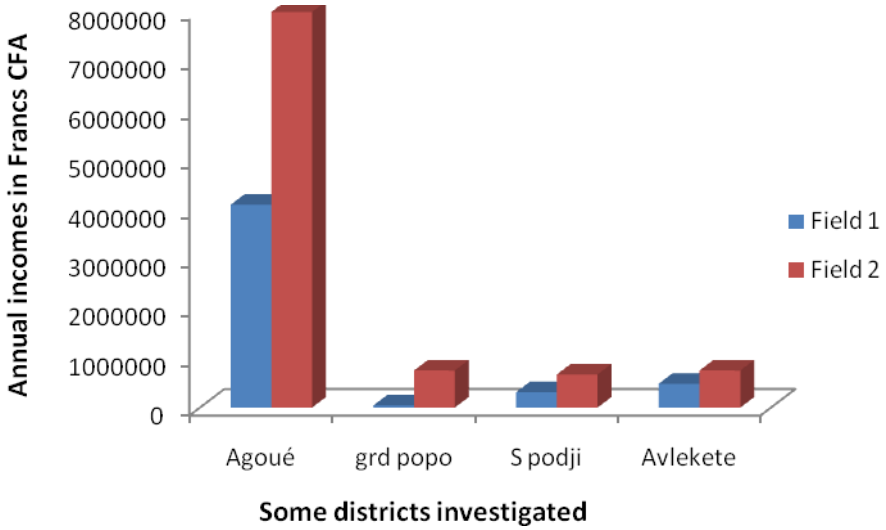

Figure 4. The Annual incomes at different locations, field 1: close to the sea and field 2: far away from the sea.

Figure 5. Method of palisade set up to abate the effect of tidal breeze

land. Tomato producers are desperate about getting other varieties which could withstand the negative impact of salinity on tomato production. Avlo district in the commune of Grand-Popo is yet to start growing vegetables and tomato in particular after they have given up their production due to high level of soil salinity.

Conclusions

The impact of climate change is real and preventive and adaptive measures must be taken to lessen its effects. Adequate cultural practices need to be adjusted and applied to avoid losses of tomato production to flooding and salinity. More tomato production is required to meet the demand of the growing population. New tomato varieties tolerant to flooding and salinity are needed to intensify the production of tomato. Tomato varieties that are resistant to both flooding and salinity will be of great advantage to the producers in the areas of study.

Conflict of interests

The authors did not declare any conflict of interests.

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Review

Possible microbial and biochemical contaminants of an indigenous banana beer 'Urwagwa': A mini review

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Indigenous traditional beers play an important role in the daily social, economic, nutritional and cultural life of the people especially in developing countries. Bananas and banana beer remain very popular in Rwanda and they continue to be an important source of income. Banana cultivation forms an essential part of the socio-economic life of Rwandan communities, and the fruit has a long and widespread history in the production of alcoholic beverages. However, there is very little documentation on this product. Although, methods of manufacture have been passed through generations in Rwanda, little is reported in the literature, and research has been minimal. As a result of increased rural-urban migration, and the adoption of Western culture by the younger generation, most of these fermentation techniques will die off, and remain history to the next generation while many other countries are expanding and scaling up the processing of their respective indigenous fermented foods and beverages. Therefore, the objective of this mini-review was to document the traditional processing techniques, characteristics of the product, traditional culture associated with this beverage and to trace its origin and the problems which farmers might be facing during processing in order to identify research topics that can alleviate some of the problems and constraints identified.

Key words: Biochemical, bananas, contamination, indigenous banana beer, urwagwa.

INTRODUCTION

Consumption of home-brewed traditional alcoholic beverages and fermented foods is one main characteristic feature, deeply rooted in African culture, as part of daily lives (Haggblade and Holzapfel, 1989). In Africa, there are numerous traditional alcoholic beverages, made from many types of agricultural sources such as: sorghum, maize, barley, wheat, millet, palm trees, bananas and/or plantains. Examples of these traditional beers are: 'thobwa' in Malawi (Matumba et al., 2010) 'burukutu' in Nigeria (Sawadogo-Lingani et al., 2010), 'sekete' in Ghana and Nigeria (Blandino et al., 2003), 'tonto' in Uganda (Mwesige and Okrutu, 1995), 'mbege' in Tanzania (Shayo et al., 1998), 'muratina' in Kenya (Bahiru et al., 2006), 'talla' in Ethiopia (Shale and Gashe, 1991), 'umqombothi', 'maiza', 'imfulamfula', 'isiquatha' and 'utshwala' in South Africa (Odhav and Naicker, 2002;

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Table 1. The examples of indigenous traditional African beers.

Product	Raw material	Region/origin	Reference
Agadagidi	Plantain	Nigeria	Iwuoha and Eke, 1996
Borde	Maize or wheat	Ethiopia	Tadesse et al., 2005
Chikokiyana	Maize and Millet	S.Africa/Zimbabwe	Gadaga et al., 1999
Dolo	Sorghum	Togo/Burkina Faso	Jespersen, 2003
Doro	Sorghum	Zimbabwe	Gadaga et al., 1999
Ikigage	Sorghum	Rwanda/Burundi	Lyumugabe et al., 2010
Kaffir beer	Sorghum	South Africa	Blandino et al., 2003
Merissa	Sorghum and Millet	Sudan	Blandino et al., 2003
Palm wine	Palm trees	West Africa	Olawale et al., 2010
Pito	Sorghum/maize	Ghana/Togo	Glover et al., 2005
Tchapalo	Sorghum	Cote d'Ivoire	Koffi et al., 2009

Shephard et al., 2005; Ikalafeng, 2008; Ikalafeng, 2008; Lues et al., 2011), 'chibuku' in Zimbabwe (Kutyauripo et al., 2009), 'bouza' in Egypt (Blandino et al., 2003) and 'tchoukoutou' in Benin (Nout, 2009). Other examples of indigenous traditional African beers are summarized in Table 1.

To express the significant role of traditional beer in African societies, in the Karamoja sub-region of north-eastern Uganda, sorghum traditional beer is termed as 'beer is the cattle of women', an explanation encompassing at once its ritual, nutritional, social and economic value. In this society, the wealth of men, relationships among families and the authority of elders are expressed through cattle (Dancause et al., 2010). In other words, cattle are an indication or a symbol of wealth.

In the olden days, indigenous traditional beers were mainly brewed for important social and cultural gatherings, such as seasonal rituals, funerals, marriage ceremonies, communicating with the ancestors, harvest gatherings and all other kinds of celebrations depending on ethnic group (Dancause et al., 2010; Lyumugabe et al., 2010).

In Rwandan culture, traditional banana beer has been given first preference in various social and ceremonial roles, where no ceremony is complete without banana beer. Custom demands it in dowries, at weddings, funerals, births and celebrations of all kinds. In welcoming visitors, Rwandans offer them banana beer and reciprocal exchanges of banana beer are the preferred means of strengthening relationships (Rukazambuga, 2008).

The offering of banana beer is considered essential before advancing any request for small favours or any kind of assistance. Mobilizing communal labour (or any social work), for clearing fields, building homes or other labour-intensive tasks, normally requires that the beneficiary provide banana beer to those who assist. In Rwanda banana plantations are more valued because they serve as an important dietary staple food and source of income to the farmers, through the selling of traditional banana beer and banana fruits at the farm level (Mpawenimana, 2005). Not only in Rwanda, even in other parts of the world, bananas are considered a significant staple food to many people, especially in developing countries in Africa, Asia and Latin America (Aurore et al., 2009), thus serving as a base for food security. To many farmers, banana plantations are a sign of wealth, security and social status, where brewing banana cultivars are mainly grown for beer production and sharing of banana beer and/or other traditional beer, serves as a mediating symbol in resolving conflicts among relatives, friends and neighbours.

The African continent has many different indigenous fermented foods and beverages (Campell-Platt, 1994), but the absence of a written culture in most countries makes the origin difficult to trace. The lack of written documents, archives and reliance on oral history, makes some of information unreliable. For example, there is no clear origin of the banana beer produced in Rwanda; historical literature does not tell exactly the time when and where banana beer was produced for the first time. The origin of bananas as the main raw material in the production of banana beer is placed in Southeast Asia and is likely to have been first domesticated in Papua New Guinea (Nsabimana and van Staden, 2007; Venkatachalam et al., 2008, Boonruangrod et al., 2009; Donohue and Denham, 2009). Areas of secondary diversity are found in East Africa, indicating a long history of banana cultivation in the region between the 5th and 10th centuries (Onguso et al., 2004). Phytolith http://en.wikipedia.org/wiki/File:Bananas_Muslim_world.JPGdiscoveries in Cameroon, dating to the first millennium BC, triggered an yet unresolved debate about the date of first cultivation in Africa (Lejju et al., 2006).

In addition to the above, there is linguistic evidence that bananas were known in Madagascar around first millennium BC. The earliest prior evidence indicates cultivation dates no earlier than late 6th century AD (Lejju et al., 2006). The dates and route of bananas from their native centre of origin (South East Asia) to Africa, remains

a subject of speculation. However, banana beer is believed to have been produced after the domestication of brewing-banana cultivars into Africa. The processing of juice, from matured, green beer-bananas, for alcoholic beverages was noted to be themain characteristic feature of East African countries, such as Rwanda, Uganda, Burundi, Kenya, Tanzania and Eastern Congo, where the majority of farmers in these banana-growing regions (East African highlands) mainly cultivate banana juice-yielding cultivars (Kyamuhangire et al., 2002; Byarugaba-Bazirake, 2008; Aurore et al., 2009) as compared to the rest of the world. In addition, Palmer (1971), quoted Baker and Grant (1864 and 1886), who described the processing of banana beer in the Kagera region (currently Tanzania) and in West-Central Uganda. Mulumba et al. (2004) also added that Uganda has a long history of cultivation of banana plantations, dating back to the 13th century.

In Africa, up to 30% of the harvested banana fruits are squeezed to produce juice that can be taken fresh, or fermented with sorghum flour, to make banana beer and wine. The idea of 'rubisi' (traditional banana beer) produced in Tanzania has records from about 300 years ago (Rivard, 2009), which started with the production of banana juice, 'mulamba'. 'Mulamba' became sour after storage for only two days and had no alcohol content. On the other hand, farmers were drinking sorghum beer with a bitter taste. After finding that 'mulamba' was non-alcoholic and sweet, while sorghum beer was bitter with alcohol, farmers tried to make a balance by sweetening sorghum beer with 'mulamba' (Rivard, 2009). However, to date, there is still a gap in the historical literature about the origin of this beer, although production and consumption of traditional banana beer is a unique feature of many African countries.

Production of traditional banana beer serves as an important source of income and employment among many farmers. Processing this traditional banana beer employs rudimentary methods, such as the use of feet, hands and spear grass to extract juice (Kyamuhangire et al., 2002; Byarugaba-Bazirake, 2008) (Figure 1A and B). Its production has remained mainly by home-based brewers in rural areas. Although the traditional methods are still preferred, improved processing techniques are indispensable to add value to beer products, particularly banana beverages, which still pose processing challenges in Rwanda and many other developing countries (Byarugaba-Bazirake, 2008; Mukantwali et al., 2008; Lues et al., 2011).

However, apart from its informal manufacturing in Rwanda, commercial production of this traditional banana beer has been developed as a business through the establishment of considerable processing plants, such as Urwibutso (local medium enterprise, owned by an individual) and COVIBAR (Compagnie de Valorisation Industrielle de la Banane au Rwanda). The latter plant was initially owned by the government but recently, through a Rwandan government initiative to promote the private sector, the plant has been privatized. The current owners have targeted exploring wider regional markets such as Common Market for Eastern and Southern Africa (COMESA) and East African Community (EAC), to which Rwanda belongs, with the aim of making more profit (Mpawenimana, 2005).

In the commercial production, improved processing technologies are employed, such as; mechanical extraction of juice, use of enzymes to facilitate ripening and extraction of juice (Mukantwali et al., 2008). The final beer products are bottled for sale within the country and a surplus is being exported to neighbouring countries and regional markets. However, many households in the country of Rwanda are involved in the production of traditional banana beer at home level, from which they get substantial cash income, similar to the South African situation as reported (Ikalafeng et al., 2009; Lues et al., 2011). To date, indigenous traditional beers are no longer produced for cultural purposes, as in the past, due to developments and western influence.

In most countries, especially in rural areas and some of the urban centres, traditional beer remains the backbone of the economy, mainly for the poor segment of the population (Kebede et al., 2002; Shackleton, 2003; Dancause et al., 2010). The income generated is used to pay school fees, medical treatment and other day-to-day home expenses (Muyanja et al., 2003; Choma and Alberts, 2007). Home-brewed banana beer and other traditional beverages like 'ikigage', 'ubushera', 'mokoko' and 'maiza', are mainly consumed in rural areas and in poor urban places, because of its affordable price as compared to commercially produced beer. This means that it is mostly the poorer segments of society who consume most of the local beverages (Kebede et al., 2002; Kayodé et al., 2007; Lues et al., 2011), except in the case of some culturally important functions, in which local beverages might have important ceremonial value. The Rwandan local banana beer, in rural areas and townships, is known to control large business markets for various reasons inspired by its need (Mpawenimana, 2005).

Even in other African societies, home-brewed traditional beverages are produced mainly for home consumption and/or for sale by low-income earners, who have no other alternative source of income to sustain their families (Dancause et al., 2010). Shackleton (2003) reported the selling of marula beer as the main source of income for many poor families in the Bushbuckridge community in South Africa. Ikalafeng (2008) also indicated a similar trend in the production of local traditional beers in the Northern Cape. It is believed that income is highly seasonal but it comes at time when money is needed for school fees, uniforms and purchase of books for students, especially after Christmas and new year celebrations, when there is shortage of money (Shackleton, 2003; Choma and Alberts, 2007).

A

B

Figure 1. A traditional way of squeezing juice out of ripe banana using feet and/or hands full of spear grass.

The processing of traditional beers varies from region to region and/or from country to country. The generic way for production of traditional beers and other indigenous, cereal-based fermented foods or beverages, involves many similar, common steps which are: malting (soaking,germination, sun drying), brewing (mashing, boiling, filtration) and fermentation (Gadaga et al., 1999; Blandino et al., 2003; Kayodé et al., 2007; Nzigamasabo and Nimpagaritse, 2009; Sawadogo-Lingani et al., 2010). In contrast, the preparation of traditional banana beer, is mainly carried out in different ways, as compared to many other traditional African beers except, 'tonto', 'mbege', 'agadagidi' (Mwesigye and Okurut, 1995; Iwuoha and Eke, 1996; Shayo et al., 1998). In the processing of traditional banana beer, juice obtained by crushing and squeezing peeled ripe bananas, is mixed with water in desired proportion and crushed roasted sorghum grains. The mixture is allowed to ferment for 2-4 days in a warm pit, covered with banana leaves to provide a conducive environment for the growth of fermenting organisms (Mwesigye and Okurut, 1995; Nzigamasabo and Nimpagaritse, 2009). The major difference in traditional banana beer-making is that sorghum grain, used as an adjunct in the banana brewing process, does not undergo a malting stage, like cereals used in the preparation of other traditional beers. Figure 2 outlines generic steps involved in the production of traditional banana beer.

A number of studies have reported that producers of home-brewed beer are predominantly women and unemployed school leavers (Ikalafeng, 2008; Amusa and Odunbaku, 2009). Most of these people go into alcohol

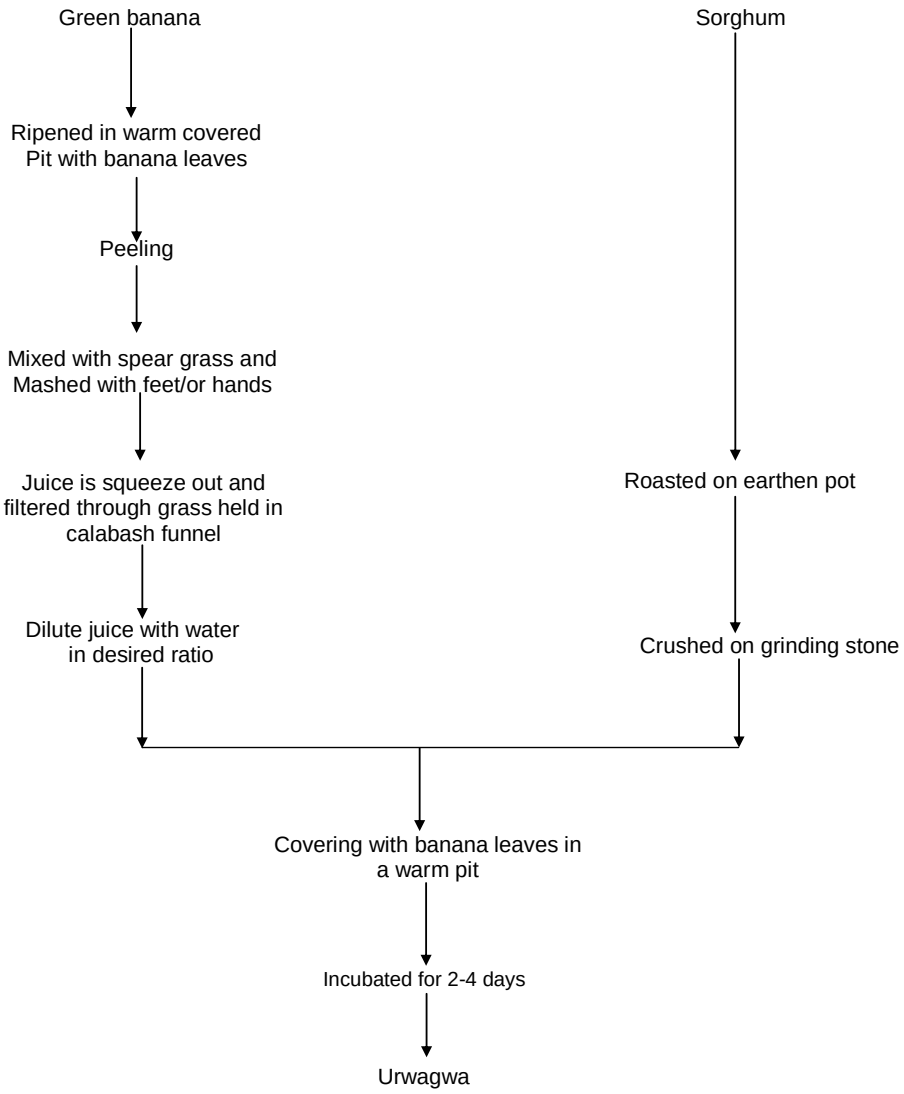

Figure 2. The generic steps involved in the production of traditional banana beer.

production due to poverty and lack of alternative income-generating choices. The lack of adequate knowledge about food handling, poor personal hygiene, lack of facilities such as clean water, toilets and equipment, sometime results in microbial contamination of traditional beverages during and after processing, as well as the addition of other contaminants, such as battery acids and concoctions known to the brewers only (Ikalafeng, 2008, Amusa and Odunbaku, 2009; Lues et al., 2011).

MICRO-ORGANISMS ASSOCIATED WITH INDIGENOUS BEER

The methods for pathogenic bacteria detection are critical to food safety and human health. Numerous media and molecular-based methods have been developed to detect and identify food-borne pathogens and other organisms from samples of different origins. Culturing and plating is an old technique used for identification of organisms and it is still widely used as a standard method for quantification of micro-organisms (Mugula et al., 2003; Bahiru et al., 2006; Cetinkaya et al., 2008). However, molecular techniques are preferred, as rapid and reliable methods for identifying even non-cultivable organisms. The examples of such molecular-based methods are: Intergenic transcribed spacer-polymerase chain reaction/restriction fragment length polymorphism (ITS-PCR/RFLP) (Glover et al., 2005; Sawadogo-Lingani et al., 2010), real-time PCR assay (Karns et al., 2005), quantitative-polymerase chain reaction (qPCR) (Andorrá et al., 2008), denaturing gradient gel electrophoresis (DGGE) (Díez et al., 2001; Temmerman et al., 2004; Stringini et al., 2009) and several other methods. Micro-organisms, either desirable or undesirable, are ubiquitous in the environment and have a variety of essential

functions. Due to the nature and origin of traditional beer, its processing is prone to microbial contamination through various routes. One aspect is the hygienic handling of raw materials and final product (traditional beer) which, when compromised, leads to contamination before consumption. Although some metabolites, such as organic acids, which are produced during the fermentation process, possess an inhibitory effect against undesirable organisms, the beer should not be assumed to be free of contamination (Holzapfel, 2002; Tetteh et al., 2004). For example, members of the bacteria genera *Staphylococcus*, *Escherichia* and *Salmonella* spp. are microorganisms closely associated with food-borne illnesses relating to poor hygiene, poor sanitation and improper food handling (Roy et al., 2007; Abraham et al., 2009). These microbes, amongst others, have been reported to be present in a number of food products, including traditional beverages (Lues et al., 2011). Protection of all types of foods and beverages from hazardous microbial contaminants is of great importance, as various gastrointestinal illnesses are the most common consequences of consuming contaminated foods and/or beverages.

Indicator microorganisms, such as total coliform bacteria, are a collection of relatively non-pathogenic micro-organisms that live in large numbers in the intestines of man, cold-blooded animals, soil and vegetation (Ksoll et al., 2007). Members of coliforms include genera such as *Citrobacter*, *Enterobacter*, *Escherichia*, *Hafnia*, *Klebsiella* and *Serratia*. Coliforms are Gram-negative bacteria, predominant facultative anaerobes in the bowel (Collins et al., 1995; Hayes et al., 2001), and they are members of *Enterobacteriaceae*. Members of the total coliform group, especially *Escherichia coli,* are used as indicator organisms of faecal contamination (Bell and Kyriakides, 1998; Oyedeji et al., 2010) and their presence in water and/or food indicates the possible presences of pathogenic bacteria, such as *Salmonella* spp., *Shigella* spp. and *Campylobacter* species (Bell and Kyriakides, 1998). Some strains of *E. coli* are human pathogens and are normally associated with diarrhoea, gastroenteritis and urinary infection (Bell and Kyriakides, 1998; Elmahmood and Doughari, 2007). Pathogenic *E. coli* that cause intestinal diseases are categorized into five classes: Enterohaemorrhagic *E. coli* (EHEC), Enteropathogenic *E. coli* (EPEC), Enteroinvasive *E. coli* (EIEC), Enteroaggregative *E. coli* (EAEC) and Enterotoxigenic *E. coli* (ETEC) (Bell and Kyriakides, 1998).

E. *coli* has been reported to be present in the following traditional beers and other fermented food products and/or beverages amongst others. Lyumugabe et al. (2010), reported the occurrence of *E*. *coli* at level of 21.90 x 10^3 cfu ml^{-1} in traditional sorghum beer ('ikigage') marketed in Rwanda, and these organisms are said to originate from water used for cooling and leavens. Roy et al. (2007), also reported the presence of *E. coli* at level ranging from 10^3-10^4 cfu g^{-1} in Indian traditional fermented foods. Coliforms were detected in 'bushera', a non-alcoholic sorghum beverage, initially at higher level followed by progressive decrease in numbers until day 4 of fermentation, when they were no longer detected (Muyanja et al., 2003). Several reports have indicated the presence of coliform counts in various fermented beverages at low level or undetectable level as pH drops (Kunyanga et al., 2009; Namugumaya and Muyanja, 2009).

One of the virulent genera, *Salmonella*, is ubiquitous and found in both cold and warm-blooded animals, including domestic and wild birds, reptiles and mammals (Pasmans et al., 2005). *Salmonella* spp. are pathogens but can frequently live in animals as transient members of the intestinal population, without causing disease. Callaway et al. (2008) stated that approximately 2 to 4 million people annually, in the United States, are affected by *Salmonella* spp. and salmonellosis is believed to be the second most common food-borne illness worldwide (Karns et al., 2005; Juneja et al., 2007). S*almonellae* are Gram-negative, rod-shaped bacteria, facultative anaerobes, which move by means of peritrichous flagella. They have an optimum temperature of 35 to 37°C and can also survive at low temperatures of 5°C, with a maximum growth temperature of 45 to 47°C. These bacteria have an optimum pH of 6.5 to 7.5 and a water activity of a_w 0.999 and 0.945. They are generally contracted by humans through the consumption of contaminated food of mainly animal origin (meat, poultry, eggs and milk), although other foods such as green vegetables have been implicated in their transmission (Bemis et al., 2007). The common symptoms associated with *Salmonella* are: nausea, intestinal cramps, diarrhoea, vomiting and sometimes arthritic (Bemis et al., 2007).

On the other hand, *Staphylococcus* is another bacterial type most often implicated in the contamination of traditional beverages (Tadesse et al., 2005; Lues et al., 2011). It has been reported as the causative agent of gastrointestinal illness world-wide, due to the production of heat-stable toxins. Staphylococcal toxins are resistant to heat and cannot be destroyed by cooking (Adams and Moss, 1997; Jørgensen et al., 2005). Staphylococci are normal microbiota of the human skin, nose, fingernails, palms, hair, throat and mucus membrane of healthy individuals. One study reported humans as being the main reservoir of *Staphylococcus cohnii* while *Staphylococcus aureus* can be found in both humans and animals (Plaatjies et al., 2004). Abraham et al., (2009) also reported that *S. aureus* are commonly present in nasal passage, skin and hair of up to 30-50% of the human population. The most common way for food to be contaminated with *Staphylococcus* spp. is through contact with food workers, who carry the bacteria on their skin and/or under the fingernails. Staphylococcal toxins are fast-acting, sometimes causing illness in as little as

30 min. The symptoms, usually developing within one to six hours after eating contaminated food, include nausea, vomiting, stomach cramps and diarrhoea (Bennett and Lancette, 1995; Martín et al., 2004).

Apart from the above-mentioned organisms, mainly associated with contamination of traditional beverages, other organisms such as lactic acid bacteria, yeasts and moulds have been isolated in a number of traditional beers (Jespersen, 2003; Kutyauripo et al., 2009). In traditional fermented foods and beverages, lactic acid bacteria are mainly responsible for the inhibition of undesirable microorganisms (Tadesse et al., 2005; Kebede, 2007); while the main function of yeasts (*Sacchromyes cerevisiae*) is the formation of alcohols and other aroma compounds (Jespersen, 2003). Cereal grains, like sorghum are frequently colonized by fungal contamination while in the field and during storage (Nkwe et al., 2005). Some of these moulds can produce mycotoxins, which may be transferred from contaminated grains into beer during brewing process (Bullerman and Bianchini, 2007).

TOXIN PROFILES OF TRADITIONAL BEER IN GENERAL

Mycotoxins and cytotoxicity

Rapid urbanization and rural reforms in developing countries have shifted the brewing and selling of traditional beers into commercial activity and this has resulted in increased consumption of these beverages, both in rural and urban areas (Choma and Alberts, 2007). Besides the risks related to ethanol consumption, home-brewed beverages contain other forms of contaminants that expose consumers to great potential health risks (Nikander et al., 1991). Raw materials frequently used in beer brewing activity, such as cereal grains, fruits and other plant materials, are vulnerable to fungal infestation in field, storage and/or during malting stages (Mbugua and Gathumbi, 2004; Nkwe et al., 2005). The use of raw materials contaminated with myctoxins in the production of beer and other fermented foods, is a serious food safety hazard, due to their severely toxic effects on human health (Westby et al., 1997; Fernández-Cruz et al., 2010).

Numerous studies have reported the incidence of mycotoxins in both traditional and commercial beer, in different parts of the world where, for example, zearalenone, deoxynivalenol, fumonisin B_1 have been detected in Kenyan lager beer (Mbugua and Gathumbi 2004), and South African commercial and home-brewed traditional beer (Odhav and Naicker, 2002; Shephard et al., 2005; Ikalafeng, 2008). The presence of such undesirable toxic metabolites (mycotoxins) in traditional beer or other food products is a concern, as it exposes the consumer to high risk of illnesses (Westby et al., 1997). Myctoxins are able to cause damage in different ways and these include: cytotoxic, immunosuppressive, neurotoxic, teratogenic or estrogenic, mutagenic, carcinogenic effects on humans and animals (Bennett and Klich, 2003).

These mycotoxins are toxic secondary metabolites, produced by many filamentous fungi, and contaminate various agricultural commodities in pre-harvest, harvest, post-harvest and storage conditions (Kumar et al., 2008; Wagacha and Muthomi, 2008; Pietri et al., 2009). Cereals are very susceptible to fungal infection in the field and/or inappropriate storage conditions. It is estimated that mycotoxins are responsible for the spoilage of approximately 25% of cereal crops worldwide (Prieto-Simón et al., 2007; Prieto-Simón and Campàs, 2009). Cereals that are particularly associated with mycotoxic contamination are: barley, maize, oats, sorghum and rye. Fungal species predominantly associated with sorghum, belong to the genera *Fusarium*, *Penicillium* and *Aspergillus* (González et al., 1997). There are about 300-400 known mycotoxins (Abdulkadar et al., 2004), but the most important common mycotoxins are: aflatoxins, fumonisin, deoxynivalenol, ochratoxins, zearalenone, T-2 toxin and T-2-like toxins (Bullerman and Bianchini, 2007). However, food-borne mycotoxins that occur frequently and are of the greatest importance in tropical developing countries, are the aflatoxins, ochratoxin, deoxynivalenol, fumonisins and zearalenone (Kumar et al., 2008; Shephard, 2008; Fernández-Cruz et al., 2010).

Mycotoxins are of concern due to their acute, potentially cytotoxic, effect on both human health and animals (Prieto-Simón and Campàs, 2009), as they are toxic to cells. Toxicological effects caused by ingestion of mycotoxins include: weakened immune system, decreased resistance to infection, reduced growth, allergens or irritants. Some have no known effect on humans and animals (Oswald et al., 2005; Waché et al., 2009), but chronic or long-term exposure to mycotoxin doses may result in reproductive disturbances, leukoencephalomalacia, pulmonary oedema, impairment of the humoral and cellular immune responses, nervous disorders, myocardial hypertrophy and several cancers (Champeil et al., 2004). Some of the mycotoxins are discussed below.

Fumonisin B_1 ($F B_1$)

Fumonisins are a group of naturally occurring toxic metabolites produced by several *Fusarium* species (Berek et al., 2001; Rao et al., 2010). These were identified and characterized for the first time in 1988 (Gelderblom et al., 1988). To date, six different fumonisins have been identified as fumonisins A_1, A_2, B_1, B_2, B_3 and B_4 (Pelagalli et al., 1999; Rheeder et al., 2002). Among the numerous members of the fumonisins family, Fumonisin B_1 (FB_1) is the most predominant,

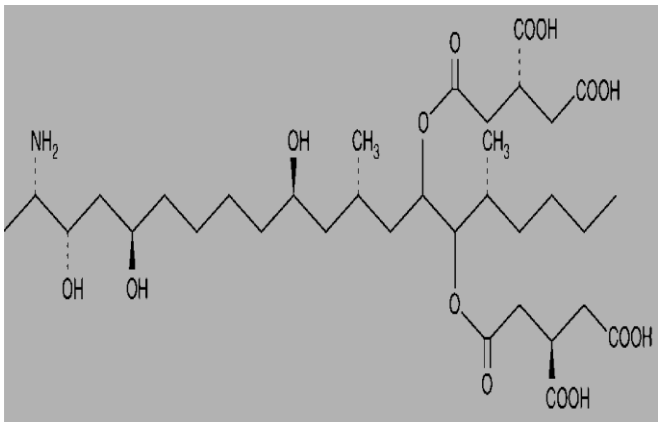

Figure 3. Chemical structure of Fumonisin B_1 (Zinedine and Maňes, 2009).

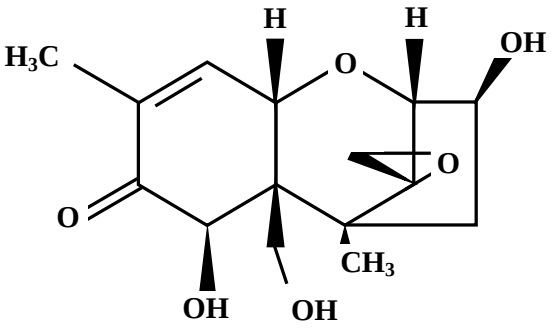

Figure 4. Chemical structure of deoxynivalenol (DON) (Sabater-Vilar et al., 2007).

classified by the International Agency for Research on Cancer (IARC) as a group 2B carcinogen (possibly carcinogenic in humans), as shown in Figure 3 (IARC, 2002; Shephard, 2008). The species producing significant quantities of fumonisins are *Fusarium moniliforme* and *Fusarium proliferatum.* They are common contaminants of maize (Fandohan et al., 2005; Halloy et al., 2005; Tardieu et al., 2006), but these strains have been isolated frequently from corn-based food and feedstuffs (Marin et al., 1999; Soriano and Dragicci, 2004), barley, rice and wheat (Munimbazi and Bullerman, 1996), sorghum (Patel et al., 1996) and banana (Jiménez et al., 1997). Amongst the *Fusarium* species, *Fusarium napiforme, F. moniliforme*, *Fusarium nygamai* and *F. proliferatum*, are the most common important producers of Fumonisin B_1 (Torres et al., 1998; Soriano and Dragicci, 2004). Fumonisin B_1 (FB_1) is structurally similar to Fumonisin B_2 (FB_2) mycotoxin and, in high concentrations, FB_1 causes a variety of species-specific acute toxicological effects in domestic and laboratory animals.

This mycotoxin has been found to be responsible for the cause of leukoencephalomalacia (ELEM) in horses (Myburg et al., 2009), porcine pulmonary oedema (Fandohan et al., 2005; Voss et al., 2007) and human oesophageal cancer (Cetin and Bullerman, 2005; Presello et al., 2007) especially in the region of South Africa, China and other countries, due to the consumption of heavily *Fusarium*-contaminated local maize (Cetin and Bullerman, 2005; Myburg et al., 2009). It also causes hepatotoxicity in all species thus far examined (Bolger et al., 2001; Haschek et al., 2001). The effects of exposure to low doses of FB_1 mycotoxin are not well documented, but several studies have shown that it does not induce any clinical symptoms in swine or in mice (Bondy et al., 2000; Zomborszky-Kovacs et al., 2002). However, ingestion of low doses of FB_1 revealed pathological alterations of the lungs and an increase of intestinal colonization by opportunistic pathogenic bacteria in piglets (Oswald et al., 2003).

Deoxynivalenol (DON)

Deoxynivalenol (DON, Figure 4), also known as vomitoxin, is a member of the trichothecenes group of mycotoxins, mainly produced by numerous strains of *Fusarium* species and some other fungi, such as *Myrothecium, Phomopsis, Stachybotrys, Trichothecium and Trichoderma* (Creppy, 2002; Döll et al., 2009; Zinedine and Maňes, 2009). Trichothecenes are a group of closely related poly-cyclic sesquiterpenoids which possesses 12, 13-epoxytrichothene as a common skeleton ring (González-Osnaya et al., 2010).

These classes of mycotoxins are well-known to be potent inhibitors of protein synthesis for both RNA and DNA (Eriksen and Pettersson, 2004; Boermans and Leung, 2007). In addition, trichothecenes are toxins of concern in mammals, as they are responsible for haematic, apoptosis, anorexic syndromes, neurotoxic and immunotoxic illnesses (Visconti et al., 2004). Acute and chronic ingestion of these mycotoxins by humans and animals can also result in a diverse toxic effect, which includes impaired immunity, diarrhoea, vomiting, fever, necrosis, anorexia, depletion of bone marrow and haemorrhage (Berthiller et al., 2005; Bimczok et al., 2007).

DON occurs predominantly in grains such as wheat, barley, oats, rye, maize, rice and sorghum. DON poisonings occur both in farm animals and humans and it is highly toxic, producing a wide range of immunological disturbances; it is particularly noted for inducing feed refusal and emesis in pigs, hence its alternative name vomitoxin (Schlatter, 2004; Cetin and Bullerman, 2005; González-Osnaya et al., 2010). Most of the time, deoxynivalenol (DON) is noted to co-exist with other *Fusarium* toxins, such as Zearalenone, Nivalenol and its derivates, as well as the group of fumonisins. The presence of this mycotoxin has been documented by Ikalafeng (2008) at levels of concern for the consumers.

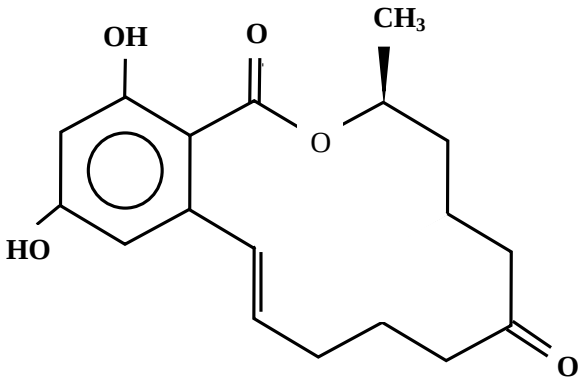

Figure 5. Chemical structure of zearalenone (Sabater-Vilar et al., 2007).

Table 2. Most notable Zearalenone-producing *Fusarium* species and other *Fusarium* strains.

Most notable *Fusarium* species	Other *Fusarium* spp.
F. graminearum	*F. sporotrichioides*
F. equiseti	*F. avenaceum*
F. semitectum	*F. napiforme*
F. proliferatum	*F. heterosporum*
F. verticillioides	*F. oxysporum*
F. moniliforme	*F. sambucinum*
	F. subglutinans
	F. solani

Zearalenone (ZEA)

Zearalenone (ZEA, Figure 5) is a non-steroid compound, also known as F-2 mycotoxin, and has frequently been implicated in numerous mycotoxicoses cases involving farm animals especially swine (Zinedine et al., 2007). It is classified as Group 3 (not classified to be carcinogenc to humans) by International Agency for Research on Cancer (IARC) (Azizi and Azarmi, 2009). Moreover, zearalenone is known to be a heat-stable mycotoxin and found worldwide in a number of cereal grains, such as maize, barley, oats, sorghum, rice, wheat, millet and bread (Zinedine et al., 2006), as well as in banana and bean leaves.

More than 25% of the world's agricultural production is mainly contaminated with mycotoxins. Apart from aflatoxins, fumonisins, deoxynivalenol and ochratoxin A, which are regarded as important mycotoxins, based on their worldwide occurrences and intoxication (Ayalew et al., 2006; Naicker et al., 2007), zearalenone is also amongst the important mycotoxins implicated in contamination of sorghum grains. Furthermore, it has been reported that *Fusarium* isolates from bananas can also produce zearalenone (Jiménez et al., 1997). Table 2 indicates a variety of *Fusarium* strains which are of great concern as they produce zearalenone in sorghum grain (González et al., 1997; Aoyama et al., 2009). Zearalenone is a mycotoxin of low acute toxicity, but some of its metabolites have high binding affinity for oestrogen receptors, which can result in reproductive problems (cause of infertility, affecting ovulation, conception, implantation, fetal development and the newborn's viability) in all animal species (Aoyama et al., 2009) and can enhance the proliferation of estrogen responsive tumor cells.

In humans, zearalenone is involved in the development of cervical cancer, breast cancer (Abid-Essefi et al., 2004; Boermans and Leung, 2007; Zinedine and Maňes, 2009) and it commonly occurs as a co-contaminant with trichothecenes mycotoxins, more particularly deoxynivalenol.

Lipopolysaccharides and pyrogenicity

Endotoxins (lipopolysaccharides, LPS) are highly pyrogenic components present in the outer membrane of Gram-negative bacteria (Nayak et al., 2008; Nilsson et

al., 2010). In chemical terms, endotoxins are lipopolysaccharide molecules, mainly consisting of three parts or regions: O-antigen, a core polysaccharide and lipid A, the portion which is responsible for the pyrogenic activities of LPS (Binding et al., 2003; Gorbet and Sefton, 2005; Hodgson, 2006; Heras et al., 2010). The term pyrogenicity refers to the ability/capacity of substance to induce or produce fever.

Pyrogens, especially lipopolysaccharides (endotoxins) are heat stable molecules, abundant in the environment and have been extensively studied in relation to their toxic effect, as compared to other pyrogens (Moesby et al., 2005; Hodgson, 2006; Schinder et al., 2006). Endotoxins are potent fever-inducing agents, hence termed as pyrogens (Gorbet and Sefton, 2005; Schinder et al., 2006).

Exposure to bacterial endotoxins triggers the release of cytokines, causing disseminated intravascular coagulation, bronchial inflammation, shock, chronically decreased pulmonary function, acute inflammation, toxin pneumonitis and even death (Barton et al., 2000; Binding et al., 2004; Nilsson et al., 2010). Nayak et al. (2008) reported that the destructive effect of Gram-negative bacteria and/or LPS is always high in chronic exposure as compared to acute exposure.

After the development of an *in vivo* rabbit pyrogen test, Limulus Amebocyte Lysate (LAL) assay was introduced as an *in vitro* alternative assay, convenient for measuring the level of bacterial endotoxins (Moesby et al., 2005; Liebers et al., 2009). Due to its limitations, the LAL test could not completely replace the rabbit test, as this assay is only limited to endotoxin detection (Andrade et al., 2003; Schinder et al., 2006). Other substances, like proteins or aluminium hydroxide, can interfere with results (Park et al., 2005). Numerous studies have focused on the Gram-negative bacterial endotoxin as the principal cause of pyrogenicity; non-endotoxin pyrogens, originating from Gram-positive bacteria, fungi or viruses, can also elicit pyrogenic response (Moesby et al., 2008). According to Moesby et al. (2003), heat sterilization procedures, recommended by the European Pharmacopoeia, cannot destroy or eliminate the pyrogenic activities of *S. aureus* and endospores of *B. subtilis*; an indication that they can result in serious health effects.

THE CONTRIBUTION OF VOLATILE COMPOUNDS

Volatile organic compounds are those compounds that have a high vapour pressure and low water solubility. Since the 1960s, several studies have focused on beer volatile compounds and this fraction remains difficult to understand (Pinho et al., 2006). Volatile organic compounds are of great importance in the brewing industry and other food industries as they affect the quality of the final product and enhance consumer acceptance (Pinho et al., 2006). Volatile organic compound are mainly classified into higher alcohols, esters, amines, organic acids, phenols, carbonyl compounds such as aldehydes and ketones, terpenes and sulphur-containing compounds. This great variety of volatile compounds, having different volatilities, polarities and a wide range of concentration, affects flavour and aroma of the product to a very different level or degree (Cortacero-Ramírez et al., 2003; Castro et al., 2004; Riu-Aumatell et al., 2004; Kobayashi et al., 2008; Silva et al., 2008). Volatiles directly affect the sensorial quality of the product in a positive or negative way as they greatly enhance beer flavour (Riu-Aumatell et al., 2004, Lui et al., 2005). Flavour is a combination of taste and aroma and it is of particular importance in determining food preferences. It is therefore, necessary to keep the concentrations of volatile compounds of the final product below their taste threshold, so that they do not affect the quality of the product.

Several studies have reported the occurrence of different volatile compounds in commercial beers as well as traditional ones. Three organic acids (lactic, citric and malic acids) were identified during production of ‘tchapalo’, a traditional sorghum beer popular in Côte d’Ivoire, using high-performance liquid chromatography (HPLC) (Aka et al., 2008). Also, using similar methods, Mugulu et al. (2003) reported 7 acids (DL-Lactic, succinic formic, pyruvic, citric, pyroglutamic and uric acids) from ‘togwa’. In addition, Bvochora and Zvauya (2001) identified formic acid and acetic acid in Zimbabwean traditional opaque beer, by HPLC. No propanoic or butyric acid was detected in the same beer sample, using the same technique. Annan et al. (2002), identified 20 alcohols, 22 carbonyls, 11 esters, seven acids, 1 furan and three phenolic compounds by GC-MS in Ghanaian maize dough samples, after 72 h of fermentation. By using gas chromatography (GC), Mugula et al. (2003) detected 5 carbonyls (acetaldehyde, 2-methyl-propanal, 2-methyl-butanal, 3-methyl-butanal), 4 alcohols (ethanol, 2-methyl-propanol, 2-methyl-butanol, 3-methyl-butanol,) plus diacetyl and acetoin in ‘togwa’, a Tanzanian traditional popular beverage. Other different methods have been used to identify volatile compounds from beer, wine and other food products, such as capillary zone electrophoresis (CZE) (Cortacero-Ramírez et al., 2003; Santalad et al., 2007) and nuclear magnetic resonance (NMR) (Rodrigues et al., 2010).

CONCLUSION

The processing of traditional brew plays a significant role in business, ritual, funerals, wedding feasts and other social gatherings in Rwandan communities and in other African countries. However, the use of low brewing technologies involving uncontrolled fermentation, unsanitary conditions and use of rudimentary methods during processing, packaging and storage can result in beers

and/or other traditional food products of low quality and short shelf-life. To foster commercial exploitation of the products, there is a need to develop appropriate brewing technologies affordable at farm level that will improve the quality of the traditional alcoholic beverages and extend their shelf-life through hygienic and controlled processing, packaging and storage. However, there is limited literature on this beverage; therefore the aim of this study was first to document the processing method, mode of consumption, traditional association with banana beer and to trace its origin for future generations.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Consumers' acceptance of composite cassava-maize-wheat breads using baking improvers

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A consumer test of composite cassava: maize: wheat (40:10:50) breads prepared with improvers, 0.3% emulsifiers, either as lecithin (LC) or diacetyl tartaric acid ester of mono-diglycerides (DATEM), and 3% hydrocolloids, either as high-methylated pectin (HM pectin) or carboxymethyl cellulose (CMC), was carried out in supermarkets in Mozambique. Overall acceptance and sensory attributes such as appearance, texture, smell, flavour, and crumb and crust colour were evaluated, and the consumption pattern and purchase intent were determined using a structured questionnaire. Composite bread quality characteristics, such as specific volume, crust colour, moisture content and firmness, were assessed instrumentally. The consumers' overall acceptance of the composite bread with a mixture of roasted and sundried cassava flours and HM pectin added and LC had a score of 7.58, which was slightly higher than 7.28 for the composite bread with roasted cassava flour. The hedonic test showed that the perceived overall quality of the optimized composite bread based on roasted cassava flour with CMC and DATEM had a score of 7.47, which was significantly higher than the corresponding bread with HM pectin and LC (7.01), but not significantly different from commercial wheat bread (7.82). Crust colour and crumb colour and firmness correlated highly with their perceived sensorial counterpart properties.

Key words: Sensory evaluation, bread quality, composite flour, cassava, hydrocolloids, emulsifiers.

INTRODUCTION

The use of composite flours for breadmaking in order to utilize locally available food crops is promoted in Mozambique due to the high cost of imported wheat flour. Partial substitution of wheat flour by flour products from sorghum, millet, maize, yam and cassava is therefore being explored and evaluated in bread quality parameters such as specific volume, structure, texture and sensory qualities.

Although it is shown that substitution of wheat flour up to a level of 20% results in acceptable composite loaves of bread, an increased substitution level may adversely affect bread and sensory qualities (Khalil et al., 2000;

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Table 1. Dough bread formulations selected from previous studies by Eduardo et al. (2013, 2014)[a].

Ingredient	Acceptance testing		Hedonic evaluation	
	Formula 1	Formula 2	Formula A	Formula B
Wheat flour (kg)	2.5	2.5	2.5	2.5
Maize flour (kg)	0.5	0.5	0.5	0.5
Roasted cassava flour (kg)	1.0	2.0	2.0	2.0
Sundried cassava flour (kg)	1.0	0.0	0.0	0.0
Yeast (%)	1.6[b]	1.6[b]	3.0[c]	3.0[c]
Margarine (%)	3.0	3.0	0.0	0.0
Oil (%)	0.0	0.0	3.0	3.0
DATEM (%)	0.0	0.0	0.3	0.0
LC (%)	0.4	0.4	0.0	0.3
HM pectin (%)	3.0	3.0	0.0	3.0
CMC (%)	0.0	0.0	3.0	0.0
Water (%)	85.0	85.0	85.0	85.0

Formulation used in the production of commercial wheat bread: 1.5% compressed yeast, 0.3% improver (soy flour, oxidant agent E300 and baking enzymes), 1.5% salt, 60-64% water. [a] based on flour weight; [b] dry; [c] compressed.

Hsu et al., 2004; Olaoye et al., 2006; Aboaba and Obakpolor, 2010; Nindjin et al., 2011; Udofia et al., 2013).

Only a few studies report the use of cassava in composite bread mixtures. According to Khalil et al. (2000) wheat breads with a 20% cassava flour substitution level and 1% malt has an overall acceptability score similar to that of wheat bread judged by a semi-trained sensory panel. Similar findings are reported by Eddy et al. (2007). Nindjin et al. (2011) found that 20% cassava or 30% yam starch substitution results in composite breads which meet consumer satisfaction with all the attributes as in the control wheat bread evaluated by an untrained consumer panel. Udofia et al. (2013) reports similar findings by a semi-trained sensory panel for composite bread of wheat:cassava:soybean (67:17:17 w/w ratio), however, higher substitution level on non-wheat flours results in bread with lower acceptability and bread quality parameters.

In addition, many other non-wheat flour products, such as rice flour (Rai et al., 2012; Sabanis and Tzia, 2009), yam flour (Hsu et al., 2004), maize flour (Păucean and Man, 2013) and sorghum flour (Keregero and Mtebe, 1994), have been tested as substitutes for wheat flour in composite bread formulations. All report that a level of 20% is the upper limit for substitution without there being an alteration in consumer acceptance of the composite bread as compared to wheat bread. The use of non-wheat flour products to partially substitute for wheat in products as bread, would help to reduce dependence on expensive wheat imports in South East Africa, including Mozambique where the production of wheat is difficult due to the climatic conditions.

The quality of composite cassava-wheat-maize bread has recently been evaluated instrumentally for breads made with different types of cassava flour (sundried, roasted and fermented) in combination with pectin (1 or 3%) and lecithin (0.4%). Eduardo et al. (2013) reports that bread firmness and crust colour are similar to that of wheat bread with a high level (40%) of roasted cassava flour or a low level (20%) of sundried cassava flour. The composite bread with a high level (40%) of roasted cassava flour is further optimized by Eduardo et al. (2014) using different emulsifiers and hydrocolloids. Based on the results of these studies, three different composite cassava breads with added hydrocolloids (carboxymethyl cellulose (CMC) or high-methylated pectin (HM pectin)) and emulsifiers (diacetyl tartaric acid ester of mono-diglycerides (DATEM) or lecithin (LC)) are proposed to be selected for consumer field tests.

The aim of the present study was therefore to (i) assess the acceptability of improved composite cassava-maize-wheat bread among local consumers in Mozambique, (ii) hedonically evaluate sensorial bread properties in order to identify the most important ones for consumer acceptance and (iii) collect general information about the bread consumption pattern, purchase intention and attributes of composite breads.

MATERIALS AND METHODS

Two consumer studies were carried out in three supermarkets in Maputo, Mozambique. The first was a consumer acceptance test (overall liking) of two composite bread formulations (40% cassava: 10% maize: 50% wheat) with an addition of baking improvers, high methylated pectin (HM pectin) at 3% level and lecithin (LC) at 0.4% level. The two bread formulations selected were based on either roasted cassava flour (40%) – formula 1, in a previous study shown to have similar bread quality characteristics as wheat bread (Eduardo et al., 2013), or a mixture of roasted (20%) and sundried (20%) cassava flour – formula 2, (Table 1). Sundried cassava flour is selected because it is the major form (>80%) of cassava flour that

Name: _____

Zone: ( ) Rural ( ) Urban Date: ____ / _____ / 2010

Age: _____ Sex: (_____)Male (_____) Female

Please evaluate the sample using the scale below to describe how much you liked or disliked the product. Mark the position on the scale that best reflects your trial.

Sample code: _____
( ) Like extremely
( ) Like very much
( ) Like moderately
( ) Like slightly
( ) Neither like nor dislike
( ) Dislike slightly
( ) Dislike moderately
( ) Dislike very much
( ) Dislike extremely

Figure 1. Sensory evaluation form used for the acceptance test.

is consumed in Mozambique (Dias, 2012).

In the second study, consumer acceptance and attitudes were further investigated for an optimized composite bread formulation containing 40% roasted cassava flour in compare-son with a compo-site bread similar to formula 1. The two formulations are based on the results of Eduardo et al. (2014), where quality aspects such as specific volume, texture, colour and moisture content were investigated when dough improvers were used. The formulations selected contained (formula A) carboxymethyl cellulose (CMC) with diacetyl tartaric acid ester of mono-diglycerides (DATEM) and (formula B) HM pectin with LC, which was similar to formula 1 in the first consumer study. Hydrocolloids were added at 3% level and emulsifiers at 0.3% level.

Materials

Commercial flours from common wheat and maize, sugar, salt, dry and compressed yeast (Anchor), baking margarine and vegetable oil were purchased from the Mozambican market. Other ingredients used were ascorbic acid (Hebei Welcome Pharmaceutical Company, China), diacetyl tartaric acid ester of mono-diglycerides (DATEM) (Panodan A2020, DANISCO, Denmark), sunflower lecithin (LC) (Sternchemie, Germany), carboxymethyl cellulose (CMC) (CEKOL® 50000 W, CP Kelco, Denmark) and high-methylated pectin (HM pectin) (GENU® pectin type BIG, CP Kelco, Denmark). Fresh roots of cassava were obtained from local producers in Mozambique and then processed into sundried and roasted cassava flour, respectively, as previously described (Eduardo et al., 2013).

Breadmaking procedure

Bread formulations are shown in Table 1. Other ingredients (based on flour weight) used were 1.5% salt, 2% sugar and 0.1% ascorbic acid. An industrial mixer (Felino, AF10.1, Portugal) was used to mix the ingredients with a simultaneous addition of water until a cohesive dough mass was obtained (~20 min). The resultant dough was left to rest at room temperature for approximately 10 min. The fermented dough was weighed and divided into portions of 200 g each, hand-rounded in "*cacete*" shapes (Figure 5), put on trays and fermented for approximately 60 min. Before baking, a cut was made with a blade in the surface of the rolled pieces of dough to orient dough expansion during the oven spring and to generate final scars on the surface, which are characteristic of this type of bread. The pieces were baked in an annular oven (Teimarmor, CE, Portugal) using wood fuel at a temperature of about 230 - 250°C for 12 min. The loaves were removed from the oven and cooled for 2 h at room temperature. The cooled loaves were packed in polyethylene bags until tested by the consumers on the same day.

Consumer acceptance test

The overall acceptability of two composite breads was evaluated by a consumer panel consisting of 79 Mozambican consumers (36 male and 43 female, aged between 16 and 65 years). The largest group of panel participants (46%) were between 21 and 30 years.

The consumer test describing the subjective quality of bread was a "hedonic" (affective) type of test and was conducted in three supermarkets in Maputo, Mozambique. The bread samples were marked with randomly chosen 3-digit numbers; they were sliced into pieces of uniform thickness and given to the consumers within 3 h after baking. Each consumer received an evaluation form (Figure 1) and one sample at the time to assess their degree of liking (Cordonnier and Delwiche, 2008). The consumers were provided with water at an ambient temperature of approximately 22°C to rinse their mouths before testing and between samples. A 9-point hedonic scale (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) (Peryam and Pilgrim 1957; Lawless and Heymann 1999, 2010) was used for overall liking (Figure 1). The results were obtained by a calculation of the overall mean, and the acceptance index was determined as the acceptance percentage that considered 100% the score of 9. Bread was considered acceptable if the mean value was above 5 (neither like nor dislike).

To determine how well composite bread is liked by consumers, the bread was compared with a commercial wheat bread (100% wheat flour) baked using the same procedure as in the case of the composite breads.

Evaluation of liking and consumption practices

In the second part, the consumer panelists hedonically evaluated sensory attributes of two composite bread types, 40% roasted cassava/HM pectin/LC and 40% roasted cassava/CMC/DATEM, in terms of appearance, texture, smell, flavour, crust and crumb colour, and overall quality. The overall quality was calculated as an average of the attributes evaluated. The sensory analysis was undertaken using 52 consumers (15 females, 37 males, aged 14-55 years). The hedonic evaluation was made for each of the properties using the same method and scale as described in Figure 1. An average response was calculated for each of the properties. Each consumer completed a structured questionnaire (Mcwatters et al., 2004) pertaining to bread consumption pattern, purchase intent and attitudes to composite breads.

Sample size estimation

The sample size of 52 persons was calculated according to Lawless and Heymann (1999, 2010):

$$N = \frac{\left(Z_\alpha + Z_\beta\right)^2 \cdot S^2}{\left(\mu_1 - \mu_2\right)^2} = [(1.96+1.65)^2.1^2]/(0.5)^2 = 52$$

where N = the number of consumers needed in the test; S = the anticipated standard deviation of the scores, 1.0, that was equal to the average standard deviation obtained in the first consumer study with 79 participants; $\mu_1 - \mu_2$ = the difference between means to be significantly detected ($p<0.05$); Z_α = 1.96 with a 95% confidence level; and Z_β = 1.65 with a 90% power of the study.

Instrumental analysis of bread quality attributes

Objective measurements of bread quality attributes were made only on the optimized breads with additives (second study).

Specific bread volume

Each bread loaf (n = 3) was weighed and the loaf volume was measured 8 h after the end of the baking process using the bread volume apparatus (TextVol Instruments BVM-L370, Sweden). The average specific loaf volume was expressed as cm^3/g.

Crumb structure

The bread crumb structure was evaluated from images captured using a flatbed scanner (HP ScanJet G2410, China). Images were scanned full scale at 300 dots per inch.

Crust and crumb colour

The colour analysis of the crust and crumb were evaluated using the Color Reader CR-10 (Minolta, Japan) and considered parameters L*, a* and b*. The L* scale ranges from 0 black to 100 white; the a* scale extends from a negative value (green hue) to a positive value (red hue); and the b* scale ranges from negative blue to positive yellow. The colour reader was calibrated with a white standard. The results were reported according to the brownness index (BI) (Maskan, 2001):

$$BI = \frac{\left[100 \cdot \left(x - 0.31\right)\right]}{0.17} \quad (1)$$

where,

$$x = \frac{a + 1.75L}{5.645L + a - 3.01b} \quad (2)$$

The measurements were carried out in triplicate.

Crumb moisture

The moisture content of bread crumb samples (n=3) was calculated by drying two to three grams of bread samples in an air oven (DigiTronic, Spain) at 105°C until constant weight was obtained (approved method Method 44-40, AACC 1995). Results were expressed on a wet weight basis.

Crumb firmness

The crumb firmness was measured 8 h after baking using an Instron Universal Testing Machine (UTM model 5542, USA). AACC standard method 74-09 was used (AACC, 1995). The measurements were carried out on 25-mm thick loaf slices taken from the centre part of the loaf of bread. Samples were compressed to approximately 10 mm (40% of the slice thickness) at a test speed of 1.7 mm/s. The measurements were carried out on three loaves from each batch, and the compression force (in Newton) was defined as crumb firmness.

Data analysis

Hedonic sensory scores of breads were subjected to analysis of variance (ANOVA) with the SPSS version 11.5 software. Differences between variables were tested for significance by Tukey's HSD multiple comparison range test. *P* values <0.05 were considered significant.

RESULTS AND DISCUSSION

Overall consumer acceptability

The overall acceptability of a food is an important factor that is influenced by the sensory quality of the product together with the consumer´s attitude towards the food (Mela, 2001). In the first part of this study, a consumer panel (n=79) evaluated the overall acceptability of two composite bread formulations containing 40% cassava flour from roasted or a mixture of roasted/sundried cassava with HM pectin and lecithin as baking improvers (Table 2). The bread with roasted/sundried had a score of 7.58, which was not significantly different from the score of 7.85 for the wheat reference bread and slightly higher

Table 2. Overall mean acceptability scores of bread samples evaluated by consumers (n=79).

Bread samples	Cassava (%)	Overall acceptability[1)]	Acceptability Index (%)
Commercial wheat	0	7.85[a]	87.2
Roasted/sundried cassava (20:20)	40	7.58[ab]	84.2
Roasted cassava	40	7.28[b]	80.9

Mean values that are followed by a different letter differ significantly ($p<0.05$). [1)]Hedonic scale (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)

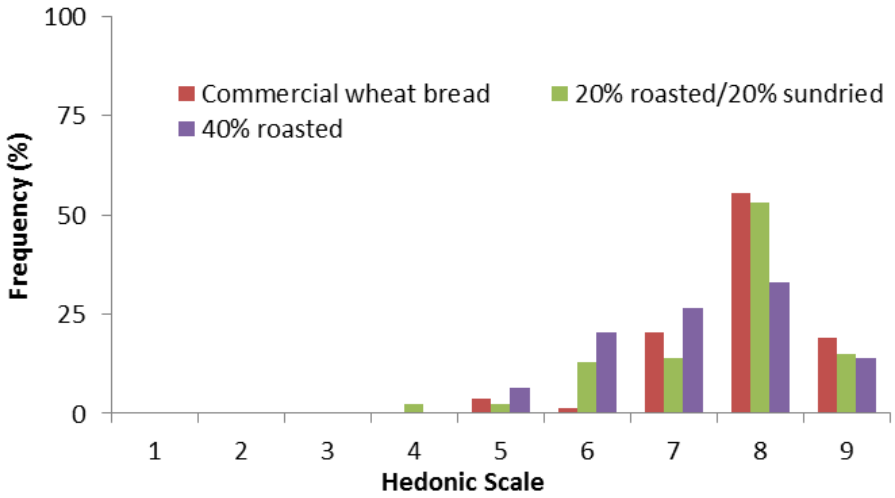

Figure 2. Frequency distribution of responses to overall consumer acceptance test of commercial wheat bread, bread with roasted/sundried cassava and roasted cassava bread.

as compared to that of composite bread with only roasted cassava (7.28). The results thus showed a good acceptability of the composite bread with 40% cassava, which is in agreement with the results reported by Eddy et al. (2007). They reported that bread with 30% cassava had an overall acceptability comparable to the mean score of wheat bread. The results are in contradiction to previous observations reported by Nindjin et al. (2011), however, who observe a decrease in the overall acceptability of composite bread made from wheat and 40% yam starch and wheat and 30% cassava starch. They explain their results by a decrease in taste, crumb appearance and texture. Aboaba and Obakpolor (2010) also reported a lower acceptability of composite bread containing 30 and 40% cassava flour due to size, crust colour, taste and texture. A possible reason for the high acceptability, similar to that of the wheat reference bread, found in the present study could be that improvers such as high-methylated pectin and lecithin were used in the formulation.

The distribution of the consumers' scores on the 9-point hedonic scale is shown in Figure 2. The majority of responses had a score of 8 (corresponding to "liked very much"), 53% for composite bread with roasted/sundried cassava and 33% for composite bread with roasted cassava, which indicates a high acceptance of both composite breads.

The acceptability index (AI), the percentage of scores above 5, was high (>80%) for both composite breads, including the commercial wheat control bread (Table 2), which means that these products are deemed by consumers as satisfactory (Dessimoni-Pinto et al., 2011). In conclusion, the two composite cassava breads with either roasted cassava or a mixture of roasted/sundried cassava flour were ranked similarly and like wheat bread, although there was a slight preference for bread formulated with a mixture of sundried/roasted cassava flour.

Sensory evaluation of quality attributes

The sensorial evaluation of quality attributes was made on the composite bread with 40% roasted cassava including an optimized formulation with respect to improvers (CMC/DATEM). Table 3 shows that the overall quality of the composite bread with CMC/DATEM was given a score of 7.47, significantly higher than HM

Table 3. Mean scores of hedonic sensory attributes and consumer attitudes towards purchasing composite cassava-maize-wheat breads with hydrocolloids and emulsifiers as compared to wheat bread (n=52).

Hedonic scale[1)]	Bread type		
	Commercial wheat	CBA	CBB
Appearance	8.33[a]	7.67[b]	6.80[c]
Texture	7.73[a]	7.40[ab]	6.98[b]
Smell	7.38[a]	7.35[a]	7.24[a]
Flavour	7.35[a]	7.50[a]	7.04[a]
Crust color	8.08[a]	7.38[b]	6.80[b]
Crumb color	8.08[a]	7.50[ab]	7.09[b]
Overall quality	7.82[a]	7.47[a]	7.01[b]
Intention of consumption[2)]	4.23[a]	4.08[a]	3.47[b]

Mean values in the same row followed by a different letter differ significantly ($p < 0.05$). CBA (composite bread with CMC/DATEM); CBB (composite bread with HM-pectin/LC). [1)]Hedonic scale (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). [2)]Scale of attitudes of consumption (5 = consume whenever had the chance, 3 = would consume if it was accessible, but not strive for it; 1 = consume only if forced).

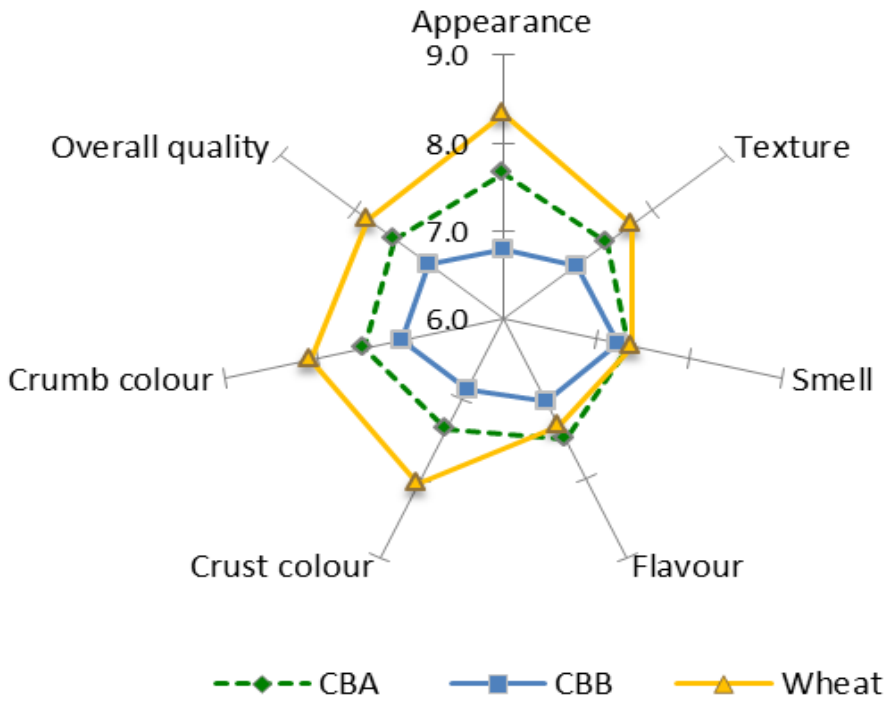

Figure 3. Radar plot of hedonic sensory evaluation of breads made from CBA (CMC/DATEM), CBB (HM pectin/LC) and wheat bread.

pectin/LC bread (7.01) but not significantly different from commercial wheat bread (7.82). The two composite breads may be regarded as highly acceptable products, where their mean scores were >6.8 for all attributes. As compared with wheat bread, the composite bread with CMC/DATEM had lower mean only for the attributes of appearance and crust colour. The mean scores for intention of consumption for the two breads were also similar.

Figure 3 shows the average results of the hedonic sensory evaluation on a radar plot for the composite breads. The attributes of appearance and crust colour

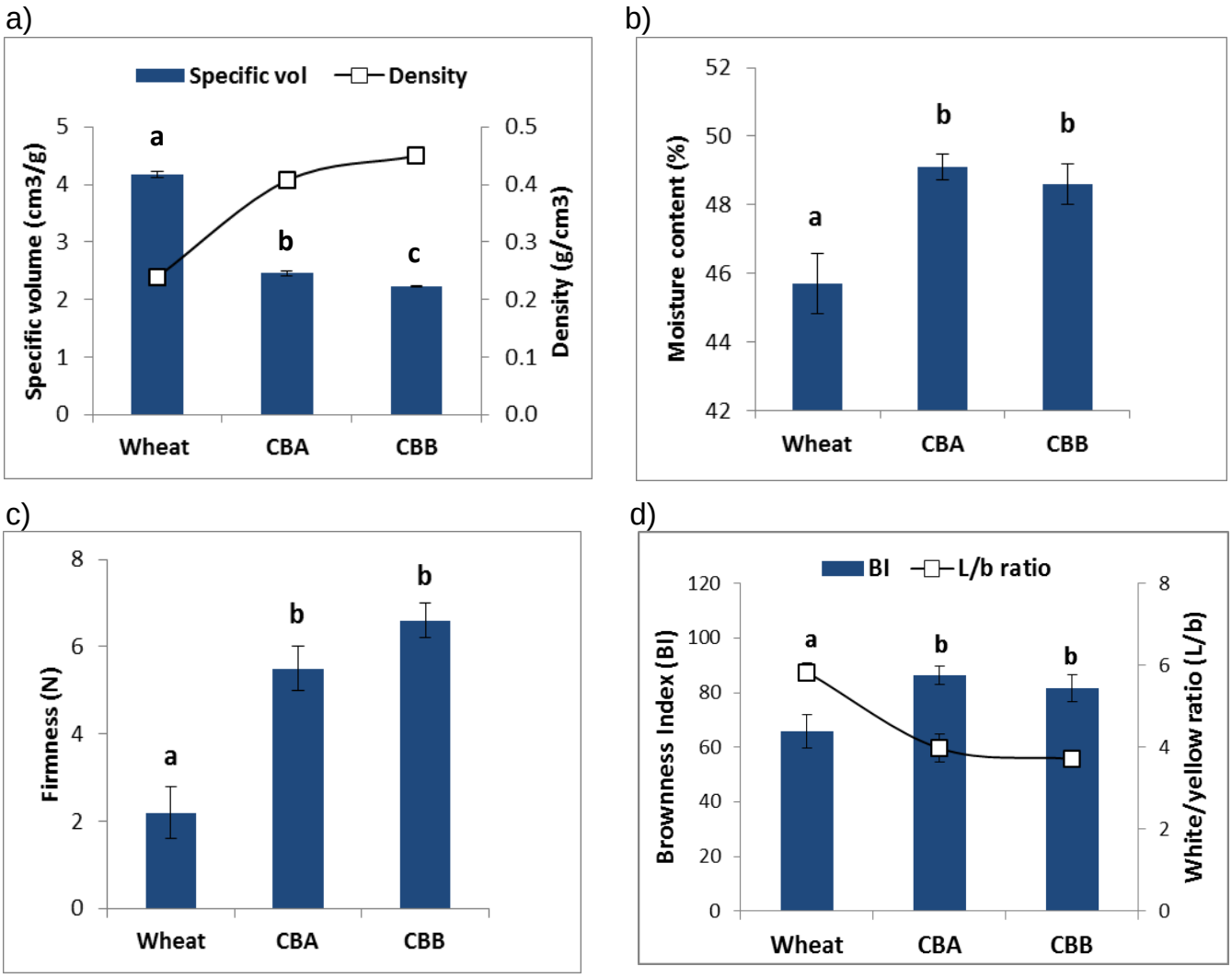

Figure 4. Bread characteristics of CBA (composite bread with CMC/DATEM), CBB (composite bread with HM pectin/LC) and wheat bread: a) specific bread volume b) moisture content c) firmness d) crust brownness index (BI) and crumb colour (L/b ratio). For each quality parameter, values with a different letter are significantly different from each other (p<0.05); n=3.

showed the most significant differences while smell and flavour showed statistically non-significant differences among the three evaluated breads. In general, all attributes for composite bread with CMC/DATEM had higher scores as compared with composite bread with HM pectin/LC, showing that results obtained instrumentally in Eduardo et al. (2014) agree well with the sensorial evaluation, as the results reported in the next section.

Instrumental evaluation of bread properties

Figure 4 (a-d) shows the values for bread specific volume and density, moisture content, firmness and colour of the wheat bread (control) and the composite breads with CMC/DATEM and HM pectin/LC at levels of 3% and 0.3% of hydrocolloids and emulsifiers, respectively.

The specific volume of the composite breads ranged from 2.2 to 2.5 cm^3/g, which was significantly lower than that of the wheat reference bread (4.2 cm^3/g). The lower specific volume of the composite breads can be explained by a lower gluten level as a result of the addition of cassava flour (40%). The gluten fraction is responsible for the elasticity of the dough by causing it to extend and trap the carbon dioxide generated by yeast during fermentation. The percentage of wheat flour required in composite flours to achieve acceptable bread qualities depends largely on the quality and quantity of wheat gluten and the nature of the product involved (Mepba et al., 2007).

The moisture content of the composite breads ranged from 48.6 to 49.1% (Figure 4b), which was significantly

higher than in wheat bread (45.7%) although the same amount of water was added in the preparation of the dough. The difference can be explained by the high water binding capacity of the hydrocolloids (CMC and HM pectin) used in the composite breads (Bárcenas and Rosell, 2005; Sivam et al., 2011), preventing moisture losses during baking.

The texture analysis showed a higher firmness in bread made with HM pectin/LC (6.6 N) when compared with CMC/DATEM (5.5 N) ($p<0.05$), and both values were significantly higher than the firmness of wheat bread (2.2 N).

The brownness index (BI) of the loaf crust was significantly higher ($p<0.05$) in the composite breads, 86.4 in bread with CMC/DATEM and 81.6 in bread with HM pectin/LC, when compared with wheat bread (65.9). These results are in line with the findings of Raidi and Klein (1983), who showed that when the level of non-wheat flour in a dough mixture is higher, the crust colour of the breads changes from creamy white to dull brown or dark. The change in crust colour may be attributed to Maillard reactions, which are influenced by the distribution of water and the reaction of reducing sugars and proteins (Raidi and Klein, 1983; Kent and Evers, 1994). The presence of partly gelatinized starch in the roasted cassava flour may contribute to an increased content of reducing sugars (Tivana et al., 2010). Esteller and Lannes (2008) further observe that, during baking, the amount of water on the dough surface quickly decreases, providing favourable conditions for Maillard reactions and thus resulting in a darker brown colour.

Relationship between the sensory evaluation and instrumental analysis

The relationships between three physical properties of the composite cassava-maize-wheat breads, crumb colour (L/b ratio), brownness index and bread firmness and their sensory counterparts, are shown in Figure 6.

There was a good correlation between the sensorial evaluation and the instrumental analysis results obtained for crumb colour and firmness, as shown by the values of the coefficient of determination (R^2 >0.8). However, a lower correlation was observed for sensorially perceived and the instrumentally measured crust colour (R^2=0.64), which is probably due to the fact that the bread crust had a central area with a more light colour while analytical measurements were done on the darker crust (Figure 5). The bread firmness was inversely correlated to the bread texture score, that is, the consumers prefer bread with a softer texture. In the case of bread crumbs, the consumers seemed to prefer bread with a lighter colour, that is, bread with a higher white-to-yellow ratio.

General information of bread consumption pattern and purchase intention

It was found in the general consumer survey that 25% of the respondents (n=52) spent less than 0.33 USD/week, 35% between 0.33 and 0.67, 19% between 0.67 and 1.34, 12% between 1.34 and 1.67, and only 10% more than 1.67 USD/week in the purchase of wheat bread, which corresponds to 1, 2-4, 4-8, 8-9 and more than 10 loaves of 200 g/week, respectively.

The results showed that most respondents buy bread more than 3 times a week (about 83%) while about 17% purchase between 1 and 3 times a week (Table 4).

Concerning the bread consumption pattern (Table 5), it was found that 33% of the respondents consume bread 5-7 times a week while 21% ate bread more than once a day. Most of the consumers, 54%, do not keep bread before eating it but 46% keep bread between 1 and 3 days before consumption. Over 60% of the respondents use appearance as a criterion to decide whether the bread is no longer edible, followed by texture (15%), length of storage (14%) and odour (only 6%). A majority of the respondents (92%) purchase their bread for consumption.

Respondents revealed their attitudes to composite breads, (Table 6). About 94% of the respondents would accept composite bread, and 92% showed interest in buying bread made with two or more flours but were not ready to buy a mixture of two or more flours to produce bread (85%).

In general, composite bread was viewed as more nutritious (50%) and as providing variety (29%), and a few respondents (15%) referred to it as an inexpensive product.

Conclusions

In the present consumer study, we found that the use of cassava flour in breadmaking is feasible and that incorporation of 40% roasted cassava in composite flour mixtures in combination with baking improvers produced highly acceptable breads in all sensory attributes including overall quality on a 9-point hedonic scale. Composite cassava bread with 20% sundried and 20% roasted cassava flour had an overall acceptability similar to commercial wheat bread.

The general information on the bread consumption pattern indicated a high acceptability and willingness to purchase composite cassava bread.

These results suggest that cassava and maize, the two major food crops produced in Mozambique, could be commercialized to be used in bread making and thus contribute to a reduced import of wheat flour.

ACKNOWLEDGEMENT

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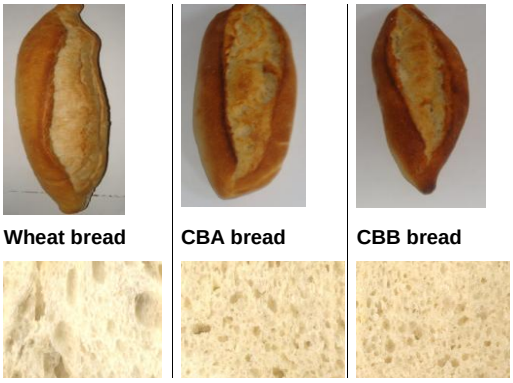

Figure 5. Photographs of composite cassava-maize-wheat breads baked with CMC/DATEM (CBA) and HM pectin/LC (CBB).

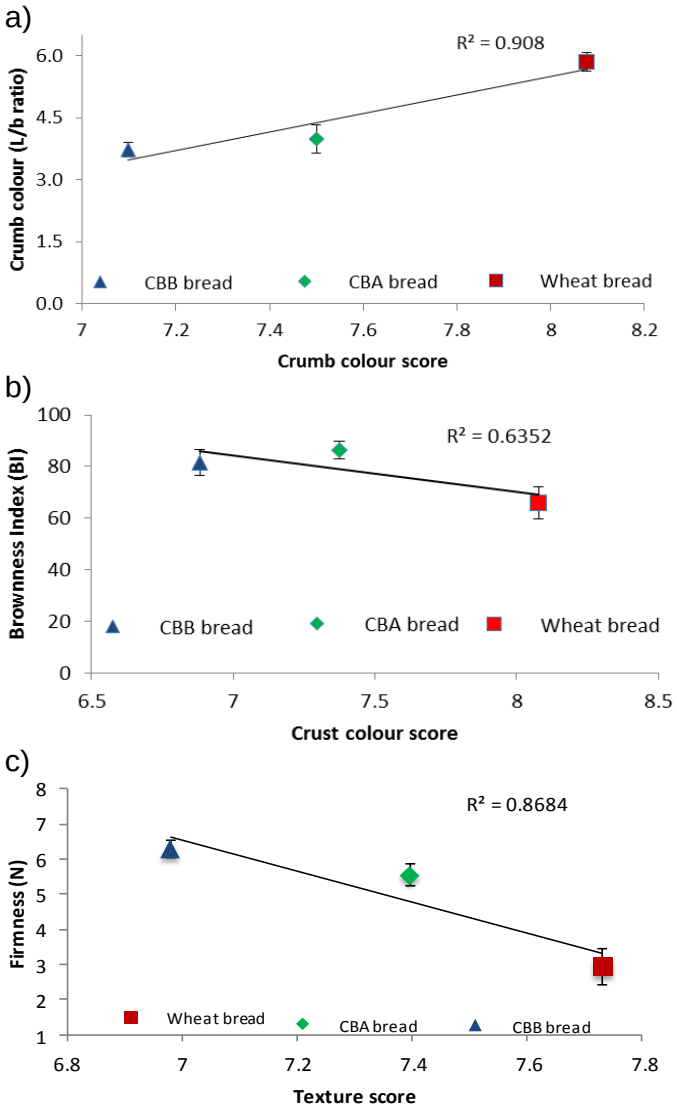

Figure 6. Relationship between the instrumental analysis and sensorial evaluation of bread properties. Wheat bread, CBA (composite bread with CMC/DATEM) and CBB (composite bread with HM pectin/LC).

Table 4. Wheat bread purchase pattern.

Parameter	Frequency	Percentage
How much do you normally pay for the bread (a loaf of bread of 200 g):		
Less than USD 0.33	13	25.0
USD 0.33-0.67	18	34.6
USD 0.67-1.34	10	19.2
USD 1.34-1.67	6	11.5
Greater than USD 1.67	5	9.6
How often do you buy bread:		
Less than once a week	0	0.0
Once a week	3	5.8
Twice a week	3	5.8
Three times a week	3	5.8
More than three times a week	43	82.7

1USD=29.91 MT (source: Banco de Moçambique, 17th of February 2013).

Table 5. Pattern of consumption of wheat bread among the study population.

Parameter	Frequency	Percentage
Bread consumption:		
Once a day	12	23.1
More than once a day	11	21.2
1-2 times a week	4	7.7
3-4 times a week	8	15.4
5-7 times a week	17	32.7
Bake bread at home:		
Yes	4	7.7
No	48	92.3
Keeping before eating:		
Yes	24	46.2
No	28	53.8
Where:		
Not keep	28	53.8
Plastic bag	23	44.2
Fridge	1	1.9
How long (day):		
0	28	53.8
1	20	38.5
2	3	5.8
3	1	1.9
more than 3	0	0.0
How do you decide when your bread is no longer edible:		
Appearance (mould, colour)	34	65.4
Texture (too hard)	8	15.4
Length of storage	7	13.5
Odour	3	5.8

Table 6. Consumer attitudes to composite cassava bread.

Parameter	Frequency	Percentage
Acceptance of composite bread:		
Accepted	49	94.2
Rejected	3	5.8
Why it is accepted:		
More nutritious	26	50.0
Provides variety	15	28.8
Pay less	8	15.4
Why it is rejected:		
Not good enough	1	1.9
Less nutritious	1	1.9
Pay more	1	1.9
Would you buy a mixture of flours:		
Yes	8	15.4
No	44	84.6
Purchase bread made of a mixture of two or more flours:		
Yes	48	92.3
No	4	7.7
Which other products do you prefer to bread:		
Rice	11	21.2
Potatoes	14	26.9
Cassava and rale	15	28.8
Maize flour	5	9.6
Cake	7	13.5

Conflict of Interest

The author(s) have not declared any conflict of interests.

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Full Length Research Paper

Physicochemical and bioactive properties of selected white yam (*Dioscorea rotundata*) varieties adapted to riverine areas of Nigeria

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Yam (*Dioscorea spp.*) is a major food of cultural, economic and nutritional importance in Nigeria and throughout West Africa. In this sub-region, white yam (*Dioscorea rotundata*) is the most dominant and important species. This study is aimed at characterizing high yielding yam varieties of this species adapted to riverine areas and forest zones of Nigeria for physical and chemical characteristics. Eleven yam varieties collected from local farmers in the South-southern part of Nigeria were evaluated for their physicochemical characteristics, bioactive compounds (vitamin C, phytic acid and tannin), functional and pasting properties. Results indicated that there were significant varietal differences (P<0.05) among the parameters evaluated. The moisture contents of the investigated varieties ranged from 59.5 to 68.8%, ash content ranged from 1.39 to 2.93%, protein content from 1.96 to 4.90%, fat content from 0.356 to 3.39%, total free sugars from 1.05 to 7.02% and total starch from 33.9 to 75.7%. The bioactive content results show that vitamin C content ranged from 5.64 mg/100 g to 6.99 mg/100 g, phytate from 1.12 to 2.37% and tannin from 0.359 to 1.18 mg/g. The pasting properties results show that peak viscosity ranged from 215 to 470 RVU, trough viscosity from 198 to 385 RVU, breakdown viscosity from 8.71 to 84.5 RVU, final viscosity from 278 to 571 RVU, setback viscosity from 66.2 to 204 RVU; peak time ranged from 4.97 to 7.0 min and the pasting temperature from 61.7 to 62.6°C. This study shows that the physical and chemical characteristics of these high yield yam varieties were similar to those reported for most yam varieties in other parts of Nigeria and has a great potential as source of bioactive compounds and protein.

Key words: Yam, *Dioscorea rotundata,* riverine areas, varieties.

INTRODUCTION

Globally, yam is grown in many tropical regions but the main production centre is the savannah region of West Africa, where more than 90% of the crop is grown (Sanusi and Salimonu, 2006; IITA, 2009), with Nigeria

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being the main producer followed by Ghana and Cote d'Ivoire (FAO, 2008). Nigeria produces 60% of the world's yam, annually producing an average of 31 million metric tons (Bergh et al., 2012), although Food and Agriculture Organisation (FAO) estimates showed the annual production to be above 37 million metric tons (FAOSTAT, 2013).

Yam (*Dioscorea* spp.) are widely grown in West Africa (Coursey and Haynes, 1970; Waitt, 1963), they are an important source of carbohydrate for many people of the sub-Sahara region, especially in the yam zone of West Africa. In Nigeria, yam has had the second highest production level of any food crop after cassava (Bergh et al., 2012). According to Food and Agriculture Organisation (FAO) estimates, there has been steady rise of 12.6% in domestic consumption of yam between 1990 and 2009 (FAOSTAT, 2013). In addition to the food and market values of yams, they play a major role in socio-cultural life of smallholder households, such as the celebrated New Yam Festival and also the presentation of yams as gifts during marriage ceremonies (Opara, 2003; IITA, 2009).

Yams are grown in the coastal region in rain forests, wood savanna and southern savanna habitats. Common species of yam include *Dioscorea rotundata* (White yam), *Dioscorea cayenensis* (Yellow yam), *Dioscorea alata* (Water yam), *Dioscorea bulbifera* (Potato yam), *Dioscorea dumentorum* (Bitter yam), *Dioscorea esculenta* (Lesser yam), *Dioscorea opposita* (Chinese yam) and *Dioscorea trifida* (Cush-cush yam) (Opara, 1999). However, *D. rotundata* is the most important species particularly in the dominant yam production zone in West and Central Africa (IITA, 2009). Yam is composed mainly of starch (75-84% of the dry weight) with small amounts of proteins, lipids and most vitamins and is very rich in minerals (Lasztity et al., 1998), and low in sodium and saturated fat content (Bergh et al., 2012). Yam's richness in carbohydrate especially starch consequently has a multiplicity of end use. Yam, sweet in flavour, is consumed as boiled yam (as cooked vegetable) or fufu or fried in oil and then consumed. It is often pounded into a thick paste after boiling and is consumed with soup. It is also processed into flour for use in the preparation of the paste. Its use as an industrial starch has also been established as the quality of some of the species is able to provide as much starch as in cereals (Izekor and Olumese, 2010).

The average crude protein content of seven yam cultivars was 7.4%, which was higher than those reported for other tropical roots, and the protein from yam also showed a better amino acid balance for human nutrition (Baquar and Oke, 1976; Bradbury, 1988; Marcus et al., 1998). Modern researches have shown that yam extracts can reduce blood sugar (Hikino et al., 1986; Undie and Akubue, 1986) and blood lipid (Araghiniknam et al., 1996), inhibit microbe activity (Hu et al., 1996, 1999; Kelmanson et al., 2000) and show antioxidative activity (Farombi et al., 2000). Yams also have pharmaceutical usage as they contain a steroid sapogenin compound called diosgenin, which can be extracted and used as base for drugs such as cortisone and hormonal drugs (Opara, 2003). There is little information in the literature on the physical and chemical properties of the high yield yams from riverine areas of Nigeria. The main objective of this study was to characterize the high yielding yam varieties (*D. rotundata*) adapted to riverine areas and forest zones of Nigeria for physical and chemical characteristics.

MATERIALS AND METHODS

Yam tubers and sample preparation

Fresh eleven (11) white yam varieties (*D. rotundata)* designated as high yielding were collected from local farmers in the South-Southern part of Nigeria. The yam samples were thoroughly washed, peeled, oven dried at 60°C. All the dried samples were milled to 0.50 mm sieve size with Perten Laboratory Hammer Mill 3102 for further laboratory analysis.

Moisture content determination

Five grams of sample was weighed into known weight of Petri-dish. The weighed sample was put into the pre-set oven (Fisher Scientific Isotemp^{R} Oven model 655F) at 110°C for 3 h. The sample was removed and cooled in a dessicator to room temperature and the weight was noted after which it was returned into the oven at temperature of 110°C for 30 min until constant weight was obtained: AOAC (2004).

Ash content determination

Five grams of sample was weighed into a previously ignited and cooled silica dish. The dish was ignited first gentle and then at 600°C for 3 h in a muffle furnace (VULCAN^{TM} furnace model 3-1750). The dish and its content were cooled in a dessicator and the remaining residue due to the ash was reweighed.

Crude fat determination

Crude fat was determined by the method of AOAC (2004). This was determined using a Soxtec System HT2 fat extractor. Crude fat was extracted from the sample with hexane, and the solvent evaporated off to get the fat. The difference between the initial and final weight of the extraction cup was recorded as the crude fat content.

Crude protein determination

Crude protein was determined by Kjeldahl method using Kjeltec^{TM} model 2300, as described in Foss Analytical manual, AB, (2003). The method involved digestion of the sample at 420°C for 1 h to liberate the organically bound nitrogen in the form of ammonium sulphate. The ammonia in the digest ammonium sulphate was then distilled off into a boric acid receiver solution, and then titrated with standard hydrochloric acid. A conversion factor of 6.25 was used to

convert from total nitrogen to percentage crude protein (AOAC, 2004).

Pasting properties determination

Pasting properties (peak viscosity, trough viscosity, breakdown viscosity, setback viscosity, peak time and pasting temperature) were determined with a Rapid Visco Analyzer (RVA) (Newport Scientific RVA Super 3) equipped with software. 3.0 g of each sample was weighed in a vessel and 25 ml of distilled water was dispensed into a new test canister. Sample was then transferred into the water surface in the canister.

The paddle was placed into the canister and the blade vigorously jogged through the sample up and down ten times. The canister was then inserted into RVA machine. The measurement cycle (12 min) was initiated by pressing the canister inside the instrument. The temperature- time lag in the RVA was as follows: started at a temperature of 50°C for 1 min, heated from 50 to 95°C in 3 min and subsequently cooled to 50°C over a 4 min period. It was followed by a period of 1 min where the temperature was kept constant at 50°C.

Determination of swelling power and solubility

This was determined by the Leach et al., (1959) method. It involved weighing 1g of milled sample into 100ml conical flask, 15ml of distilled water was added and mixed gently at low speed for 5minutes. The slurry was heated in a thermostated water bath (Thelco model 83, USA) at 80°C for 40 min. During heating, the slurry was stirred gently to prevent dumping of the starch. The content was transferred into a pre weighed centrifuge tube and 7.5 ml distilled water was added.

The tubes containing the paste were centrifuged at 2,200 rpm for 20 min using Sorvall glc-1 table top centrifuge (model 06470, USA). The supernatant was decanted immediately after centrifuging into a preweighed can and dried at 100oC to constant weight. The weight of the sediment and weight of soluble were taken and recorded.

Determination of water binding capacity

This was determined using the method described by Medicalf and Gilles (1965). 2.5 g of each sample was weighed in a tared % 50 ml centrifuge tube and 37.5 ml of distilled water was added. The tube was capped and agitated on a wrist action shaker for 1 h. Centrifuged for 10 mins at 2.200g or approximately 7,500 rpm and decanted the water. The centrifuge tube with content was weighed and and the amount of water bound was calculated.

Determination of tannin (polyphenols)

Tannin content was determined by the Folin-Dennis colorimetric method described by Joslyn (1970) with modifications. 5 g sample was dispersed in 50 ml of distilled water and shaken. The mixture was allowed to stand for 30 min at 28°C before it was filtered through what man No 42 grade of filter paper. 2 ml of the extract was dispensed into a 50 ml volumetric flask. Similarly, 2 ml standard tannin solution (tannin acid) and 2 ml of distilled water were put in separate volumetric flasks to serve as standard and Folin reagent was added to each of the flask and the 2.5 ml of saturated Na_2CO_3 solution added. The content of each flask was made up to 50 ml with distilled water and allowed to incubate at 28°C for 90 min. Their respective absorbance was measured in a spectrophotometer at 260 nm using the reagent blank to calibrate the instrument at zero.

Determination of Phytic acid content

Phytate was determined by a combination of two methods. The extraction and precipitation of phytic acid was done according to the method of Wheeler and Ferrel (1971). Extraction was done by mechanical shaking of the mixture for 30min and then centrifugation for 15 mins at 3,500 rpm. A 10 ml aliquot of the supernatant was transferred into a 40 ml conical centrifuge tube. 4 ml Ferric chloride solution was added by blowing rapidly from the pipette. The tube and its contents were heated in a boiling water bath for 45 min. The suspension was centrifuged at 3500 rpm for 15mins and the supernatant carefully decanted.

The precipitate was washed twice by dispersing well in 25 ml of 3% TCA, heating in boiling water bath 5min and centrifuging. The volume was made up to 30 ml with distilled water and the mixture heated in boiling water bath for 30 min. The suspension was filtered hot, and precipitate washed with 60ml hot water. The filtrate was discarded and the precipitate from the paper was dissolved with 40ml hot 3.2 M HNO_3 into 100ml volumetric flask.

A 5 ml aliquot was transferred to another 100ml volumetric flask and diluted to 70 ml. 20 ml 1.5 M KSCN was added and volume made to 100ml. Absorbance was read (within 1 min) at 480nm. Iron in the precipitate was then measured according to the method of Makover (1970). A 4:6 Fe/P atomic ratio was used to calculate the phytic acid content.

Determination of apparent amylose content

The apparent amylose was determined by the method of Williams et al. (1985). Starch (500 mg) was defatted by standard AOAC (2004) method using hexane. The defatted starch (100 mg) was dispersed in ethanol (1 ml) and 1 M NaOH (9 ml). The volume was made up to 100 ml with distilled water and a 5 ml aliquot transferred to a volumetric flask containing water, 25 ml. 1 M acetic acid (0.5 ml) and 1 ml iodine solution (0.2% iodine in 2% potassium iodide) were added and the volume made up to 50 ml with water and absorbance recorded at 620 nm.

Starch and sugar contents

The starch and total sugars content were determined using a colorimetric method described earlier by Onitilo et al. (2007). This involves weighing 0.02 g of the sample into a centrifuge tube with 1 ml ethanol, 2 ml distilled water, and 10 ml hot ethanol. The mixture was vortexed and centrifuged at 2000 rpm for 10 min. The supernatant was decanted and used for determining sugar content while the sediment was hydrolyzed with perchloric acid and used to estimate starch content.

Phenol- sulfuric reagent was used for colour development and glucose standards were used for estimation of sugar. The absorbance was read with a spectrophotometer (Milton Roy Spectronic 601, USA) at 490 nm.

Stastical analysis

Data were subjected to analysis of variance (ANOVA) using SAS version 8e (SAS 2001) software at $P<0.05$.The least significance difference (LSD) test was used for mean comparison.

Table 1. Proximate composition (dry weight basis) of selected white yam varieties.

Variety	Moisture (fresh) (%)[a]	Dry matter (%)	Ash (%)	Protein (%)	Fat (%)	Sugar (%)
Ndoni Aggah	62.1±0.117^{e}	37.9±0.117^{b}	2.36±0.033^{b}	2.42±0.134^{e}	0.562±0.224^{fgh}	1.72±0.211^{f}
Oyonku	59.5±0.080^{f}	40.5±0.080^{a}	1.72±0.046^{ef}	3.37±0.037^{b}	2.53±0.157^{b}	3.63±0.011^{d}
Legbaka Gambari	62.7±0.456^{d}	37.3±0.456^{c}	1.68±0.006^{f}	4.90±0.183^{a}	0.454±0.023^{gh}	1.05±0.121^{g}
Ndoni Ekpe	62.0±0.263^{e}	38.0±0.263^{b}	1.95±0.019^{d}	2.54±0.047^{e}	0.356±0.011^{h}	2.15±0.111^{e}
Asoko	65.7±0.012^{b}	34.3±0.012^{e}	1.52±0.031^{g}	2.36±0.235^{e}	1.27±0.151^{c}	6.28±0.193^{b}
Legbaka Awana	63.7±0.059^{c}	36.3±0.059^{d}	2.13±0.081^{c}	3.22±0.169^{cc}	0.904±0.090^{de}	7.02±0.012^{a}
Ndoni Abi	62.1±0.242^{e}	37.9±0.242^{b}	2.93±0.106^{a}	3.18±0.103^{bc}	3.39±0.124^{a}	2.34±0.219^{e}
He - Abalo	63.0±0.111^{d}	37.0±0.111^{c}	2.18±0.063^{c}	1.96±0.058^{f}	0.673±0.034^{efg}	1.61±0.056^{f}
Alomako	68.8±0.042^{a}	31.2±0.042^{f}	2.08±0.037^{c}	2.43±0.109^{e}	0.992±0.007^{d}	2.34±0.065^{e}
Omin	68.7±0.168^{a}	31.3±0.168^{f}	1.83±0.047^{e}	2.68±0.245d^{e}	0.724+0.112^{ef}	5.24±0.023^{c}
Asukwu	62.2±0.068^{e}	37.8±0.068^{b}	1.39±0.008^{h}	2.96±0.203^{cd}	1.39±0.069^{c}	3.60±0.159^{d}
Means	63.7	36.3	1.98	2.91	1.20	3.36
SD	2.91	2.91	0.433	0.788	0.944	2.01
Min	59.5	31.2	1.39	1.96	0.356	1.05
Max	68.8	40.5	2.93	4.90	3.39	7.02
CV (%)	0.281	0.493	2.78	5.43	8.89	4.09
LSD(0.05)	0.399	0.399	0.122	0.352	0.238	0.307
Pr >F (entry)	***[b]	***	***	***	***	***

[a]Parameters mean value ±SD; [b]***, **, *- Significant at P<=0.001, P<=0.01 and P<=0.05, respectively; ns -not significant, P>0.05. Means with the same letter are not significantly different.

RESULTS AND DISCUSSIONS

The results of one way analysis of variance (ANOVA) showed that there were significant varietal differences (P<0.05) among the parameters evaluated. The proximate composition results show that the moisture content of the investigated varieties ranged from 59.5 to 68.8%, ash content ranged from 1.39 to 2.93%, protein content from 1.96 to 4.90%, fat content from 0.356 to 3.39%, free total sugars from 1.05 to 7.02% and total starch from 33.9 to 75.7% (Tables 1 and 2). The bioactive content results showed that vitamin C content ranged from 5.64 mg/100 g to 6.99 mg/100 g, phytate from 1.12 to 2.37%, and tannin from 0.359 mg/g to 1.8 mg/g (Table 3). The functional properties show that the swelling power ranged from 6.66 to 9.68, solubility ranged from 4.72 to 10.0% and water binding capacity ranged from 108 to 144% (Table 4). The pasting properties results show that peak viscosity ranged from 215 to 470 RVU, trough viscosity from 198 to 385 RVU, breakdown viscosity from 8.71 to 84.5 RVU, final viscosity from 278 to 571 RVU, setback viscosity from 66.2 to 204 RVU; peak time ranged from 4.97 to 7.0 min and the pasting temperature from 61.7 to 62.6°C (Table 5). The solubility index and water binding capacity ranged from 4.72 to 10.0% and observed among the water binding capacities of starches from the selected white yam varieties. The chemical composition of yam is characterized by a high moisture content and dry matter which is composed mainly of carbohydrate, vitamins as well as protein and minerals (Osunde, 2008; Ezeocha and Ojimelukwe, 2012). The total starch differed significantly among the different white yam varieties, ranging between 33.9 and 75.7%. *Alomako* variety had the lowest starch content. Decrease in amylose content was observed as amylopectin content increased, this is an indicator that one is a function of the other; however both properties are important in food preparation and development (Eke-Ejiofor and Owuno, 2012).

The amylopectin content of the different white yam varieties was between the range of 61.9 and 75.7%, *Asoko* variety had the highest amylopectin content while *Asukwu* had the lowest value. The amylose content was lower than the amylopectin content in the selected white yam varieties as it was also observed in *Ozibo*, another variety of *D. rotundata* (Okorie et al., 2011). Mali et al. (2004) observed that starch from yam had more amylose content than starches from corn and cassava. Moisture content in the selected varieties was high when compared with those reported in the literature and this might due to the environmental factor. Yam varieties with low moisture content are suitable for high yield flour production (Polycarp et al., 2012). *Oyonku* variety had the lowest moisture contentand therefore may be more suitable for flour production.

The protein values for the selected white yam varieties were significant and higher than the value reported for *D. rotundata* and *Colocasia esculenta,* majority of the selected white yam varieties also had lower fat contents as compared to that of cocoyam (Alinnor and Akalezi,

Table 2. Proximate composition (dry weight basis) of selected white yam varieties.

Variety	Starch (%)[a]	DCHO (%)[b]	TCHO (%)[c]	Amylose (%)	Amylopectin (%)	TME (KJ)[d]
Ndoni Aggah	58.2±0.442[e]	60.0±0.653[ef]	32.6±0.208[ab]	25.3±0.121[f]	74.7±0.121[a]	605±7.16[d]
Oyonku	58.1±2.43[e]	61.8±2.42[df]	32.9±0.159[a]	27.3±0.174[e]	72.7±0.174[b]	701±3.82[a]
Legbaka Gambari	62.6±0.815[d]	63.6±0.936[d]	30.3±0.610[c]	28.3±0.108[de]	71.7±0.108[bc]	605±7.98[d]
Ndoni Ekpe	57.4±0.669[e]	59.5±0.781[f]	33.2±0.186[a]	33.4±0.109[b]	66.6±0.109[e]	609±4.31[d]
Asoko	71.6±0.783[b]	77.8±0.975[b]	29.1±0.366[d]	24.3±0.142[f]	75.7±0.142[a]	573±3.44[f]
Legbaka Awana	75.7±0.333[a]	82.7±0.345[a]	30.1±0.062[c]	27.7±0.078[e]	72.3±0.078[b]	590±0.482[e]
Ndoni Abi	68.9±0.021[c]	71.3±0.198[c]	28.4±0.575[e]	24.4±0.190[f]	75.6±0.190[a]	654±3.26[b]
He - Abalo	49.8±0.657[f]	51.4±0.714[g]	32.2±0.266[b]	30.0±0.200[cd]	70.0±0.200[cd]	595±2.21[f]
Alomako	33.9±0.023[i]	36.2±0.088[i]	25.7±0.108[f]	33.1±1.94[b]	66.9±1.94[e]	507±0.236[g]
Omin	39.7±0.851[h]	44.9±0.874[h]	26.0±0.082[f]	30.3±1.07[c]	69.7±1.07[d]	507±1.28[g]
Asukwu	47.3±0.573[g]	50.9±0.732[g]	32.0±0.058[b]	38.1±2.14[a]	61.9±2.14[f]	637±0.157[c]
Means	56.7	60.0	30.2	29.3	70.7	598
SD	13.1	13.9	2.66	4.26	4.26	57.2
Min	33.9	36.2	25.7	24.3	61.9	507
Max	75.7	82.7	33.2	38.1	75.7	701
CV (%)	1.55	1.58	1.06	2.92	1.21	0.547
LSD(0.05)	1.96	2.11	0.717	1.90	1.90	7.29
Pr >F(Entry)	***[e]	***	***	***	***	***

[a]Parameters mean value ±SD; [b]DCHO = Digestible carbohydrate; [c]TCHO = Total carbohydrate[d]; TME = total metabolisable energy, KJ = Kilojoules; [e]***, **, * -Significant at P<=0.001, P<=0.01 and P<=0.05, respectively. ns- not significant P>0.05. Means with the same letter are not significantly different.

Table 3. Bioactive contents (dry weight basis) of selected white yam varieties.

Variety	[a]Vitamin C (mg/100 g)	Phytate (mg/g)	Tannin (mg/g)
Ndoni Aggah	6.35 ± 0.145[d]	2.37 ± 0.04[a]	0.64 ± 0.017[ef]
Oyonku	6.04 ± 0.082[e]	1.73 ± 0.044[e]	0.68 ± 0.017[d]
Legbaka Gambari	5.64 ± 0.071[f]	1.12 ± 0.025[h]	1.18 ± 0.019[a]
Ndoni Ekpe	6.67 ± 0.076[c]	2.29 ± 0.024[ab]	0.74 ± 0.018[c]
Asoko	6.99 ± 0.016[a]	1.55 ± 0.021[f]	0.89 ± 0.010[b]
Legbaka Awana	6.83 ± 0.004[abc]	1.40 ± 0.052[g]	0.67 ± 0.000[ed]
Ndoni Abi	6.73 ± 0.097[bc]	1.75 ± 0.023[e]	0.69 ± 0.001[d]
He - Abalo	6.17 ± 0.068[ed]	1.47 ± 0.053[gf]	0.69 ± 0.008[d]
Alomako	6.88 ± 0.064[ab]	2.16 ± 0.047[c]	0.36 ± 0.019[g]
Omin	6.96 ± 0.071[a]	1.91 ± 0.047[d]	0.62 ± 0.027[f]
Asukwu	6.12 ± 0.069[e]	2.24 ± 0.025[bc]	0.64 ± 0.026[ef]
Means	6.49	1.82	0.708
SD	0.448	0.412	0.200
Min	5.64	1.12	0.359
Max	6.99	2.37	1.18
CV (%)	1.26	2.22	2.45
LSD(0.05)	0.182	0.090	0.039
Pr > F Entry)	***[b]	***	***

[a]Parameters mean value ±SD; [b]***, **, * -Significant at P<=0.001, P<=0.01 and P<=0.05 respectively; ns- Not significant at P>0.05. Means with the same letter are not significantly different.

2010). *Legbaka Gambari* variety had the highest protein content, while *Legbaka awana* variety had the highest sugar content. It was reported that yamsgenerally have considerably higher protein content than the 1.2-1.8% on

Table 4. Functional properties of flour from selected white yam varieties.

Variety	Swelling power[a]	Solubility (%)	Water binding capacity (WBC) (%)
Ndoni Aggah	8.69 ± 0.094^{a}	7.85 ± 0.016^{bh}	126 ± 0.812^{abcd}
Oyonku	8.21 ± 0.158^{cd}	6.67 ± 3.15^{bc}	116 ± 0.132^{cd}
Legbaka Gambari	7.07 ± 0.016^{e}	4.72 ± 0.150^{c}	133 ± 0.779^{bcd}
Ndoni Ekpe	7.04 ± 0.128^{e}	6.48 ± 0.117^{bc}	124 ± 0.258^{abc}
Asoko	7.94 ± 0.192^{d}	7.94 ± 0.176^{ba}	132 ± 1.01^{abc}
Legbaka Awana	7.71 ± 0.203^{d}	10.0 ± 1.68^{a}	133 ± 0.341^{a}
Ndoni Abi	8.80 ± 0.531^{b}	7.88 ± 0.184^{ba}	144 ± 0.053^{abc}
He - Abalo	6.66 ± 0.557^{e}	4.84 ± 2.01^{c}	134 ± 0.208^{abc}
Alomako	9.04 ± 0.029^{b}	4.73 ± 0.011^{c}	108 ± 27.6^{d}
Omin	9.68 ± 0.037^{a}	6.47 ± 0.689^{bc}	143 ± 1.39^{ab}
Asukwu	8.09 ± 0.258^{d}	7.52 ± 0.327^{abc}	130 ± 2.28^{abc}
Means	8.09	6.83	129
SD	0.930	1.65	10.5
Min	6.66	4.72	108
Max	9.68	10.0	144
CV (%)	3.23	18.7	6.39
LSD(0.05)	0.582	2.85	18.4
Pr > F(Entry)	***[b]	*	*

[a]Parameters mean value ±SD; [b]***, **, * - Significant at P<=0.001, P<=0.01 and P<=0.05 respectively; ns- not significant at P>0.05; Means with the same letter are not significantly different.

dry weight basis as reported by Charles et al. (2005) for cassava. The protein contents observed in the selected varieties of white yam were however lower than reported value of 10.27% for *D. alata*. *He-Abalo* had the lowest protein value. The vitamin C contents of the varieties fall within the range of 4.00 - 18.00 mg for edible yam species (Osagie, 1992) and between 6.5 and 11 mg/100g as observed by Coursey and Aidoo (1966). *Asoko* variety had the highest vitamin C content. However, different cooking techniques may affect the retention of vitamin C in yams.

The ash contents observed in the selected white yam varieties were lower than those obtained from other *Dioscorea* spp. reported by Shanthakumari et al. (2008)

Peak viscosity indicates the water binding capacity of the starch or mixture occurs at the equilibrium point between swelling causing an increase in viscosity rupture and alignment causing its decrease (Adegunwa et al., 2011). It is also indicative of the strength of the pastes which are formed from gelatinization during processing in food applications (Eke-Ejiofor and Owuno, 2012). There was no significant difference between the pasting temperatures of the selected white yam varieties. Similar ranges were also observed by Adegunwa et al. (2011). Flours from all the selected *D. rotundata* varieties had peak viscosity higher than flour from *D. alata,* but only a few were higher than that of cassava flour (Babajide and Olowe, 2013). Swelling power, as described by Richard et al. (1991) is a factor of the ratio of amylose toamylopectin, *Omin* variety had the highest swelling power while *He-Abalo* variety had the lowest. *Asukwu* variety had the highest, peak, trough, breakdown and final viscosity values, while *Legbaka Gambari* variety had the highest setback viscosity value. The pasting temperature is the temperature at which the viscosity starts to rise (Liang and King, 2003), thus, the lower the pasting temperature, the faster the swelling. Flours from the selected *Dioscorea rotundata* varieties had higher pasting temperature than *D. dumetorum* flour and wheat flour (Eke-Ejiofor and Owuno, 2012).

The water binding capacity varied significantly among the different varieties studied (P<0.05). Tannins are water-soluble polyphenols that are present in many plant foods (Chung et al., 1998). These phenolic compounds usually interfere with iron absorption through a complex formation with iron in the gastrointestinal tract, decreasing the bioavailability of iron (Adegunwa et al., 2011), though tannins have anti-carcinogenic and anti-mutagenic potentials due to their antioxidative property (Chung et al., 1998). The tannin contents recorded in this study were however significant at P<0.001. The tannin content was similar to that observed by Adegunwa et al. (2011) and also falls within the range observed for other *Dioscorea* spp. (Shanthakumari et al., 2008). *Legbaka*

Table 5. Pasting properties of flour from selected white yam varieties.

Variety	Peak 1[a]	Trough 1	Breakdown	Final viscosity	Setback	Peak time	Pasting temperature
Ndoni Aggah	337 ± 9.37^{c}	300 ± 1.12^{c}	37.665 ± 8.25^{b}	402 ± 4.77^{d}	103 ± 3.66^{ef}	5.84 ± 0.049^{ef}	61.9 ± 0.141^{a}
Oyonku	231 ± 5.77^{h}	222 ± 6.42^{e}	8.71 ± 0.651^{f}	311 ± 5.19^{g}	89.0 ± 3.66^{fg}	6.30 ± 0 .042^{cb}	61.9 ± 0.177^{a}
Legbaka Gambari	245 ± 2.71^{g}	213 ± 1.94^{e}	32.04 ± 0.764^{bc}	418 ± 3.30^{cd}	204 ± 1.24^{a}	6.20 ± 0 .000^{cbd}	61.8 ± 0.247^{a}
Ndoni Ekpe	289 ± 4.72^{e}	266 ± 9.02^{d}	22.375 ± 4.31^{cde}	371 ± 3.71^{e}	104 ± 5.30^{ed}	5.53 ± 0.000^{f}	61.7 ± 0.354^{a}
Asoko	215 ± 3.95^{i}	198 ± 3.30^{f}	17.46 ± 0.651^{def}	278 ± 2.88^{h}	80.1 ± 0.420^{gh}	7.00 ± 0.000^{a}	62.3 ± 0.566^{a}
Legbaka Awana	275 ± 4.48^{ef}	264 ± 3.66^{d}	10.83 ± 8.13^{f}	330 ± 0.420^{f}	66.2 ± 4.07^{h}	6.44 ± 0.049^{b}	61.9 ± 0.071^{a}
Ndoni Abi	269 ± 4.13^{f}	253 ± 0.18^{d}	15.875 ± 3.95^{def}	370 ± 2.72^{e}	117 ± 2.54^{d}	5.90 ± 0.141^{ed}	61.9 ± 0.071^{a}
He - Abalo	311 ± 5.78^{d}	287 ± 2.83^{c}	23.75 ± 2.94^{cd}	431 ± 10.31^{c}	144 ± 13.1^{c}	6.90 ± 0.141^{a}	61.9 ± 0.035^{a}
Alomako	356 ± 5.78^{b}	344 ± 12.55^{c}	12.045 ± 4.07^{ef}	461 ± 19.50^{b}	117 ± 6.95^{d}	6.87 ± 0.191^{a}	62.6 ± 1.379^{a}
Omin	355 ± 12.90^{b}	341 ± 16.86^{b}	14.375 ± 3.95^{def}	423 ± 15.80^{c}	81.8 ± 1.06^{g}	6.03 ± 0.424^{ed}	61.9 ± 0.141^{a}
Asukwu	470 ± 4.77^{a}	385 ± 1.29^{a}	84.54 ± 6.07^{a}	571 ± 8.84^{a}	186 ± 10.1^{b}	4.97 ± 0.049^{g}	61.9 ± 0.035^{a}
Means	305	279	25.4	397	118	6.18	62.0
SD	72.9	59.3	21.6	80.2	44.0	0.621	0.256
Min	215	198	8.71	278	66.2	4.97	61.7
Max	470	385	84.5	571	204	7.00	62.6
CV (%)	2.13	2.27	18.4	2.12	5.50	2.63	0.748
LSD(0.05)	14.5	14.1	10.4	18.7	14.4	0.362	1.03
Pr > F(Entry)	***[b]	***	***	***	***	***	ns

[a]Parameters mean value ±SD; [b]***, **, * -Significant at P<=0.001, P<=0.01 and P<=0.05 respectively; ns -Not significant at P>0.05. Means with the same letter are not significantly different.

Gambari variety had the highest tannin content. Phytate has a strong ability to chelate multivalent metal ions,specially zinc, calcium and iron, making them biologically unavailable, it is also regarded as an anti-nutritional factor in the diet of humans because of their inability to utilize it (Bohn et al., 2008). The phytate values recorded in selected white yam varieties were also significant (P< 0.001). The presence of enzyme inhibitors in yams could affect digestion of starch and protein, limiting their utilization as food (Polycarp et al., 2012). This study observed low levels of tannin and phytate in the selected varieties of white yam.

Lower levels of tannin and phytate were also recorded in yam varieties studied by Polycarp et al. (2012) and are recommended as safe for food processing application.

Conclusion

The result of this study revealed that the physical and chemical characteristics of these yam high yielding varieties were similar to those reported for most yam varieties in other parts of Nigeria. These yam varieties have better functional and pasting properties, hence better poundability and mealiness. They also have a great potential as source of bioactive compounds and protein for the people in the zone.

Conflict of interests

The authors did not declare any conflict of interests.

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