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Full Length Research Paper

Harvesting, postharvest handling, hygiene knowledge and practices of guava fruit farmers: A comparative study of two counties of Kenya

Judith N. Katumbi[1*], Jasper K. Imungi[1], George O. Abong[1], Charles K. Gachuiri[2], Agnes W. Mwang'ombe[3], Duke G. Omayio[1] and Joshua O. Owade[1]

[1]Department of Food Science, Nutrition and Technology, Faculty of Agriculture, University of Nairobi, P.O. Box 29053-00625, Nairobi, Kenya.
[2]Department of Animal Production, Faculty of Veterinary Sciences, University of Nairobi, P.O. Box 29053-00625, Nairobi, Kenya.
[3]Department of Plant Science and Crop Protection, Faculty of Agriculture, University of Nairobi, P.O. Box 29053-00625, Nairobi, Kenya.

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The guava (*Psidium guajava*) grows on farms or in the bush in many parts of Kenya, including Kitui and Taita Taveta, and remains virtually unattended. Guava fruit value chain is commercially disorganized and standard postharvest handling and storage procedures are not practiced as there is no bulk handling. This study evaluated the harvesting and postharvest handling practices of the guava fruit in two counties of Kenya. A total of 417 farmers were selected from the two counties (Kitui, n=214 and Taita Taveta, n=203). Using a structured questionnaire, data was collected utilizing Open Data Kit (ODK). Results showed that the main indicative maturity indices in Kitui and Taita Taveta were skin color (98.59 and 92.12%) and full ripe (38.79 and 18.72%) respectively. Results indicated that no packaging was done at farm level as only small quantities were harvested. Storage period was short (< 4 days) mainly to await consumption as reported by 41.6 and 55.2% handlers in Kitui and Taita Taveta, respectively. A cluster analysis of hygiene and postharvest handling practices indicated that Kitui farmers were more knowledgeable (71.9%) as compared to Taita Taveta (49.8%). Additionally, female farmers were more knowledgeable (65.4%) on postharvest handling than males (55.4%). Postharvest handling practices were informal with little packaging, poor hygiene practices, short term storage and informal marketing of small quantities in both Counties.

Key words: Guavas, postharvest, preservation, postharvest handling, hygiene, postharvest losses.

INTRODUCTION

Guava (*Psidium guajava* L.) is a climacteric fruit belonging to the family Myrtaceae (Chiveu et al., 2017). There are three main varieties of the fruit with different flesh color namely, pink, white and strawberry guavas

(Masud et al., 2018). The fruit is however, highly perishable (Rawan et al., 2017). The major guava growing areas in Kenya include Elgeyo-Marakwet, Kakamega,Uasin-Gishu, Kwale, Kilifi, Meru, Homabay, Siaya, Vihiga, Mombasa, Kitui, and TaitaTaveta among others (Chiveu et al., 2017). Guava trees survive in most agro ecological zones in Kenya except the arid areas (Omayio et al., 2019). The trees grow naturally unattended and grow from seeds dispersed by animals, birds and other agents (Chiveu, 2019).

Guavas are nutritious and have high levels of ascorbic acid, riboflavin (vitamin B2), vitamin A (beta carotene) and minerals like phosphorus, iron and calcium (Jiménez-Escrig et al., 2001). The ascorbic acid content in guavas is 4-5 times higher than that of citrus fruits; 200-400mg per 100g of guava (Augustin and Osman, 1988; Crane and Balerdi, 2015; Naseer et al., 2018). The nutritional quality of guavas is however, affected by the maturity levels and postharvest handling of the fruit (Zhou et al., 2014). The fruit is fragile and is prone to bruising and physical damage (Vishwasrao and Ananthanarayan, 2016). The vulnerability to damage is dependent on the maturity stage and level of ripeness (Kamsiati, 2016). The maturity level at harvest determines the shelf life and ultimate fruit quality (Sharma, 2019). The fruit skin color is mostly used to assess maturity of guavas (Sharma, 2019). They are harvested at color break when they change from green to light green or slightly yellow (Kamsiati, 2016).

Harvested guavas require proper postharvest handling to maintain quality, increase shelf life and reduce losses (Rawan et al., 2017). The guavas should be sorted by separating healthy fruits from bruised, wounded and damaged fruits (Barboza et al., 2016). Quality guavas are washed to remove dirt, dust, field heat and reduce microbial load on the surface. The disinfectants in the water prevent spoilage by bacteria and fungi (Kamsiati, 2016). The fruits can be packaged appropriately and stored to extend shelf life (Sharma, 2019). Manipulation of storage temperature is an effective means to extend the shelf life of guava (Paull and Chen, 2014). They can be stored for 7 days at 20°C and 2-3 weeks at 8-10°C and 85-90% relative humidity (Sharma, 2019). Guava postharvest losses are estimated at 25-30% which is attributed to poor storage and postharvest handling (Krishna and Kabir, 2018). Damage in guava is caused by rough handling, which results in bruises and wounds that makes it susceptible to microbial spoilage (Augustin and Osman, 1988; Singh, 2011). Good handling practices maintain quality of guava and reduce the huge postharvest losses experienced by farmers (Kamsiati, 2016). In Kenya, guava fruit receives minimal processing and value addition leading to neglected postharvest management (Omayio et al., 2019). The guava fruit is normally harvested by handpicking with no sorting or grading, resulting in heavy economic losses (Kamsiati, 2016). The fruit is also attacked by numerous diseases that cause rotting (Soares-Colletti et al., 2015) which reduces its marketability and processing.

Poor postharvest handling has contributed to huge guava postharvest losses in Kenya as the fruit is neglected and farmers mostly depend on natural production (Omayio et al., 2019). There is high production of the fruit in Kenya with minimal utilization due to short shelf life and low marketability (Chiveu, 2019). The study aimed at documenting harvesting and postharvest handling practices and marketing of the guava fruit. Kitui and Taita Taveta counties were selected as they are among the high guava producing areas (Chiveu et al., 2017).

MATERIALS AND METHODS

Study design

The study was cross-sectional in design, comparative between two Counties. Survey was conducted in April and May 2019 in the Counties of Kitui and Taita Taveta. A total of 417 farmers including 214 from Kitui and 203 from Taita Taveta were interviewed. Data was collected using semi-structured questionnaires by utilizing the digital Open Data Kit application. The data related to the harvesting and postharvest handling practices of guavas from the two Counties.

Study area

The study was conducted in Kitui and TaitaTaveta counties. Kitui County (Figure 1) is located in the former Eastern Province of Kenya. It covers an estimated area of 30,496.4 km^2 and comprises of 1.136 million people according to the 2019 Kenya National Bureau of Statistics census (KNBS, 2019). It is located between latitudes 0° 10" and 3° 0" South and longitudes 37° 50" and 39° 0" East. The altitude of the county ranges between 400 and 1800m above sea level (County Government of Kitui, 2018). It has a low lying topography with arid and semi-arid climate. The rainfall distribution is erratic and unreliable except for the highlands which receive relatively high rainfall annually compared to the lowlands. The annual rainfall ranges between 250-1050 mm per annum with 40% reliability for the long rains and 66% reliability for the short rains (Kitui County Intergrated development, 2018). The County

*Corresponding author. E-mail:judithkatumbi@gmail.com.

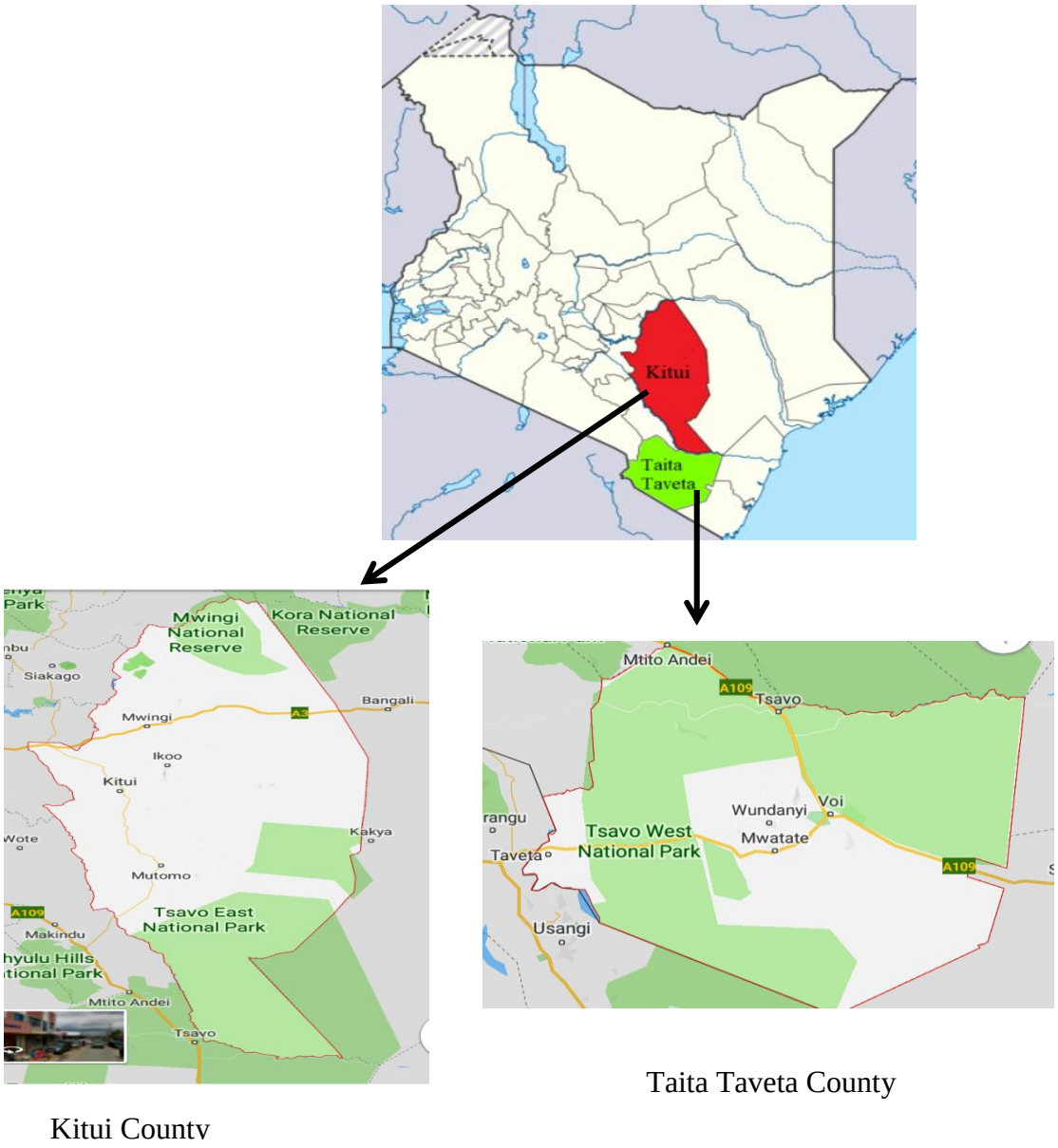

Figure 1. Map of Kenya showing the location of Kitui and Taita Taveta Counties.
Source: Google Maps, (2019).

experiences high temperatures with annual temperature ranges between 26 and 34°C and minimum mean annual temperature ranges between 14and 22°C (Cassim and Juma, 2018). The county is also divided into agro ecological zones which support subsistence crop and livestock agriculture which is the major economic activity(Chiveu et al., 2017). The guava trees grow in the highland areas of the county which has sub-humid climate. Other horticultural crops produced in the county are fruit crops such as mangoes, paw paws, water melons, tomatoes, avocado and castor fruit (Kitui County Intergrated development, 2018). Taita Taveta County (Figure 1) is located in the Coastal region of Kenya bordering Tana River, Kitui Makueni, Kwale and Kilifi, Kajiado and the Republic of Tanzania on the Southern side. The county covers an estimated area of 17,084.1km^2 and has an estimated population of 340,671 persons according to 2019 census (KNBS, 2019). The county lies between longitude 37° 36$^{'}$east and 30°14$^{'}$ east and latitude 2°46$^{'}$ south and 4° 10$^{'}$ south. Altitudes range from 500 m above sea level to almost 2300 m at the highest point in the county Vuria Peak. Taita Taveta is mainly dry, with the exception of Taita Hills which are considerably wet. Rainfall distribution is usually uneven, with higher rainfall amounts being recorded in highland areas as compared to the lowlands. Annually, mean rainfall is 650 mm (County Government of Taita Taveta, 2018). The average temperature in Taita Taveta County is 23°C, with lows of 18°C in

the hilly areas and rises to about 25°C in the lower zones (Tirra et al., 2019). The guava fruit grows in the highlands with Sisal estates and hilltop forests occupying less than 100 km^2.

The Taita hills form the highlands which support agricultural activities. Horticultural activities include fruit crops (bananas, mangoes, oranges, passion fruit, guavas) (County Government of Taita Taveta, 2018).

Study population

The study included farmers in the two Counties. The guava farmers constituted the guava farming households.

Sample size calculation

The sample size for the respondents was determined as per the Fisher's formula (Fisher et al., 1991).

$$N = \frac{Z^2 pq}{d^2}$$

Where;
N -Quantity of sample size desired
P- Proportion of the farmers expected to have guavas in their farms, taken as 50%

q (1-p)- The ratio in the selected population not expected to have guavas in their farms (50%)
d=Level of precision or absolute error (0.048^2)
Z- Normal standard variation at the required confidence level, a 95% confidence level will be used.
Therefore;
N= (1.962^* 0.5*0.5) ÷ ($0.048^{2)}$ = 417 respondents

There was no attrition rate because all respondents returned completely filled forms.

Sampling procedure

A multi-stage sampling was used in getting the sampling units for the study. The two counties were selected due to their high guava production and the fact that the project that funded this study was based there. Two Sub-counties were selected in each County based on high production quantities from which two wards were selected as the study sites. The respective households were then selected randomly and interviews conducted with a respondent in each household.

Hygiene and knowledge practices

Knowledge and hygiene practices scores of the respondents was assessed using the "Yes", "No" and "Don't Know" statements while the practice was assessed using "Yes" and "No" questions. Blooms cut-off point's was used in assessment of knowledge in previous studies by Abdullahi et al. (2016) and Nahida (2008).

Grades of ≤59% were scored as low, 60-79% moderate and 80-100% high. These scores were obtained by summing up correct scores for 1-18 knowledge statements which were categorized with postharvest knowledge having of 10 points and hygiene practices 8 points.

Statistical data analysis

Data analysis was done using statistical package for Social Sciences Software (IBM SPSS Statistics for Windows, version 25 (IBM Corp., Armonk, N.Y., USA) and R package for statistical computing (R Core Team, 2019). Each postharvest handling practice and hygiene knowledge response was transformed and categorized as either correct or incorrect. Frequencies were used to summarize scores for each question on hygiene and practices. Inferential statistics (t-test, chi square, frequencies and correlations) were used to analyze the data. A cluster analysis was done using R for data science to analyze knowledge by clustering the respondents in terms of their levels of knowledge.

RESULTS

Socio-demographic characteristics of guava producing farmers

Guava production in both Kitui and Taita-Taveta Counties largely involved women (57.6%). Taita Taveta had more men (51.72%) involved in guava production as compared to Kitui where there were more women (66.35%) than men (P<0.001). The mean age of guava farmers differed significantly (t (415) =2.2, P<0.05) in both counties with Taita Taveta having aged farmers 48.2±15.9 years as compared to Kitui (44.9±15.7) years. There was no significant (P>0.05) association between county and levels of education of guava producing farmers (χ^2=4.3, P=0.2) with most respondents (58.5%) having attained primary education and 10.1% were illiterate. Although the level of tertiary- educated respondents was low, Kitui had a slightly higher number of farmers who had attained tertiary education (7.5%) as compared to Taita Taveta with only 4.4%. Those who attained secondary level were low in both counties 25.9%. The level of education was significantly associated (χ^2=23.533, P<0.001) with gender with both counties recording more educated women than men. The major source of household income was farming and it significantly differed (χ^2=7.9, P=0.1) in both counties with Kitui (70.9%) and Taita Taveta (74.9%) (Table 1).

Harvesting practices

The harvesting practice is shown in Table 2.

Guava postharvest handling practices

Seven in every ten farmers (70.7%) transported guavas using human labor using sacks, baskets or buckets after harvesting. There were significant differences (χ^2=45.9, P<0.001)in methods of transporting guavas between the counties. Manual transportation of guavas was the most

Table 1. Socio-demographic characteristics of guava handlers in Kitui and Taita Taveta Counties.

Demographic characteristic	Levels	Taita Taveta %	Kitui %
Gender	Male	51.7	33.6
	Female	48.3	66.4
Age of respondents	Mean	48.4	44.9
Level of education	Did not attend school	8.9	11.2
	Primary	57.6	58.4
	Secondary	29.1	22.9
	Tertiary	4.4	7.5
Marital status	Married	74.8	77.6
	Widowed	2.9	7.9
	Divorced/separated	5.4	0.9
	Single	16.8	13.6

Table 2. Maturity indices and harvesting practices by guava farmers in Kitui and Taita Taveta counties.

Parameter		Taita Taveta %	Kitui %
Maturity indices	Color	92.1	87.4
	Fruit sizes	18.7	17.8
	Full ripe stage	31.0	29.4
Immediately after harvesting guava	Keep exposed to sunlight	0.5	15.4
	Keep under shades	53.7	76.6
Washing harvested guavas	Yes	56.2	35.0
	No	43.8	65.0

common means of transportation in Taita Taveta and Kitui with 77.8 and 64.9% of farmers respectively transporting their fruits from the farms using buckets and sacks. The main packaging materials among the farmers who packaged the fruits (Kitui, n= 214, Taita n=203) in Kitui was sacks (29%) paper boxes (39%) in Taita Taveta. The two counties differed in choice of packaging material as shown in Figure 2.

Guava deterioration

On average guavas lasted for 4.1±1.9 days prior to deterioration in both counties. There was a significant difference of guava shelf life between Kitui and Taita Taveta ($t(415) = 8.4$, $P<0.001$) with Kitui having a shorter period (3.4±1.9) compared to Taita Taveta (4.9±1.8). Approximately 76.6% of guava farmers experienced massive postharvest losses which were significantly different ($t(415) = -8.3$, $P<0.001$) between both counties being more rampant in Taita Taveta where 93.1% of farmers reported postharvest losses as compared to Kitui where only 61.2% did. Farmers in both counties reported similar kinds of losses and their major causes as shown in Table 3. Losses from shriveling were higher in Kitui (20.5%). Most of the fruits were left to rot in the fields as shown Figure 3. Approximately 93.8% of farmers experienced pests and diseases with no measures in place to control them. Pests and diseases were more frequent in Kitui (95.3%) than in Taita Taveta (77.8%). Eight in every ten farmers (81.1%) did not have an alternative use for overripe guavas and these were left to rot in the farms (Taita Taveta (84.7%), Kitui (75.7%). Farmers in the two counties used various strategies to

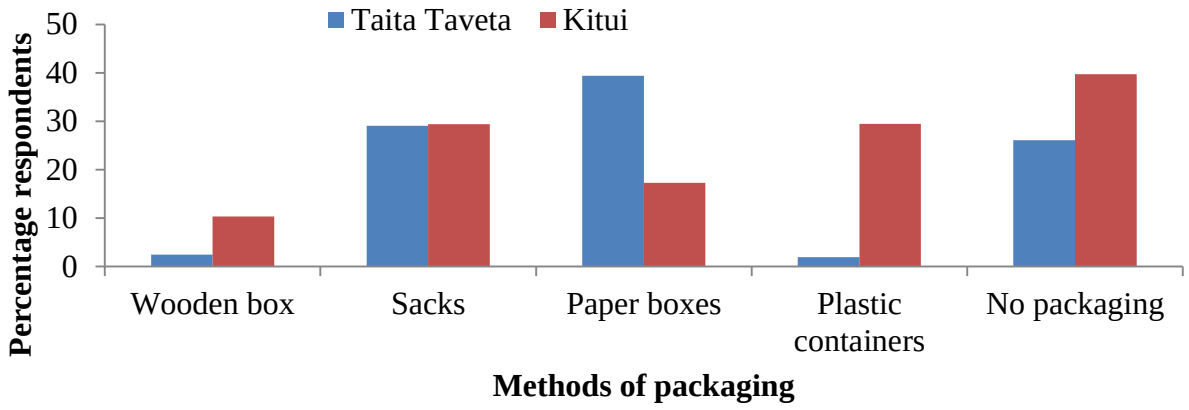

Figure 2. Methods used by farmers for packaging guavas in Kitui and Taita Taveta counties, Kenya.

Figure 3. Picture of a guava rotting under a tree in a farm in Kitui, Kenya. High postharvest losses were reported in Kitui and Taita Taveta as most of the guavas are left to rot in the farm.

reduce guava deterioration with aim of reducing losses (Figure 4).

Storage of guava fruit

In both counties, guavas were mainly stored for later consumption and sometimes for market. More than half of the farmers (55.1%) did not store guavas after harvesting. Slightly more farmers in Kitui (58.4%) stored guava compared with Taita Taveta where more than half (55.2%) did not. This was due to low commercialization of the fruit. A low proportion of farmers practiced guava storage and there was a significant differences (t (415) =2.8, P=0.05) between the proportions of farmers that stored guavas between the two counties as most farmers

Table 3. Types and causes of guava deterioration in Kitui and Taita Taveta counties.

Kinds of deterioration	Taita Taveta (%)	Kitui (%)	χ^2
Mechanical injuries	24.1	21.5	3.1
Over ripening and rotting	87.7	54.6	2.5
Guava shriveling	2.5	20.5	57.1 **
Microbial damage	49.7	30.8	0.3
Causes of guava deterioration in Kitui and Taita Taveta counties, Kenya			
Poor storage	29.6	39.7	4.7*
Pests and diseases	77.8	95.3	27.8**
Inadequate knowledge on postharvest handling	39.5	36.5	0.4
Excess rain	18.7	28.9	5.0*
Lack of market	53.7	12.6	78.9**
Poor packaging	2.9	22.9	36.2**

*Correlation is significant at the 0.05 level, **. Correlation is significant at the 0.001 level (Chi-square tests).

in both counties harvested small quantities. The farmers who stored guavas used various methods of storage (Table 4). There was, however, no significant association between the method of storage and the shelf life of guavas (χ^2=24.439, P=0.041). Farmers employed various strategies of extending guava shelf life which included sorting, harvesting small quantities, cold storage and minimizing mechanical damages (Figure 4). There was a correlation between the shelf life of guavas and the county of origin (r = 0.77, P<0.001) hence the county had an influence on how long guavas stored before spoiling.

Hygiene knowledge by handlers in postharvest handling of guava fruit

Clustering of knowledge on hygiene and postharvest handling practices generated two components that explained more than three quarters of data variability (76.0%) (Figure 5), Cluster one had relatively low mean scores of knowledge on food hygiene, household hygiene, harvesting, storage and packaging (Table 5). This was lower than the scores of cluster two where those with knowledge had relatively higher scores. Kitui had a higher proportion of farmers (71.9%) with knowledge on hygiene and postharvest handling practices as compared to Taita Taveta (49.8%). Furthermore, the female farmers (65.4%) were more knowledgeable than the male farmers (55.4%). The level of education had an influence on hygiene knowledge where a greater proportion of those with knowledge were among the educated farmers who had attained tertiary education (87.5%) compared to those with primary (62.7%) and secondary education (52.8%). The respondents' level of training on hygiene and postharvest practices associated significantly (χ^2= 6.3, P<0.5) with hygiene knowledge on handling of fruits. Farming was the main occupation for both clusters; however, cluster two had the highest number of respondents who were farmers by occupation (60.4%) than cluster one (32.3%). The overall knowledge assessment adopted Blooms cut-off point's grade scores, at P<0.001, t (415) =-6.8, at 95% confidence interval. Kitui county had a higher score (80.8±27.2) compared to Taita Taveta (65.1±19.2) knowledge on post-harvest handling practices. Respondents from both counties had higher knowledge on hygiene practices compared to postharvest handling with Kitui and Taita Taveta scoring a mean of 89.6±17.3 and 81.3±6.3 respectively (t=81.8, P<0.001). Responses on postharvest handling practices rangedfrom 60-79% hence farmers had moderate knowledge on postharvest practices. On hygiene knowledge correct responses were between 80-100% which indicated that the farmers had high knowledge on hygiene. Clustering of knowledge on hygiene and postharvest handling practices generated two components that explained more than three quarters of data variability (76.0%) indicating varying levels of knowledge among guava handlers. Cluster 1(component 1) had relatively low mean scores of knowledge on food hygiene, household hygiene, harvesting, storage and packaging. This was lower than the scores of cluster (component 2) where those with knowledge had relatively higher scores.

DISCUSSION

Socio-economic and demographic characteristics of guava producing farmers

The higher involvement of women in guava production in

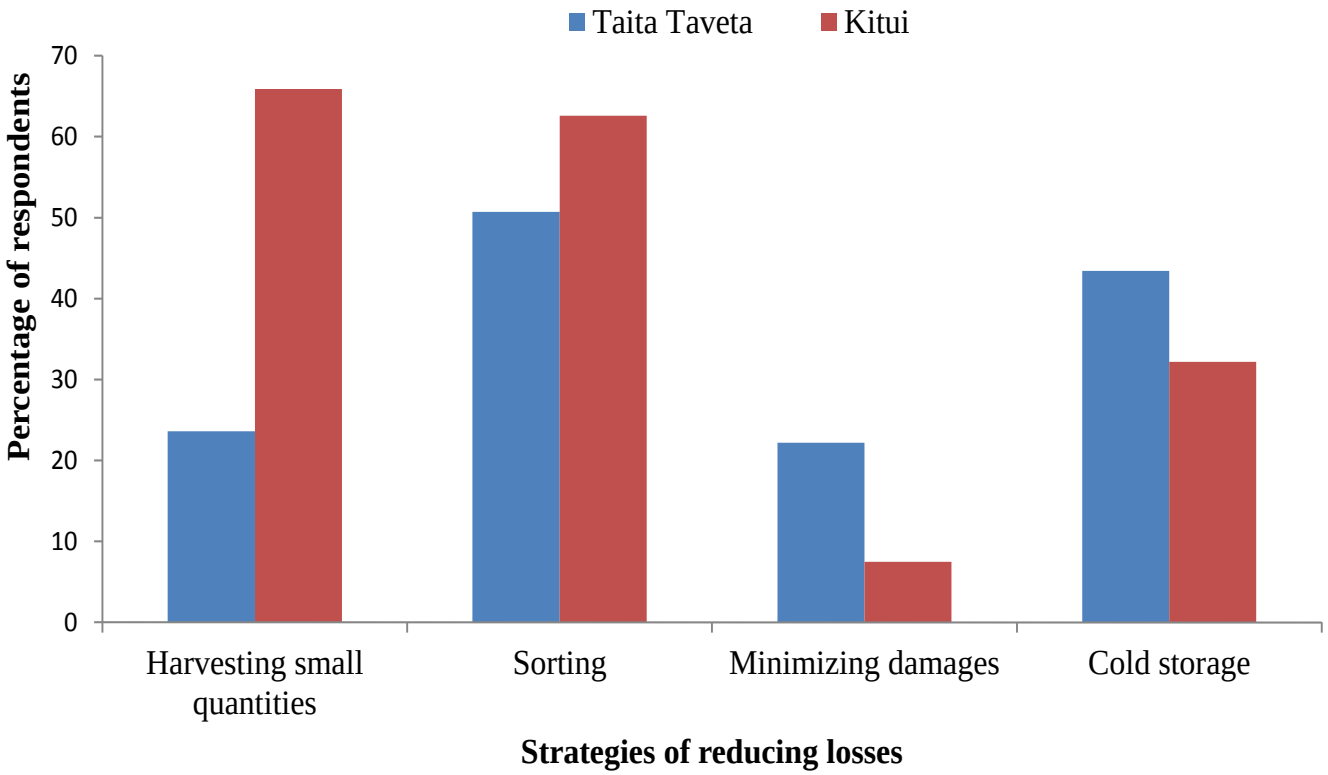

Figure 4. A comparison of the strategies for reducing guava deterioration in Kitui and Taita Taveta counties, Kenya ($\chi 2=149.8$, $P<0.001$).

Table 4. Storage containers used to store guavas by farmers in Kitui and Taita Taveta counties.

Method of storage	Taita Taveta (%)	Kitui (%)	χ^2
Crates	11.3	20.1	6.0*
Sealed plastic bags(Modified atmosphere)	0	14.5	31.8**
Low temperature (Refrigeration)	1.9	26.2	49.5**
Carton/plastic papers	27.1	15.4	8.5*
No storage	55.2	41.6	7.7*

***Correlation is significant at the 0.05 level, **.Correlation is significant at the 0.001 level (Chi-square tests).

both Kitui and Taita Taveta is linked to factors such as societal roles where women are entitled to carry out farm activities especially for subsistence farming (Ogunlela and Mukhtar, 2009). Majority of farmers had low levels of education which is in agreement with other studies that have reported that most people involved in fruits and vegetable production have low education (Rahiel et al ., 2018). This is attributed to lack of interest in education and high poverty levels in the two counties where most of the household income is used to purchase food (Brewer et al., 2017; Tacoli, 2017). Household education influenced their postharvest handling of fruits where low levels of education led to poor handling practices thus increasing guava losses (Sharif and Obaidat, 2013). This was well reflected in Kitui where there were more educated farmers and equally higher knowledge scores on hygiene and postharvest management compared to respondents from Taita Taveta County. Women were found to be more educated than men in both counties as indicated by the number of females who attended school which can be linked to the increased women empowerment in the country leading to increased interest

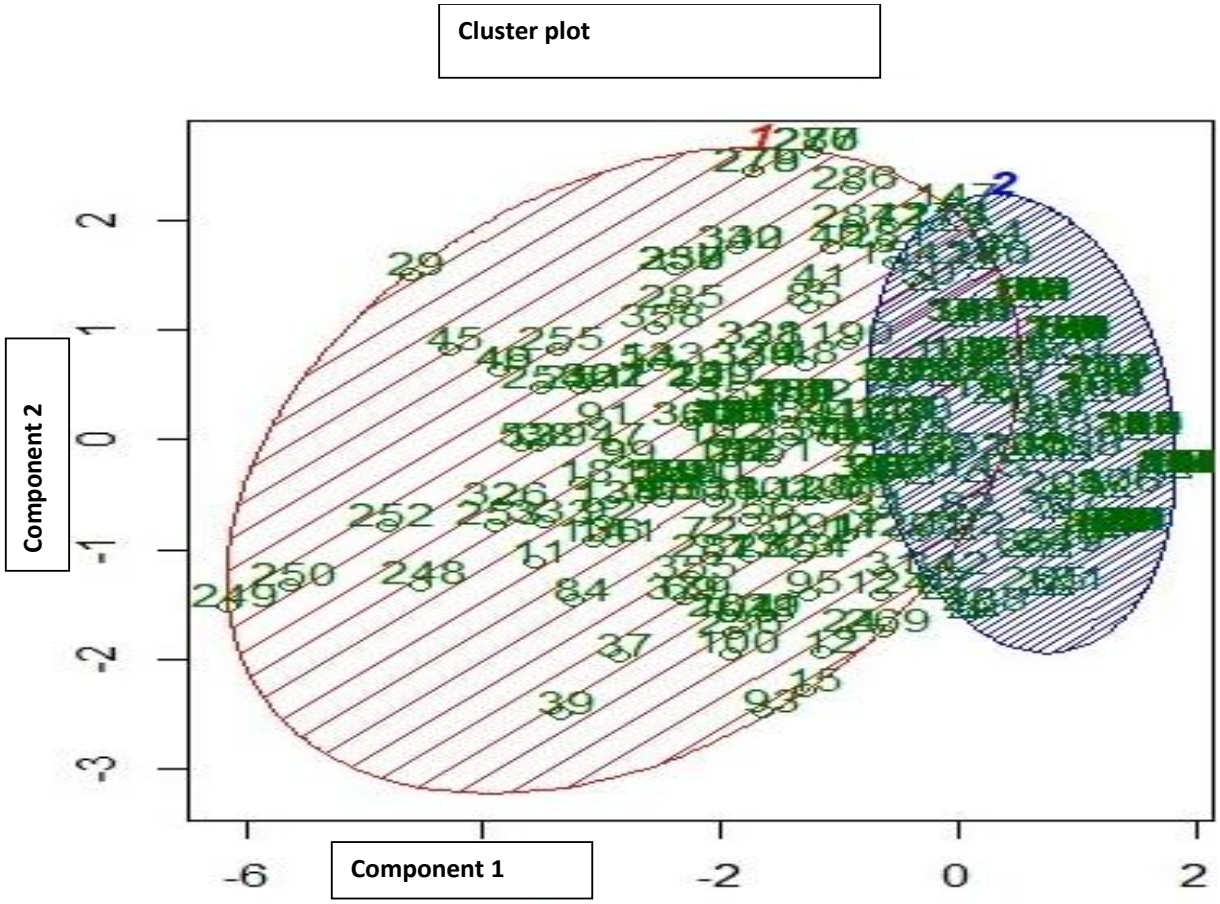

Figure 5. WSS plot of knowledge clustering of farmers in Kitui and Taita Taveta counties, Kenya.

Table 5. General hygiene and postharvest handling knowledge of guava farmers and handlers in Kitui and Taita Taveta counties**.**

Cluster	Food hygiene	Household Hygiene	Harvesting	Storage	Packaging
1	-0.8707538	-0.9238673	-0.7749838	-0.8656509	-0.8767342
2	0.5531847	0.5531847	0.4923427	0.5499429	0.5569841

The means have been standardized to z-distribution with a mean of 0 and standard deviation of 1.

in education (Habib et al., 2019). Socio-economic and demographic characteristics of guava farmers influenced guava production and postharvest handling practices.

Harvesting practices

The maturity stage at harvest has an implication on the shelf life and quality of guava fruit (Cavalini et al., 2006). The maturity indices for harvest of guava fruits is usually based on subjective evaluation of color, fruit size and texture which vary with location, time, fruit size, type and age of the plant (Kamsiati, 2016). In both Kitui and Taita Taveta, guava fruits were harvested when fully ripe. Fruits harvested at full ripe stage are of high quality but has short shelf life, while those harvested at mature green stage tend to have low quality but longer shelf life (Kamsiati, 2016). On the other hand, harvesting of the immature guava fruit results in product losses due to slow ripening or failure to do so (Singh, 2011; Prasad et al.,

2020). In Kitui and Taita Taveta, farmers harvested fully ripe guavas for household use only and the rest were left to rot in the farm which contributed to huge postharvest losses (Omayio et al., 2019). The fruits should be harvested at mature green stage to ensure effective postharvest management (Cantwell and Davis, 2014). The use of skin color as indicator of the maturity of the fruit in both counties is in agreement with the findings reported by Singh (2011) in his study on guavas which indicated that color is a determinant of maturity in guavas. Additionally, this technique is employed in establishing maturity in several fruits including mangoes, bananas, papayas (Cantwell and Davis, 2014). Removal of field heat from guava fruits was a common practice in both regions by washing or keeping the fruits under shade with the aim of slowing down processes that lead to rapid ripening and decay (Rawan et al., 2017). Farmers in Kitui and Taita Taveta counties manually harvested guavas at full ripe stage by use of color and this had great influence on the shelf life of their fruits. Additionally, this harvest stage contributes to high postharvest losses.

Guava postharvest handling practices

Postharvest handling of the guava fruit includes sorting, cleaning, grading, packaging, storage and transportation (Kamsiati, 2016; Sharma, 2019). Postharvest guava storage was not a major practice in both Kitui and Taita Taveta as farmers harvested enough for their consumption. This is explained by the low marketability and consumption of the fruit in Kenya (Chiveu, 2019). After harvesting, the guavas were manually transported to the homestead and market using buckets, sacks, crates or cartons. Such packaging practices are likely to increase mechanical damage of the fruits especially when harvested at full ripe stage (Bakshi, 2015). Most farmers in Kitui and Taita Taveta did not package guavas as the fruit had minimal economic value. Besides, only small quantities were normally harvested for household consumption. Sacks were mainly used for packaging during storage and transportation of the fruits in Kitui. Although the sacks have air spaces that allow for respiration and prevent anaerobiasis (Momin et al., 2018) they should be discouraged as they cause surface injury. In Taita Taveta, farmers opted to use paper boxes to package guava. This was as recommended by (Kaur and Kaur, 2019) that paper boxes were good in ensuring the lowest weight loss, ethylene and respiratory rates, highest soluble solids and vitamin C concentrations in the fruit. However, these packages can expose the fruits to mechanical damages if used for transportation without cushioning the fruits (Singh et al., 2014). Additionally, the fruit is highly perishable and has a delicate skin that is prone to mechanical damage (Gill, 2018). Farmers in Kitui and Taita Taveta counties did not have standard postharvest handling practices for guavas which was a main contributor to huge postharvest losses reported in the two regions.

Guava deterioration

Most of the households harvested small quantities of guava for home consumption and the rest were left to rot in the field which contributed to huge losses. A study conducted by Shivaraj and Patil (2017) in India found that guava losses at harvest and postharvest were approximately 16% increasing the economic losses to guava farmers. Overripe guavas were left to rot in the farm with no alternative use due to low value addition of the crop to shelf stable products such as juices, jams, nectars, wine, animal feeds and in compost making (Kadam et al., 2015). Microbial attacks and mechanical injuries were the major causative factors of the guava losses as reported in Kitui and Taita Taveta. The fruit is highly prone to fruit fly infestation and other pests which reduce shelf life and increase losses (Keith and Zee, 2010). Most respondents (93.8%) reported pests and diseases as the major cause of losses to guavas although they did not use any control measures given that the fruits are neglected and have low commercial value (HCD, 2014) Studies indicate that guavas are highly infested by fruit flies becoming one of the major causes of the fruit loss especially during the rainy seasons (Jatinder, 2017).

Inadequate knowledge on postharvest handling was reported as the second challenge leading to huge losses in Kitui and Taita Taveta and this was attributed to lack of standard postharvest handling procedures affecting harvesting, storage and utilization of the fruit. The significant difference in shelf life of guavas in Kitui (3 days) and Taita Taveta (5 days) is linked to the temperature difference between the counties as Kitui is relatively hotter than Taita Taveta with temperature ranges of 24-34°C and 21-32°C respectively (Cassim and Juma, 2018; Tirra et al., 2019). Higher temperatures result in higher respiration rates that cause rapid fruit deterioration thus resulting in shorter shelf life for fruits in Kitui (Renato et al., 2012). Additionally, guavas have a thin, delicate skin which increases susceptibility to injuries and pest attack resulting in infection that tends to reduce shelf life (Pal, 2009; Singh, 2011). The farmers' strategies of extending guava shelf life by sorting, harvesting small quantities and cool storage have been shown to be effective with other fruits like mango, banana, avocadoes and pawpaw (Kamsiati, 2016). The rate of guava deterioration if influenced by the handling practices preceding storage and the prevailing storage

conditions, this was a major problem in Kitui and Taita Taveta thus huge postharvest losses were recorded.

Storage of guava fruit

Farmers harvested guavas at full ripe stage, which made them highly perishable and prone to mechanical injuries. This is attributed to high respiration rates that increase the ripening process during storage (Rawan et al., 2017). The maturity stage highly influences the storage life of the fruit (Prasad et al., 2020) as it affects its postharvest life by influencing the rate of deterioration. Storage of guavas was not a common practice in both counties which could be linked to lack of knowledge on postharvest handling and storage of guavas. In both counties, farmers did not practice cold storage of guavas which was due to lack of electricity and refrigerators. In the work done by Mitra et al (2012) and Sharma (2019), guavas stored at low temperature (8 to 10°C) had a longer shelf life than those stored at room temperature (20 to 25°C). The strategies put in place to reduce rate of deterioration were sorting of the fruits into unripe, ripe and over ripe and harvesting small quantities. There are other storage methods that were not practiced in Kitui and Taita Taveta but have the potential to extend guava shelf life; use of modified atmosphere storage, individual packaging using cling films, salts (calcium chloride and calcium nitrate) and freeze drying (Adrees et al., 2010; Miano and Jokhio, 2010). Guava shelf life could be extended by combing methods that reduce the rate of processes in the fruit.

Knowledge on hygiene and practices

The clustering of farmers' hygiene and handling knowledge resulted into two major clusters which revealed that guava farmers either had low or relatively high knowledge of hygiene practices. The low knowledge can be linked to the fact that most farmers have low exposure on postharvest handling of the produce (Muhammad et al., 2012). Guava fruit handlers in Kitui had more knowledge on hygienic handling of the fruits which greatly influenced how they handled the fruits after harvest. This could be linked to higher education level of farmers in Kitui than in Taita Taveta. Besides, there was a guava market in Kitui and may have contributed to this as the farmers and guava traders practiced hygienic handling of the fruits to extend shelf life and reduce unnecessary losses from poor handling. A study by Sharif and Obaidat,(2013a) on food hygiene knowledge and practices showed that knowledge scores increased with the levels of education.

Additionally, gender was found to have an influence on knowledge with women tending to be more knowledgeable on handling and hygiene than men, this is attributable to the fact that women had high education level than men (Habib et al., 2019). These results correlate with the findings of Samapundo et al. (2016) that gender significantly influenced knowledge on food safety and hygiene practices where women were found to be more hygienic in handling food than men. Other studies have reported that training on food handling and safety results in increased levels of knowledge (Azmi, 2006). Despite the fact that the respondents from both counties had not received any formal training on postharvest handling of fruits, they displayed somewhat high levels of knowledge which could be influenced by other trainings on food sanitation and food safety. There is therefore need for training of guava handlers on hygiene practices and postharvest handling to reduce losses.

Conclusion

Guava fruit production in Kitui and Taita Taveta is largely subsistent with limited commercialization. Households producing the fruit practiced limited postharvest management to improve the keeping quality of the fruit. However, limited information is available on postharvest handling properties of the fruit. Despite this, the households had acceptable levels of knowledge on postharvest handling of the fruit although there exists a gap in the actual practice and implementation of the knowledge possessed in actual practice. Harvesting of guava was not a common practice as farmers harvested just enough for household consumption and the rest is left to rot in the farms, eaten by birds and animals. This is due to low value addition of the fruit due to its low economic value.

Recommendations

(i) Training farmers on postharvest management of guavas with the aim of increasing its marketability to enhance its production and increase farmer income from the fruit.
(ii) Development of guava postharvest handling standards, guidelines and manuals to be availed to farmers to enhance their postharvest management with aim of averting the huge losses.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Abdullahi A, Hassan A, Kadarman N, Saleh A, Baraya YS, Lua PL (2016). Food safety knowledge, attitude, and practice toward compliance with abattoir laws among the abattoir workers in Malaysia. International Journal of General Medicine 9:79-87.

Adrees M, Younis M, Farooq U, Hussain K (2010). Nutritional Quality Evaluation of Different Guava Varieties. Pakistan Journal of Agricultural Sciences 47:1-4.

Augustin M, Osman A (1988). Post-harvest Storage of Guava (*Psidium guajava* , L , var . Taiwan). Pertanika 11:45-50.

Azmi S (2006). The evaluation of food hygiene knowledge, attitudes and practices of food handlers Õ in food businesses in Turkey. Food Control 17:317-322.

Bakshi P (2015). Maturity indices of Guava. Journal of Agricultural Science P 18.

Barboza HTG, Mamede AMGN, Soares AG, Neves ACV, de Oliveira Fonseca MJ (2016). Postharvest physiology and technology for fresh guavas. Trop. Fruits - From Cultiv. to Consum. Heal. Benefits Guava Mango pp. 91-108.

Brewer M, Etheridge B, Dea CO (2017). Why are Households that Report the lowest incomes so well-off?. The Economic Journal 127(605):24-49.

Cantwell M, Davis UC (2014). Maturation and Maturity Indices When to Harvest ? University of California, Davis.

Cassim J, Juma G (2018). Temporal analysis of drought in Mwingi sub-county of Kitui County in Kenya using the standardized precipitation index (SPI). Climate Change Analysis 4(16).

Cavalini FC, Ortega EMM, Jacomino AP, Lochoski MA, Kluge RA (2006). Maturity indexes for “Kumagai” and “Paluma” guavas. Revista Brasileira de Fruticultura 28(2):176-179.

Chiveu CJ (2019). Fruit species Genetic diversity of common guava in Kenya: an underutilized naturalized fruit species. https://doi.org/10.17660/th2019/74.5.4

Chiveu J, Naumann M, Pawelzik E, Kehlenbeck K (2017). Nutrient composition of guava (Psidium guajava L.) fruits as influenced by soil nutrients. Future Agriculture: Socio-ecological transitions and bio-cultural shifts, Tropentag, Bonn, Germany pp. 20-22.

County Government of Kitui (2018). Kitui County integrated development plan 2018-2022. County Government of Kitui, Kenya.

County Government of Taita Taveta (2018). Taita Taveta County Integrated Development Plan 2018-2022. County Government of Taita Taveta, Nairobi, Kenya.

Crane JH, Balerdi CF (2015). Guava Growing in the Florida Home Landscape 1 Production (Crop Yields). University of Florida.

Fisher AA, Laing JE, Stoeckel JE, Townsend (1991). Handbook for family planning operations research design (2nd Edition). TT - (2nd Edition). Population Council, New York, USA.

Gill KBS (2018). Techniques for extending shelf life of guava fruits : a review. Acta Horticulturae pp. 959-969.

Habib K, Shafiq M, Afshan G, Qamar F (2019). Impact of Education and Employment on Women Empowerment 1, Euros Online. International Journal of Natural and Social Sciences 8(3):62-74.

HCD (2014). HCD Horticulture Validated Report. Retrieved from Agriculture, Fisheries and Food Authority (AFFA). Horticulture Performance Report.

Jatinder SKS (2017). Effect of Postharvest treatment of Guava fruits with 1- methylcyclopropene and Gibberellin on storage life and fruit quality Jatindr. International Journal of Applied Research and Technology 8:35-40.

Jiménez-Escrig A, Rincón M, Pulido R, Saura-Calixto F (2001). Guava fruit (*Psidium guajava* L.) as a new source of antioxidant dietary fiber. Journal of Agricultural and Food Chemistry 49:5489-5493.

Kadam DM, Kaushik P, Kumar R (2015). Evaluation of Guava Products Quality. https://doi.org/10.5923/j.food.20120201.02

Kamsiati E (2016). Postharvest Handling Practices in Maintaining Quality and Shelf Life of Guava (*Psidium guajava*), Indonesian Agricultural Agency for Research and Development (IAARD).

Kaur M, Kaur A (2019). Improvement in storability and quality of peach Cv. Flordaprince with post-harvest application of various chemicals. Journal of Pharmacognosy and Phytochemistry 8(1):460-464.

Keith LM, Zee FT (2010). Guava Diseases in Hawaii and the Characterization of Pestalotiopsis spp. Affecting Guava. Acta Horticulturae 849:269-276.

KNBS (2019). Kenya Population and Housing Census Volume 1: Population by County and Sub-County, 2019. Kenya Population and Housing Census.

Krishna B, Kabir J (2018). Effect of Post Harvest Treatments on Physico-Chemical Changes and Marketability during Storage of Guava. International Journal of Pure and Applied Bioscience 6(5):1296-1303.

Masud P, GM, Uzzaman S, Miah Akanda K, Mehjabin S (2018). A short review on a Nutritional Fruit : Guava. Open Access Toxicology Research 1:1-8.

Miano TF, Jokhio JA (2010). Effect of different packaging materials and storage conditions on physico-chemical characteristics of guava (var. Allahabadi). Journal of Agroforestry and Environment 4(2):33-36.

Momin MC, Kabir J, Jamir AR (2018). Effect of Different Post-Harvest Treatments and Prepackaging on Storage Behavior of Guava (*Psidium guajava*) cv, Khaza. International Journal of Current Microbiology and Applied Sciences 7(1):3186-3195.

Muhammad RH, Hionu GC, Olayemi FF (2012). Assessment of the post-harvest knowledge of fruits and vegetable farmers in Garun Mallam L. G. A of Kano, Nigeria. International Journal of Development and Sustainability 1(2):510-515.

Nahida A (2008). Knowledge, attitude and practice of dengue fever prevention among the people in male, Maldives, Published Master’s Dissertation, Chulalongkorn, University, Thailand. Journal of Health Research 22(1):33-37.

Naseer S, Rahman M, Pervaiz M, Naeem N, Hussain S (2018). The phytochemistry and medicinal value of *Psidium guajava* (guava). Clinical Phytoscience P 4.

Ogunlela YI, Mukhtar AA (2009). Gender Issues in Agriculture and Rural Development in Nigeria : The Role of Women. Journal of Humanities and Social Science 4:19-30.

Omayio DG, Abong GO, Okoth MW, Gachuiri CK, Mwang’ombe AW (2019). Current Status of Guava (*Psidium Guajava* L .) Production , Utilization , Processing and Preservation in Kenya : A review. Current Agriculture Research Journal 7:318-331.

Pal S (2009). Prospective and retrospective approaches to postharvest quality management of fresh guava (*Psidium guajava* L.) fruit in supply chain. Fresh Produce 4:36-48.

Paull RE, Chen CC (2014). Guava: Postharvest Quality-Maintenance Guidelines. College of Tropical Agriculture and Human Resources. Fruit, Nut, and Beverage Crops.

Prasad K, Jacob S, Siddiqui MW (2020). Fruit Maturity , Harvesting , and Quality Standards. Researchgate, Delhi. https://doi.org/10.1016/B978-0-12-809807-3.00002-0

R Core Team (2019). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Rahiel HA, Zenebe AK, Leake GW (2018). Assessment of production potential and post ‐ harvest losses of fruits and vegetables in northern region of Ethiopia. Agriculture and Food Security 7:1-13.

Rawan S, Bibi F, Khan N, Khattak AM, Shah Z, Iqbal A, Haq SU, Kamal

A, Shah FA, Naeem A, Ali W (2017). Research Article Postharvest Life of Guava. Pakistan Journal of Agricultural Research 30:155-161.
Renato de ABREU J, Donizete dos SANTOS C, Maria Patto de ABREU C, Carla Marques PINHEIRO A, Duarte CORRÊA A (2012). Ripening pattern of guava cv. Pedro Sato Padrão de amadurecimento de goiaba cv. Pedro Sato. Ciênc. Tecnol. Aliment 32:344-350. https://doi.org/10.1590/S0101-20612012005000052
Samapundo S, Thanh TNC, Xhaferi R, Devlieghere F (2016). Food safety knowledge , attitudes and practices of street food vendors and consumers in Ho Chi Minh city , Vietnam. Food Control 70:79-89.
Sharif L, Obaidat MM (2013). Food Hygiene Knowledge, Attitudes and Practices of the Food Handlers in the Military Hospitals pp. 3–10. https://doi.org/10.4236/fns.2013.43033
Sharma S (2019). Post – Harvest Management in Guava Post – Harvest Management in Guava. Agrobios Newsletter 15:19-21.
Shivaraj G, Patil BL (2017). Economics of Guava Cultivation in Dharwad District of Northern Karnataka. International Journal of Agricultural Science 9:3876-3879.
Singh P, Singh S, Singh BR, Mishra DK (2014). Standardization of Packaging for Transportation of Guava Fruits. The International Journal of Emerging Technology and Advanced Engineering4:541-546.
Singh SP (2011). Guava (*Psidium guajava* L .), Woodhead Publishing Limited. Woodhead Publishing Limited. https://doi.org/10.1016/B978-1-84569-735-8.50010-3
Soares-Colletti AR, Fischer IH, Lourenço S de A (2015). Incidence of postharvest diseases on “Kumagai” and “Pedro Sato” guavas at wholesale markets in Brazil. Tropical Plant Pathology 39(6):478-482.
Tacoli C (2017). Food (In) Security in Rapidly Urbanising , Low-Income Contexts. International Journal of Environmental Research and Public Health 14:1554.
Tirra A, Nyang HT, Wakesho A (2019). Factors influencing the level of commercialization among smallholder cassava farmers in Taita-Taveta and Kilifi Counties, Kenya. African Journal of Agricultural Research 14(32):1584-1592.
Vishwasrao C, Ananthanarayan L (2016). Postharvest shelf-life extension of pink guavas (*Psidium guajava* L.) using HPMC-based edible surface coatings. Journal of Food Science and Technology 53(4):1966-1974.
Zhou L, Paull RE, Chen NJ (2014). Papaya: Postharvest Quality-Maintenance Guidelines. Journal of the American Society for Horticultural Science 114:937-942.

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Effect of flour types and flour concentrations on the physicochemical and sensory characteristics of an indigenous senescent plantain cake (*ofam)*

Doreen Dedo Adi[1*], Ibok N. Oduro[2] and Charles Tortoe[3]

[1]Faculty of Vocational Education, Akenten Appiah – Menka University of Skills Training and Entrepreneurial Development, Kumasi, Ghana.
[2]Department of Food Science and Technology, Kwame Nkrumah University of Science and Technology, PMB Kumasi, Ghana.
[3]Council for Scientific and Industrial Research, Food Research Institute, Accra, Ghana.

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***Ofam* is a Ghanaian indigenous cakelike product made mainly from senescent plantain and local flours from cereal, grain and/or tuber sources. The effect of three flour types (steeped corn flour (SCF), roasted corn flour (RCF) and *kokonte* flour (KF)) and flour concentrations (20, 17.5, 15, 12.5 and 10%) on the physicochemical characteristics and sensory acceptability *ofam* was investigated. Parameters such as moisture, pH, total soluble solids (TSS), viscosity, colour and texture profile were measured using standard methods. A 50-member untrained panelist was used to conduct a sensory acceptability test using a 9-point hedonic scale. *Ofam* batter were characterised by high moisture content (ranging from 52.7 to 55.1%), pH (ranging from 5.4 to 5.5), TSS (ranging from 2.30 to 2.62) and a dark colouration (L-value ranging from 30.39 to 45.55). The flour type and concentration affected the viscosity of the batter which also influenced the hardness of *ofam*. RCF *ofam* was the hardest (1541.49 g Force) while KF ofam was the softest (966.79 g Force). Generally, RCF ofam was the most preferred (7.0) whilst KF of was the least preferred (6.68). Also, *ofam* with flour inclusion of 15% was also the most preferred (7.89) while products with 20% flour inclusion were the least preferred (6.47). This would form the basis for the standardisation of the product and formulation of a convenient powder mix suitable for *ofam*.**

Key words: Senescent plantain, *ofam*, batter, physicochemical, sensory.

INTRODUCTION

Ofam is a Ghanaian indigenous cakelike product produced mainly from senescent plantain, which is taken as a snack or as an accompaniment to a main meal. Senescent plantain puree or paste, flour and unrefined palm oil are homogenously mixed into a batter and subsequently baked to make *ofam*. Other optional

*Corresponding author. E-mail: dedoadi07@gmail.com.

ingredients such as onion, ginger, African pepper, calabash nutmeg and cayenne pepper may be added as flavour and taste enhancers. These flavour and taste enhancers improves consumers acceptability of the product (Adi et al., 2019). There are variations in the preparation of this indigenous cakelike product across different ethnic backgrounds and hence the different derivatives (Adi et al., 2018). The use of senescent plantain for these products contributes to value addition of the already deteriorating commodity (Flore et al., 2013; Severin et al., 2013).

Senescent plantain and flour form the most substantial ingredients in the *ofam* recipe, and they considerably influence the texture of the product. The most commonly used flours for *ofam* and other senescent plantain products have been cassava flour (*kokonte*), roasted corn flour and steeped corn flour (Adi et al., 2018). Flour provides the structural matrix around which all the other ingredients are mixed to form a dough or batter in baked foods. The texture, appearance and even shelf-life of flour products are influenced by the type of flour and the nature of starch present in the flour (Gallagher et al., 2003, 2004; Marston et al., 2016; Niba, 2005). These attributes are also influenced by the presence of fat. In addition to its flavour enhancing properties, fat provides tenderness to most baked goods. An adequate amount is essential to prevent product dryness or sogginess (Agrahar-Murugkar et al., 2016).

Baking is associated with heat transformation of dough or batter (which contains flour) into a unique food product with special sensory characteristics (Mondal and Datta, 2008). This complex process results in a series of physical, chemical and biochemical changes in food as the gelatinization of starch, denaturation of protein, liberation of carbon dioxide from leavening agents, volume expansion, evaporation of water, crust formation and browning which contribute to the quality of the finished product (Sumnu, 2001; Yolacaner et al., 2017). Browning reactions such as caramelization and Maillard reaction are a non-enzymatic chemical reactions resulting in coloured and flavour compounds formation during baking (Fennema, 1996; Purlis, 2010).

According to Nashat and Abdullah (2016), sensory quality attributes which influence consumer preference for baked goods are the external or crumb colour, texture and flavour. In a consumer study on senescent plantain products, sensory quality attributes such as taste, appearance, texture and aroma were identified as the indicators of product acceptability. These quality attributes are influenced by the constituents of the baked product. During *ofam* preparation, the variation in the type and quantity of flour used is expected to affect its colour, flavour, texture and ultimately its sensory acceptability. However, there is no study to elucidate these. Establishing these baseline data is required for product standardization and commercialisation. Therefore, this study was aimed at evaluating the effect of different flour types and flour concentrations on the physicochemical characteristics of *ofam* batter and baked *ofam* and also to evaluates the sensory acceptability of the baked products.

MATERIALS AND METHODS

Raw material preparation

Matured plantain at ripening stage 1 was harvested at JE Farms in Mankessim (Central Region, Ghana). The plantain was de-handed and kept on a bench in a room at ambient temperature (27 ± 2°C) and allowed to ripen to stage 7 (at the onset of senescence) for processing. At ripening stage 7, the plantains were washed, peeled packaged in Ziploc bags (in 1.0 kg portions) and kept frozen for further use. Frozen senescent plantain pulp was allowed to thaw in an ice chest overnight. The thawed senescent plantain was milled into a puree using a Philips Food Processor (hr7761/00, Brighouse, UK). The puree was used for the batter preparation and subsequent baking.

Ofam batter preparation and baking

A total of fifteen *ofam* batters were prepared for this study. The batter preparation and subsequent baking followed a 3 × 5 design, where three different flour types (*kokonte* (KF), steeped corn flour (SCF) and roasted corn flour (RCF)) were used as binders at five different concentration. The flour concentrations were generated by the Minitab software (version14) using a lower limit of 10% and an upper limit of 20% with two midpoints to obtain flour concentrations of 20, 17.5, 15 12.5, and 10% for all three different flour types. All other ingredients were kept constant for all fifteen samples (Table 1).

Ofam samples were prepared as described by Adi et al. (2018). Batter samples were prepared in 1.0 kg portions. A weighed amount of senescent plantain puree was mixed with a weighed amount of flour depending on the sample. Every 1.0 kg portion of batter was mixed with 50 g onion powder, 4.0 g African pepper, 0.5 g calabash nutmeg, 15 g cayenne pepper powder and 15 g ginger powder. Unrefined palm oil (100 mL) was added to the mixture and stirred with a wooden spatula to form a homogenous mixture. The batter was transferred into a greased aluminium loaf pan (305 × 105 × 70 mm), and baked in a preheated Ariston electric oven (C522E EX, Fabriano, Italy) at 170°C for 90 to 110 min (Figure 1).

Physicochemical analysis of ofam batter and baked ofam

Moisture content of ofam batter

The moisture content of *ofam* batter was determined by drying 2 g of samples at 105°C for 6 h (AOAC method 925.10).

pH of batter and total soluble solids

A measured amount (10 g) of the batter was mixed with 100 mL of distilled water and held for at least 30 min at room temperature and then filtered. The filtrate was used to determine the pH using pH meter (Corning 240, New York 14831, USA) and the °Brix of the samples using a hand-held refractometer (r^2 mini, Reichert Inc., Japan) (Kirk and Sawyer, 1991).

Table 1. Description *ofam* samples and their respective composition for formulation.

Sample name	Senescent plantain puree (%)	Kokonte (KF, %)	Roasted corn flour (RCF, %)	Steeped corn flour (SCF, %)
$OFKF_{20}$	80	20	-	-
$OFKF_{10}$	90	10	-	-
$OFKF_{17.5}$	82.5	17.5	-	-
$OFKF_{15}$	85	15	-	-
$OFKF_{12.5}$	87.5	12.5	-	-
$OFRCF_{20}$	80	-	20	-
$OFRCF_{10}$	90	-	10	-
$OFRCF_{17.5}$	82.5	-	17.5	-
$OFRCF_{15}$	85	-	15	-
$OFRCF_{12.5}$	87.5	-	12.5	-
$OFSCF_{20}$	80	-	-	20
$OFSCF_{10}$	90	-	-	10
$OFSCF_{17.5}$	82.5	-	-	17.5
$OFSCF_{15}$	85	-	-	15
$OFSCF_{12.5}$	87.5	-	-	12.5

$OFKF_{20}$ – *Ofam* with 20% kokonte flour incorporation; $OFKF_{10}$ – *Ofam* with 10% kokonte flour incorporation; $OFKF_{17.5}$ – *Ofam* with 17.5% kokonte flour incorporation; $OFKF_{15}$ – *Ofam* with 15% kokonte flour incorporation; $OFKF_{12.5}$ – *Ofam* with 12.5% kokonte flour incorporation; $OFRCF_{20}$ – *Ofam* with 20% roasted corn flour incorporation; $OFRCF_{10}$ – *Ofam* with 10% roasted corn flour incorporation; $OFRCF_{17.5}$ – *Ofam* with 17.5% roasted corn flour incorporation; $OFRCF_{15}$ – *Ofam* with 15% roasted corn flour incorporation; $OFRCF_{12.5}$ – *Ofam* with 12.5% roasted corn flour incorporation; $OFSCF_{20}$ – *Ofam* with 20% steeped corn flour incorporation; $OFSCF_{10}$ – *Ofam* with 10% steeped corn flour incorporation; $OFSCF_{17.5}$ – *Ofam* with 17.5% steeped corn flour incorporation; $OFSCF_{15}$ – *Ofam* with 15% steeped corn flour incorporation; $OFSCF_{12.5}$ – *Ofam* with 12.5% steeped corn flour incorporation.

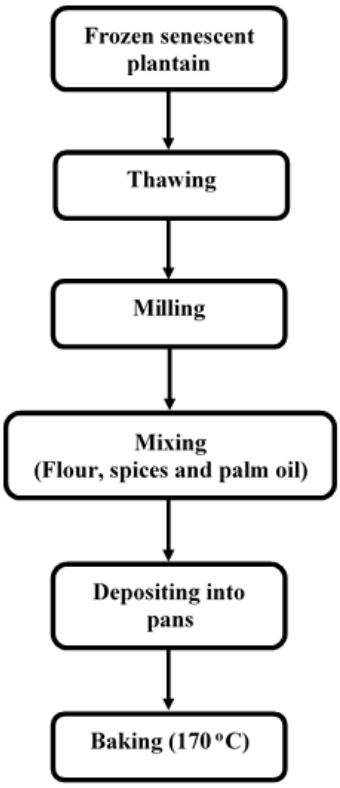

Figure 1. Process flow diagram for the preparation of *ofam*.

Batter viscosity

Batter viscosity was measured using a Brookfield RVDV-2T Viscometer (Brookfield Engineering Laboratories, Middleboro, MA, USA), with the guard leg detached. Viscosity was measured using 220 ± 1 g of *ofam* batter in a 250 mL glass beaker at ambient temperature (27 ± 2°C). In determining the viscosity of the batter, a flow profile was obtained (at different spindle speeds of 40 rpm, 60 rpm and 80 rpm for a period of 30 min for each speed) as proposed by Dikeman and Fahey (2006), Reppas et al. (1999) and Schemann and Ehrlein (1986) for non-Newtonian fluids. The viscometer was set to measure viscosity every 5 min, and the average speed was calculated for each spindle speed. A 07-spindle size was used for the study and three measurements were taken for each batter sample.

Texture profile analysis of ofam

Texture profile analysis (TPA) of baked *ofam* samples were evaluated by the method described by Agrahar-Murugkar et al. (2016) with slight modifications, using the Stable Micro Systems texture analyser (TA-XT plus - 13051, Surrey, UK). A two-bite compression test was performed on samples of height 30 mm after a size 15 cork borer (22.5 mm outside diameter) was used to obtain cylindrical-shaped samples from the baked product. The analysis was done at a test speed of 5 mm/s, pre-test speed of 1 mm/s, post-test speed of 5 mm/s and a deformation of 75% using an aluminium cylindrical probe of 75 mm diameter. Data acquisition rate was at 200 pps. Using the exponent software, the measurements for hardness, fracturability, adhesiveness, springiness, cohesiveness, gumminess, chewiness and resilience were obtained.

Table 2. Effect of flour type and flour concentrations on the mean moisture, pH and total soluble solids (TSS) contents of *ofam* batter.

Sample description	Moisture (%)	pH	TSS (°Brix)
Flour type			
KF	52.70^{a} ± 4.65	5.53^{c} ± 0.07	2.30^{a} ± 0.25
RCF	55.13^{b} ± 1.85	5.48^{b} ± 0.07	2.38^{a} ± 0.26
SCF	52.88^{a} ± 3.58	5.41^{a} ± 0.05	2.62^{b} ± 0.30
Flour concentration			
20	49.47^{a} ± 2.77	5.54^{a} ± 0.07	2.25^{a} ± 0.38
17.5	51.80^{b} ± 2.22	5.50^{ab} ± 0.07	2.16^{a} ± 0.12
15	52.63^{b} ± 2.12	5.48^{bc} ± 0.01	2.50^{b} ± 0.17
12.5	57.70^{c} ± 1.75	5.43^{cd} ± 0.05	2.67^{b} ± 0.25
10	56.24^{c} ± 1.56	5.40^{d} ± 0.08	2.59^{b} ± 0.14

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

Colour analysis of batter and ofam

The colours of *ofam* batters and baked *ofam* samples were measured by a CR-300 Chromameter (Konica Minolta CR series, NJ 07446, USA). The CIE L, a, b colour system was used to measure the colour (MacDougall, 2010). Measurements were taken in triplicate and their mean values were used to represent the colour values of the samples. The total colour difference (ΔE) for each baked sample was calculated using the colour of their respective batters as a reference point. The values for the Browning index, Chroma and the Hue angle of the batter and *ofam* were then calculated using the following expression:

$$\Delta E = \left[\left(L_o - L\right)^2 + \left(a_o - a\right)^2 + \left(b_o - b\right)^2 \right]^{\frac{1}{2}} \quad (1)$$

where subscript 'o' is the initial value for the blanched ripe plantain puree.

$$BI = \left[\frac{100.\left(x - 0.31\right)}{0.17} \right] \quad (2)$$

Where x is defined as:

$$x = \frac{a + 1.75L}{5.645L + a - 3.01b} \quad (3)$$

$$Chroma\,(c^*) = (\mathrm{a}^2 + b^2)^{\frac{1}{2}}$$

$$\mathrm{h}^o = \tan^{-1}\left(\frac{a}{b}\right) \quad (4)$$

Consumer acceptance test

Fifty untrained panellists participated in this study. They were made up of students and staff at the Food Research Institute (FRI) of the Council for Scientific and Industrial Research (CSIR). The evaluation was carried out in CSIR-FRI designated sensory laboratory which conforms to ISO 8589 standard. The criteria for recruitment were as follows:

(a) The panellists were older than 18 years;
(b) They were non-smokers;
(c) They had no allergies to any of the ingredients used in the preparation of *ofam* (that is, plantain, onion, ginger cayenne pepper, calabash nutmeg, African pepper, *kokonte*, steeped corn flour and roasted corn flour);
(d) They were willing and available to participate in the study.

Panellists were presented with three-digit coded samples. The codes were generated using XLSTATS version 2014 following a randomised design matrix. They were also served with plain crackers (unsalted) for palette cleansing and water to rinse their mouths in between samples. Each panellist evaluated 5 samples per day for appearance, external or crust colour, internal crumb colour, aroma, oiliness, hardness, stickiness, smoothness, sweetness, spiciness, flavour and overall acceptability on a 9-point Hedonic scale (1 represents dislike extremely, 5 represents neither like nor dislike, 9 represents like extremely) (Stone and Sidel, 2004).

Data analysis

Data were subjected to analysis of variance (ANOVA) using Statgraphics (Centurion XVI). Significantly different means were separated using Duncan's Multiple Range Test (DMRT) 5% significance level. Principal component analysis (PCA) was use to visualise the effect of flour types and concentrations on the sensory attributes of *ofam*. Graphical representation was by Microsoft Excel.

RESULTS AND DISCUSSION

Moisture content of ofam batter

The mean moisture contents of the batters were 52.7, 52.9 and 55.1% for *ofam* mixture containing *kokonte* flour (KF), steeped corn flour (SCF) and roasted corn flour (RCF), respectively (Table 2). An insignificant variation in

moisture contents for the different flour types was observed ($p > 0.05$). However, there were significant differences ($p < 0.05$) in moisture contents in the *ofam* as flour concentrations were varied. Generally, the batter moisture content decreased with increasing flour concentration. The mean moisture contents of the batter ranged from 56.2 to 49.5% for batter with flour inclusions at 10 and 20%, respectively. According to Zhou et al. (2014) moisture content of batters influences the quality, texture, volume, taste, aroma, flavour and mouthfeel of bakery products. These sensory attributes are influenced by moisture dependent reactions as gelatinization and Maillard reaction. The reduction of the batter moisture with increasing levels of flour inclusion may be attributed to the increasing concentration of hydrophilic sites such as starches and proteins which bind to the free water in the batter.

Ofam batter pH

The pH of the batter was influenced significantly by both the type of flour and its concentration ($p < 0.05$). Batter containing KF recorded the highest mean pH of 5.53 while the SCF containing batter recorded the lowest pH of 5.41. Also, mean batter pH ranging between 5.4 and 5.5 was recorded for batter samples with 10 and 20% flour concentrations, respectively (Table 2).

The taste of a cake is affected by its batter pH. Cakes with low pH levels would have an acidic sour flavour, whereas cakes with high pH will exhibit a soapy taste and a coarse texture. Generally, cakes have relatively high pH (6.5 - 7.5) owing to the presence of baking powder (sodium bicarbonate) acting as a leavening agent as observed by Masoodi et al. (2002).

Total soluble solids of batter (TSS)

The total soluble solids of a sample is indicative of the dissolved solids in the sample and its sweetness (Magwaza and Opara, 2015). The total soluble solids of the batter samples were influenced by both flour type and concentration. Batter containing SCF recorded the highest TSS of 2.62°Brix while KF batter recorded the lowest TSS value of 2.30°Brix. The SCF batter might be perceived to be sweeter than KF batter. This trend suggests that the flours contributed little in terms of TSS. As a result, the sweetness could be attributed largely to the ripe plantain used in the product. Generally, the batter TSS decreased with increasing flour concentration. *Ofam* batter samples containing 17.5% of flour had the least TSS value of 2.16°Brix. However, there was no statistical significance when compared with batter samples containing 20% flour (2.25°Brix). The highest mean TSS value of 2.59°rix was obtained for batter samples with 10% flour incorporation. The presence of soluble solids especially sugars in bakery products (cake) has been reported to increase gelatinization temperature, resulting in a tenderizing effect on the final product (Mariotti and Lucisano, 2014; Psimouli and Oreopoulou, 2012). The sugars may also influence the colour and aroma of the final product through Maillard reaction and Caramelization (Fennema, 1996; Purlis, 2010). The presence of the sugars also provides humectancy to the product and regulates the product's uptake and loss of water.

Colour characteristics of batter and baked ofam

The data for colour are presented in Table 3. The L value for the batter samples varied significantly with variations in flour types and flour concentrations ($p < 0.05$). Batter containing roasted corn flour (RCF) was the darkest with L value of 30.39 and KF batter obtained the lightest colour (L value of 45.55). This was expected as the RCF was the darkest in colour among all the flour samples.

The RCF batter also had the highest intensity of redness (a = 6.24) and yellowness (b = 12.85). This could have been as a result of the combination of the light brown colour and the reddish colour of the unrefined palm oil used in the formulations. The variations in the redness (a) and the yellowness (b) of both the batter and the baked products were statistically significant ($p < 0.05$).

There was a general increase in L value with increasing four concentrations. Batter with 10% flour recorded the lowest mean L value of 37.81 while the batter with 20% flour recorded the highest mean L value of 40.43. Batter samples with 17.5 and 20% flours recorded the highest a (5) and b (12.29) values, respectively. It is noteworthy that the differences in the colour parameters of the batter at different flour concentrations were insignificant ($p > 0.05$). This implies that the variations in flour concentrations between 10 and 20% did not affect the colour of the batter.

The Hue angle and the Chroma of the batter ranged from (RCF = 64.16 to KF = 73.6) and (SCF = 11.41 to RCF = 14.32), respectively. The KF batter had a more yellowish tone than the rest of the samples. The variations in both the Hue angle and the Chroma for the different flour concentrations were insignificant ($p > 0.05$). The Hue angle ranged between 68.60 and 70.94 for the batter for 17.5 and 20% flours, respectively. Batter containing 10% flour recorded the lowest Chroma of 11.42, while the highest Chroma reading was observed for batter containing 20% flour concentration.

Comparatively, there was an increase in brownness when all the batters were baked. The L values of the products decreased significantly after baking. Results indicate that the variations in the L values for the *ofam*

Table 3. Effect of flour types and concentrations on the colour characteristics of *ofam* batter and baked *ofam*.

Flour type	Batter					Baked *ofam* crust					ΔE	BI
	L	a	b	H°	C	L	a	B	H°	C		
KF	45.33^{c} ± 1.17	3.49^{a} ± 0.49	11.87^{b} ± 0.88	73.68^{c} ± 1.52	12.38^{b} ± 0.95	26.21^{b} ± 1.64	4.70^{a} ± 0.78	6.25^{ab} ± 1.86	52.15^{ab} ± 6.00	7.85^{ab} ± 1.86	20.08 ± 2.35	9.53^{ab} ± 2.11
RCF	30.39^{a} ± 1.57	6.24^{b} ± 1.23	12.85^{c} ± 1.20	64.16^{a} ± 3.93	14.32^{c} ± 1.38	24.11^{a} ± 1.94	4.09^{a} ± 1.29	5.11^{a} ± 2.20	50.19^{a} ± 4.16	6.56^{a} ± 2.50	10.34 ± 4.39	8.49^{a} ± 3.03
SCF	42.88^{b} ± 1.47	3.63^{a} ± 0.35	10.81^{a} ± 1.06	71.33^{b} ± 1.74	11.41^{a} ± 1.06	26.15^{b} ± 132	4.77^{a} ± 0.60	6.90^{b} ± 1.93	54.40^{b} ± 5.54	8.84^{b} ± 1.86	17.42 ± 2.61	10.41^{b} ± 2.23
Flour concentration (%)												
20	40.43^{a} ± 8.16	4.29^{a} ± 1.13	12.29^{b} ± 1.029	70.94^{a} ± 4.03	13.05 ± 1.21	26.34^{b} ± 1.15	5.42^{c} ± 0.30	8.09^{b} ± 0.66	56.09^{bc} ± 3.15	9.75^{b} ± 0.49	15.21^{ab} ± 6.20	12.27^{b} ± 0.72
17.5	39.46^{a} ± 6.55	5.00^{a} ± 2.25	12.24^{b} ± 1.09	68.60^{a} ± 6.66	13.32 ± 1.91	24.64^{a} ± 1.67	4.24^{ab} ± 0.59	4.46^{a} ± 0.96	47.25^{a} ± 3.62	6.29^{a} ± 1.05	17.36^{b} ± 3.19	7.86^{a} ± 1.05
15	40.10^{a} ± 5.96	4.34^{a} ± 0.93	12.35^{b} ± 1.64	70.76^{a} ± 2.24	13.10 ± 1.82	23.79^{a} ± 1.74	3.51^{a} ± 0.62	4.75^{a} ± 1.36	52.64^{b} ± 4.41	5.92^{a} ± 1.44	18.62^{b} ± 3.14	7.77^{a} ± 1.66
12.5	39.87^{a} ± 7.15	4.47^{a} ± 0.81	11.79^{b} ± 0.43	69.26^{a} ± 3.54	12.64 ± 0.48	24.94^{a} ± 0.73	3.93^{ab} ± 0.76	4.33^{a} ± 0.78	47.94^{a} ± 4.11	5.86^{a} ± 1.02	17.24^{b} ± 5.32	7.24^{a} ± 1.37
10	37.81^{a} ± 7.09	4.18^{a} ± 1.99±	10.54^{a} ± 1.41	69.06^{a} ± 6.73	11.42 ± 1.98	27.75^{c} ± 0.76	5.49^{c} ± 0.32	8.61^{b} ± 0.89	57.33^{c} ± 3.12	10.23^{b} ± 0.76	11.32^{a} ± 5.15	12.23^{b} ± 0.80

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

were statistically significant ($p < 0.05$). This implies that the differences in the flour samples used and the variations in the flour concentration influenced the L values of the baked *ofam* samples. The baked samples containing RCF recorded the least L value of 24.11, showing the darkest colouration, while KF recorded the highest L value among the three flour types. However, the differences in the L values for *ofam* containing KF and SCF were insignificant ($p > 0.05$). The darkening of cakes during baking has been attributed to non-enzymatic browning phenomenon.

The yellowness (b) and redness (a) of the baked *ofam* samples were statistically significant ($p < 0.05$). The baked *ofam* samples decreased in the yellowness (b) compared to their respective batters. *Ofam* containing RCF was the least in terms of the yellow colour intensity (b = 5.11) while SCF *ofam* samples were the highest (b = 6.90). However, the yellow colour of *ofam* with KF was not statistically different from RCF and SCF.

There was no specific trend observed for the redness (a-value) of baked products. For the different flour samples, KF and RCF recorded an increase in redness after baking from 3.5 to 4.7 and 3.6 to 4.8, respectively. *Ofam* samples with 20 and 10% flour concentrations also experienced an increase in redness relative to that of their respective batter as their final values for redness (a-value) were 5.42 and 5.49, respectively. The final redness (a-value for *ofam* containing RCF, however, decreased from 6.24 (being the a-value for its batter) to 4.09 (a-value for the baked product). A decreasing redness was also observed for *ofam* samples containing 17.5, 15.0 and 12.5% of flours compared to their respective batter samples. These differences in the redness of the samples could be attributed to the differences in flour types and flour interactions with other ingredients in the products during baking.

There was also a general decrease in the Hue angle (H°) and Chroma (C) of the baked products compared to their respective batters. Hue angle values recorded were 50.2, 52.2 and 54.4 for *ofam* samples containing RCF, KF and SCF, respectively. The reduced H-values for the baked products indicate a shift of the colour of the samples from a yellow dominance to an increase in redness.

The total colour difference (ΔE) accounts for the differences in the colour of the baked products compared to their respective batters. The ΔE of the products were significantly influenced by both the type of flour used and the variations in the flour concentrations ($p < 0.05$). The RCF *ofam* samples had the least ΔE of 10, while KF recorded the highest (20.1).

The samples with 15% flour had the highest ΔE of 18.6 while samples with 10% flour recorded the lowest value of 10.2. According to Rodríguez-García et al. (2012), colour differences of ΔE > 3 are obvious to the human eye. It is consistent with this current study as all the colour changes in the baked samples compared to their respective batter were obvious. The similarities existing in the ΔE of the *ofam* samples containing 20% flour and the samples with other flour concentration could be as a result of their net change in their ΔE values being less than 3.

The Browning index (BI) measures the degree

of browning in the product. The browning which occurred as a result of the thermal treatment is attributed to the Maillard reaction between amino acids and reducing sugars and caramelization of sugars (Fennema, 1996; Gómez et al., 2008; Peressini and Sensidoni, 2009; Purlis, 2010; Toyosaki and Koketsu, 2007). Similar to ΔE, the BI was also significantly ($p < 0.05$) influenced by both the flour type and concentrations. *Ofam* containing RCF recorded the lowest BI of 8.5 while SCF recorded the highest BI of 10.4. The average BI for *ofam* containing 12.5% flour, with 7.2 being the lowest. *Ofam* containing 20% flour obtained the highest BI of 12.3. Browning index of the *ofam* samples was largely influenced by the type of flour used. The BI obtained for the *ofam* samples in this study were lower than values usually obtained for cakes. These variations in the BI reported in the various studies could be attributed to differences in the product formulations.

Viscosity of ofam batter

The viscosity of the *ofam* batter was influenced by both flour type and variation in flour concentration. In general, for spindle speeds of 40, 60 and 80 rpm, RCF batter recorded the highest average viscosity ranging from 8.3 to 14.6 Pa.s for 10 and 20% flour concentrations, respectively (Figure 2). This was followed by SCF batter 4.38 Pa.s (10% flour concentration) to 10.09 Pa.s (20% flour concentration), while the KF batter had the least viscosity values of 4.19 Pa.s (10% flour concentration) to 9.28 Pa.s (20% flour concentration). The starch properties in the flours would influence the water absorption hence affecting the viscosity food of the matrixes.

Results also indicated that the batter viscosities increased with increasing flour concentration (Figure 2). However, the most remarkable changes occurred at higher flour inclusion levels (that is, 17.5 and 20%). According to Bourne (2002), there is a direct non-linear relationship between the concentration of a solute and viscosity at a constant temperature. The increase in the concentration of the flour increases the solid matter in the batter which impedes the rotational movement of the spindle during the viscosity measurement. However, the increase in the impedance of the spindle results in high viscosity values. The viscosity of the batter would have a direct relationship with the batter density as the changes in the batter viscosity were a result of increasing solids. The batter exhibited a pseudoplastic behaviour; the average batter viscosities decreased with increasing spindle speed (from 40 to 80 rpm). This behaviour is typical of cake batters, fruit juice concentrates, apple sauce, and banana puree.

There was an observed decrease in the viscosity of the batter at the various spindle speeds with time. This behaviour may require further investigation to determine whether the batter would exhibit a thixotropic behaviour or shear thinning, which are both typical of starch paste.

Textural characteristics of baked ofam products

Results of the texture profile analysis (TPA) of baked *ofam* samples are presented in Table 4. The hardness of the *ofam* crumbs was affected by both the flour type and varying flour concentration. The variations in the hardness of the *ofam* crumbs as influenced by the flour type and flour concentrations were statistically significant ($p < 0.05$). The average hardness of the crumb was 966.8, 1378.6 and 1542.5 g Force for *ofam* containing KF, SCF, and RCF, respectively. There was a direct linear relationship between the viscosity of the batters and their corresponding baked product. Products that had a relatively high viscosity had high values for hardness. The high solids present in the high viscosity batter could limit the amount of free water available in the *ofam*, contributing to the increased hardness with increasing viscosity. This observation is not consistent with the finding of Lebesi and Tzia (2011) who observed a decrease in the firmness of cupcakes with increasing batter viscosity. The high batter viscosity helps in incorporating and retaining air bubbles, providing a stable voluminous cake, which is less dense. However, *ofam* lacks of ingredients with foaming properties, hence the increase in batter viscosity does not contribute to a less dense product. It is noteworthy that the properties and consumer expectation of cakes, in general, are different from *ofam*. The hardness of the *ofam* also increased with increasing flour concentration. *Ofam* with 20% flour recorded the highest mean value for hardness (1783.52 g Force) whereas the *ofam* samples containing 10% flour recorded the lowest mean value of hardness (784.0 g Force). Aziah et al. (2011) also reported an increasing trend of sponge cake hardness when the amount of mango pulp flour and mango peel flour is increased.

Fracturability is a measure of the force required to fracture the sample. It is normally experienced in products with a high degree of hardness and low cohesiveness (Al-Haq and Sugiyama, 2004; Szczesniak, 2002). The fracturability of the *ofam* samples was dependent on the type of flour used and also the concentration of flour added to the batter ($p < 0.05$). Whereas *ofam* containing KF had no fractures, *ofam* containing RCF had the highest fracturability (1665.25 g). The fracturability of the samples also decreases with decreasing flour inclusion, with mean values ranging from 678.54 to 1449.72 g for 10 and 20% flour inclusion, respectively. The sensory perception related to fracturability is crunchiness according to Barrett et al. (1994). This implies that the *ofam* samples containing RCF and SCF would be crunchier than the *ofam* samples

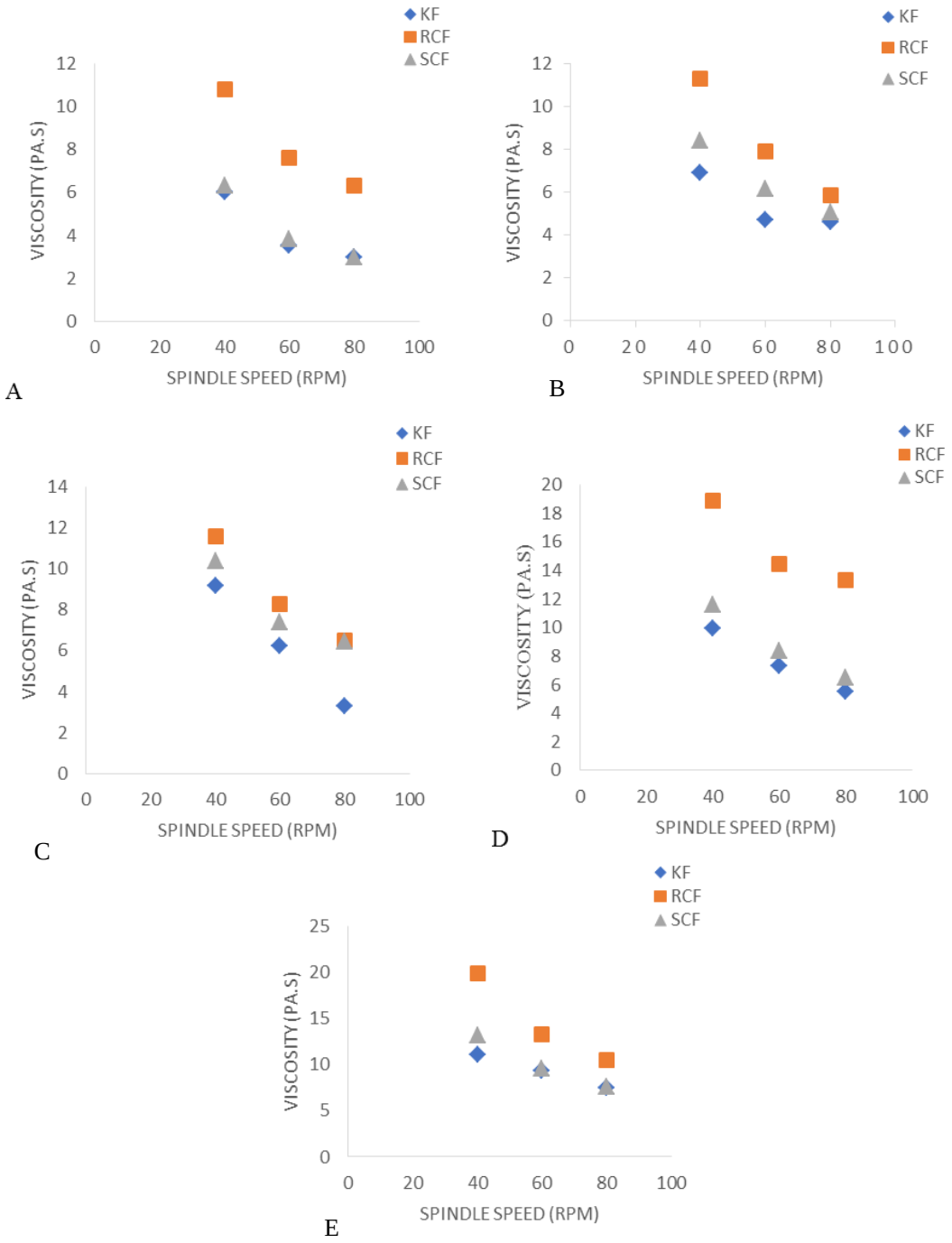

Figure 2. Effect of flour type and concentration and spindle speed on *ofam* batter viscosity. A 10% flour concentration; B 12.5% flour concentration; C 15% flour concentration; D 17.5% flour concentration; E 20% flour concentration.

containing KF. Likewise, the crunchiness of samples will increase with increasing flour inclusion.

Adhesiveness is measured as the ability of a sample to hold onto the probe after the first compression (Szczesniak, 2002). It is the measure of the force required to remove materials adhering to the palate during the normal eating process. The adhesiveness of RCF *ofam* samples and SCF *ofam* samples were significantly ($p < 0.05$) lower than *ofam* made from KF. There was no clear relationship observed in the effect of

Table 4. Effect of flour types and flour concentrations on the textural characteristics of baked *ofam*.

Flour Type	*Ofam*							
	Hardness(g)	Fracturability (g)	Adhesiveness (g.s)	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience
KF	$966.79^{a} \pm 241.13$	0.00^{a}	$-12.85^{a} \pm 7.25$	$0.28^{a} \pm 0.063$	$0.18^{c} \pm 0.02$	$178.07^{a} \pm 57.54$	$52.87^{a} \pm 27.42$	$0.06^{b} \pm 0.01$
RCF	$1541.49^{b} \pm 429.51$	$1665.25^{b} \pm 560.83$	$-2.74^{b} \pm 1.19$	$0.28^{a} \pm 0.04$	$0.12^{a} \pm 0.01$	$191.78^{ab} \pm 58.12$	$54.86^{a} \pm 22.93$	$0.04^{a} \pm 0.01$
SCF	$1378.55^{b} \pm 439.88$	$1447.57^{b} \pm 408.40$	$-3.11^{b} \pm 3.17$	$0.35^{b} \pm 0.08$	$0.17^{b} \pm 0.03$	$238.30^{b} \pm 106.72$	$90.41^{b} \pm 55.67$	$0.06^{b} \pm 0.01$
Flour concentration (%)								
20	$1783.52^{d} \pm 407.61$	$1449.72^{a} \pm 1133.52$	$-1.90^{b} \pm 0.63$	$0.39^{b} \pm 0.06$	$0.17^{b} \pm 0.04$	$295.79^{e} \pm 59.97$	$116.69^{d} \pm 41.79$	$0.06^{c} \pm 0.02$
17.5	$1539.35^{cd} \pm 354.76$	$1219.19^{a} \pm 963.61$	$-6.80^{ab} \pm 7.69$	$0.34^{b} \pm 0.05$	$0.17^{b} \pm 0.03$	$254.87^{d} \pm 49.59$	$88.34^{c} \pm 28.07$	$0.06^{c} \pm 0.01$
15	$1294.66^{bc} \pm 242.46$	$962.04^{a} \pm 750.04$	$-8.29^{b} \pm 9.70$	$0.28^{a} \pm 0.05$	$0.16^{ab} \pm 0.03$	$207.93^{c} \pm 49.59$	$60.28^{b} \pm 25.07$	$0.06b^{c} \pm 0.01$
12.5	$1076.49^{ab} \pm 131.78$	$878.54^{a} \pm 681.40$	$-6.42^{ab} \pm 6.12$	$0.26^{a} \pm 0.02$	$0.14^{a} \pm 0.03$	$148.67^{b} \pm 16.39$	$38.16^{ab} \pm 6.04$	$0.05^{ab} \pm 0.01$
10	$784.03^{a} \pm 202.35$	$678.54^{a} \pm 516.13$	$-7.77^{ab} \pm 3.88$	$0.25^{a} \pm 0.04$	$0.14^{a} \pm 0.02$	$106.26^{a} \pm 18.60$	$26.75^{a} \pm 6.40$	$0.04^{a} \pm 0.01$

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

the flour concentration on the adhesiveness of the *ofam* samples. However, samples with the highest flour concentration (20%) recorded the lowest adhesiveness (-1.90 g/s) while *ofam* samples containing 15% flour was relatively highly adhesive (-8.29 g/s). The variations in the adhesiveness of the *ofam* samples containing 17.5, 15, 12.5 and 10% flour concentrations were not statistically significant ($p > 0.05$).

Springiness is the extent of recovery between the first and second compressions. It is a measure of elasticity of a sample (Lu et al., 2010; Szczesniak, 2002). The TPA results indicated that the flour type influenced the springiness of the *ofam* samples significantly ($p < 0.05$). The KF and RCF *ofam* samples recorded the same values for springiness (0.28). The springiness of SCF *ofam* samples was the highest (0.35). There was an increasing trend in springiness with increasing flour concentration. The values of springiness ranged from 0.25 to 0.39 for *ofam* containing 10 and 20% flour, respectively.

The TPA results also showed an increase in cohesiveness, gumminess and chewiness to increasing flour concentration. However, these increments became significant only when the flour proportion was beyond 17.5%. Cohesiveness relates to the amount of force required to chew food. It gives an idea about the extent of the internal bonds present and the hardness of the samples (Friedman et al., 1963; Szczesniak, 2002).

Sensory characteristics of ofam

The mean sensory scores of *ofam* samples obtained for all the sensory attributes assessed; appearance, external/crust colour, internal/crumb colour, aroma, oiliness, hardness, stickiness, smoothness, sweetness, spiciness flavour and overall acceptability were above 5 on the nine-point Hedonic scale (Table 5). There were significant differences in all the fifteen formulations of *ofam* ($p < 0.05$) (Table 7). This indicates that even though the products exhibited some similarities in some attributes, on the whole, every product had its unique properties. The different formulations resulted in products with unique sensory properties.

Effect of flour types on sensory attributes of ofam

Results on the effect of flour type on the sensory acceptability of *ofam* are presented in Table 6. Generally, *ofam* samples containing KF were most preferred for appearance, smoothness and sweetness. However, the differences in the panellist preferences for *ofam* containing SCF and RCF compared to the KF *ofam* were statistically insignificant ($p > 0.05$).

The SCF samples also had the highest scores for attributes such as the external/crust colour, internal/crumb colour, aroma, oiliness, hardness, stickiness and flavour. The average responses for flavour for all three flour samples were statistically insignificant ($p > 0.05$). RCF samples were most preferred for spiciness. Expectedly, the differences in the spiciness of all the *ofam* types were also statistically insignificant ($p > 0.05$) as the quantities

Table 5. Effect of flour types and flour concentrations on the mean sensory acceptability of *ofam* sample.

Sample	Mean values											Overall
	Appearance	External Colour	Internal Colour	Aroma	Oiliness	Hardness	Stickiness	Smoothness	Sweetness	Spiciness	Flavour	
KF20	7.04^{c} ± 0.10	7.04^{d} ± 0.09	6.86^{bc} ± 0.10	7.76^{def} ± 0.10	7.50^{de} ± 0.11	7.01^{d} ± 0.12	5.71^{a} ± 0.15	7.13^{cd} ± 0.12	6.47^{c} ± 0.12	7.07^{de}± 0.11	7.03^{a} ± 0.12	6.53^{d} ± 0.09
KF10	6.87^{c} ± 0.09	6.96^{d} ± 0.1	6.89^{bc} ± 0.11	7.53^{bcde} ± 0.11	6.39^{a} ± 0.12	5.30^{a} ± 0.12	5.84^{a} ± 0.13	7.40^{de} ± 0.10	6.73^{cd} ± 0.11	6.44^{a} ± 0.11	7.26^{abc} ± 0.09	5.96^{a} ± 0.09
KF17.5	6.99^{c} ± 0.10	7.07^{d} ± 0.09	7.39^{d} ± 0.10	7.66^{cde} ± 0.09	7.39^{bc} ± 0.07	7.46^{e} ± 0.08	7.12^{c} ± 0.10	7.77^{f} ± 0.10	6.90^{de} ± 0.10	7.01 ^{cde} ± 0.11	7.60^{def} ± 0.09	7.36^{f} ± 0.11
KF15	8.04^{e} ± 0.86	7.77^{e} ± 0.09	7.87^{e} ± 0.10	7.86^{def} ± 0.09	7.54^{de} ± 0.08	8.10^{h} ± 0.10	7.30^{cd} ± 0.12	7.74^{f} ± 0.90	7.56^{e} ± 0.12	7.31^{d} ± 0.08	7.70^{ef} ± 0.09	7.51^{fg} ± 0.06
KF12.5	6.46b ± 0.14	6.30^{b} ± 0.01	6.77^{abc} ± 0.10	7.11^{a} ± 0.10	6.39^{a} ± 0.11	5.97^{b} ± 0.11	6.74^{b} ± 0.09	6.90^{c} ± 0.90	7.13^{d} ± 0.10	6.39^{a} ± 0.08	7.53^{cdef} ± 0.11	6.06^{ab} ± 0.11
RCF20	5.84^{a} ± 0.11	5.44^{a} ± 0.13	6.49^{a} ± 0.16	7.96^{ef} ± 0.10	7.91^{gh} ± 0.83	6.66^{c} ± 0.10	7.50^{def} ± 0.11	5.54^{a} ± 0.14	6.01^{a} ± 0.15	7.03^{cde} ± 0.09	7.21^{abc} ± 0.12	6.26^{bc} ± 0.09
RCF10	6.40^{b} ± 0.13	6.84^{cd} ± 0.10	6.86b^{c} ± 0.09	7.57^{bcde} ± 0.11	7.19^{bc} ± 0.13	6.67^{c} ± 0.15	7.34^{cde} ± 0.12	7.13^{cd} ± 0.11	6.66^{ab} ± 0.10	6.61^{ab} ± 0.12	7.11^{abc} ± 0.12	6.81^{d} ± 0.09
RCF17.5	7.57^{d} ± 0.11	7.83^{e} ± 0.12	7.31^{d} ± 0.10	7.74^{def} ± 0.10	7.26^{cd} ± 0.05	7.71^{ef} ± 0.10	7.64^{efg} ± 0.08	7.61^{ef} ± 0.08	6.87^{cd} ± 0.12	6.99^{cde} ± 0.12	7.66d^{ef} ± 0.08	7.77^{ghi} ± 0.09
RCF15	7.76^{de}± 0.10	7.73^{e} ± 0.09	7.94^{e} ± 0.08	7.59^{bcde} ± 0.10	7.57^{de} ± 0.10	7.97^{gh} ± 0.10	7.82^{fg} ± 0.10	7.90^{f} ± 0.96	7.20^{d} ± 0.12	7.36^{e} ± 0.10	7.64^{ef} ± 0.10	7.65h^{i} ± 0.09
RCF12.5	6.40^{b} ± 0.14	6.34^{b} ± 0.17	6.73^{ab} ± 0.11	7.39^{abc} ± 0.10	6.57^{a} ± 0.11	6.77^{cd} ± 0.11	7.07^{c} ± 0.09	6.76^{bc} ± 0.12	7.03^{cd} ± 0.12	6.72^{abcd} ± 0.17	7.49 ^{cdef} ± 0.11	6.66d^{e} ± 0.08
SCF20	6.53^{b} ± 0.08	6.23^{b} ± 0.10	7.29^{d} ± 0.15	8.53^{ef} ± 0.06	8.19^{h} ± 0.10	7.06^{d} ± 0.11	7.90^{g} ± 0.13	6.50^{b} ± 0.18	6.71^{bc} ± 0.15	6.93^{bcd} ± 0.09	7.14^{ab} ± 0.09	6.46^{cd} ± 0.06
SCF10	6.40^{b} ± 0.15	6.50^{b}± 0.15	7.07^{cd} ± 0.10	7.37^{abc} ± 0.11	7.30^{cd} ± 0.12	6.90^{cd} ± 0.12	7.67^{efg} ± 0.10	6.91^{c} ± 0.13	6.71^{bc} ± 0.14	6.67^{abc} ± 0.14	7.40^{bcde} ± 0.11	6.07^{ab} ± 0.12
SCF17.5	7.89^{de} ± 0.09	8.04^{e} ± 0.09	8.03^{e} ± 0.09	7.76^{def} ± 0.10	6.54^{a} ± 0.11	8.16^{h} ± 0.10	7.67^{efg} ± 0.09	7.03^{c} ± 0.15	6.94^{cd} ± 0.13	7.01^{cde} ± 0.11	7.73^{ef} ± 0.09	7.80^{ij} ± 0.09
SCF15	7.87^{de} ± 0.10	7.86^{e} ± 0.91	7.94^{e} ± 0.10	7.74^{def} ± 0.10	7.74^{ef} ± 0.10	8.04^{h} ± 0.10	7.80^{fg} ± 0.09	7.87^{g} ± 0.10	7.21^{d} ± 0.14	7.03^{cde} ±0.10	7.79^{f} ± 0.09	7.96^{i} ± 0.09
SCF12.5	6.53^{b} ± 0.13	6.56^{b}c ± 0.14	6.93^{bc} ± 0.10	7.33^{ab} ± 0.10	6.96^{b} ± 0.07	6.83^{cd} ± 0.12	7.21^{cd} ± 0.90	6.89^{c} ± 0.12	6.87^{cd} ± 0.12	6.71^{abcd} ± 0.15	7.34^{abcd} ± 0.11	6.54^{d} ± 0.09

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

Table 6. Effect of flour types and flour concentrations on the mean sensory acceptability of *ofam*.

Flour type	Mean values											Overall
	Appearance	External (Crust) Colour	Internal (Crumb) Colour	Aroma	Oiliness	Hardness	Stickiness	Smoothness	Sweetness	Spiciness	Flavour	
KF	7.08^{b}	7.03^{b}	7.15^{a}	7.58^{a}	7.15^{a}	6.77^{a}	6.55^{a}	7.39^{b}	6.96^{ab}	6.84^{a}	7.42^{a}	6.68^{a}
RCF	6.79^{a}	6.83^{a}	7.06^{a}	7.65^{ab}	7.06^{a}	7.16^{b}	7.48^{b}	6.99^{a}	6.75^{a}	6.94^{a}	7.42^{a}	7.02^{b}
SCF	7.04^{b}	7.04^{b}	7.45^{b}	7.75^{b}	7.45^{b}	7.40^{c}	7.65^{c}	7.04^{a}	6.89^{b}	6.87^{a}	7.48^{a}	6.97^{b}
Flour concentration												
20	6.47^{a}	6.23^{a}	6.88^{a}	8.08^{d}	7.87^{d}	6.91^{c}	7.03^{a}	6.39^{a}	6.40^{a}	7.01^{c}	7.13^{a}	6.41^{a}
10	6.56^{a}	6.77^{b}	6.94^{a}	7.49^{b}	6.96^{b}	6.29^{a}	6.95^{a}	7.14^{c}	6.70^{b}	6.57^{a}	7.26^{a}	6.28^{a}
17.5	7.48^{b}	7.65^{c}	7.58^{b}	7.71^{c}	7.06^{b}	7.78^{d}	7.48^{b}	7.47^{d}	6.90^{c}	7.00^{c}	7.66^{c}	7.64^{b}
15	7.89^{c}	7.78^{c}	7.92^{c}	7.72^{c}	7.62^{c}	8.03^{e}	7.64^{b}	7.84^{e}	7.32^{e}	7.23^{d}	7.71^{c}	7.70^{b}
12.5	6.46^{a}	6.40^{a}	6.80^{a}	7.27^{a}	6.63^{a}	6.52^{b}	7.01^{a}	6.83^{b}	7.01^{d}	6.61^{a}	7.44^{b}	6.41^{a}

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

Table 7. Multivariate test on the sensory acceptability of *ofam*.

Effect	Value	F	Hypothesis df	Error df	Significance
Sample Pillai's trace	1.842	13.402	168.00	12420.00	0.00
Wilks' Lambda	0.081	17.683	168.00	9420.995	0.00
Hotelling's trace	3.769	22.930	168.00	12266.00	0.00
Roy's largest root	2.006	148.271	14.00	1035.00	0.00

of the spices used for all the formulations were the same. The results indicate that consumers generally liked the spiciness of the products.

Ofam samples containing RCF were the most preferred (7.0) and the KF samples were the least preferred (6.68). The differences in the preferences RCF *ofam* and SCF *ofam* were statistically insignificant ($p > 0.05$). An earlier study indicated that consumers have different flour preferences for senescent plantain products (Adi et al., 2019). The preference of RCF *ofam* was in contrast with the finding by Adi et al. (2019), where majority of senescent plantain consumers preferred senescent plantain product with *kokonte.* The preference of *kokonte* could be due to the familiarity of the flour in such senescent plantain products. It means that it is possible for consumer preferences to change upon tasting alternatives.

Effect of flour concentrations on sensory acceptability of ofam

The mean consumer acceptance scores, which depict respondents' liking of *ofam* based on the flour concentration used are presented in Table 6. Results indicate that the most preferred *ofam* samples were the ones containing 15% flour. The liking for *ofam* containing 17.5% flour was comparable to the most preferred *ofam* sample, and the difference was statistically insignificant ($p > 0.05$). Samples containing 15% flour had the highest preference of all the attributes except oiliness. *Ofam* samples containing 20%, were the most preferred for oiliness. These samples seem to be less oily than the rest of the samples. The inclusion of more flour in the formulation could have increased the interface for oil absorption. The differences in the preferences of attributes such as aroma, stickiness, flavour and overall acceptability for *ofam* samples with 15 and 17.5% flour were statistically insignificant ($p > 0.05$). Implying that respondents preferred samples made from RCF and SCF, with average hardness. Dzomeku et al. (2007) reported on the sensory evaluation of four FHIA tetraploid hybrid for *kaakle* (a steam senescent plantain product) similar to *ofam*. The overall acceptability of the *kaakle* prepared with the inclusion of 20% flour was good. However, Edwige et al. (2014) reported between 10 and 15%, to be the acceptable levels for rice and maize flours in the formulation of both optimised steamed and baked *dockounou* (an Ivorian derivative of *ofam*).

Principal component analysis

The bi-plot (product-attribute) space using principal component (PC) 1 and 2 is presented in Figure 3. The similarity map of the attributes was defined by two principal components PC1 and PC2, accounting for 56.24 and 22.73%, respectively. From the PCA score plot, panellists' overall acceptance of the *ofam* samples was positively influenced by the internal colour, hardness, spiciness, stickiness, oiliness and aroma, and negatively influenced by appearance, external colour, flavour, smoothness and sweetness. Consumers seemed to prefer products containing 15 and 17.5% flour irrespective of the flour type. This seem to confirm the consumer preference of 15% maize flour inclusion for optimised *dockounou,* lower than the 10% inclusion of rice flour for optimised product reported by Edwige et al. (2014). The appearance, external/crust colour, internal colour, hardness, aroma and sweetness, contributed significantly to the overall differences among the products. These factors have also serve as very important consumer buying indicator.

Conclusion

The physicochemical characteristics of the *ofam* batter and baked *ofam* such as moisture, pH, Total Soluble Solids (TSS), L-value, viscosity, hardness and fracturability were influenced by both flour type and flour concentration. The type of flour used in the batter formulation influenced the *ofam* colour. Generally, the RCF batter was the most viscose and its *ofam* was the hardest. All the fifteen samples evaluated had their unique sensory differences. The RCF *ofam* was the most preferred by the panellist and KF was the least preferred. The sensory panellists generally preferred *ofam* with 15% incorporation. This would form the basis for the formulation of *ofam* powder mix. The different flour types influenced the sensory characteristics of the products differently. Further studies on the sensory acceptability of

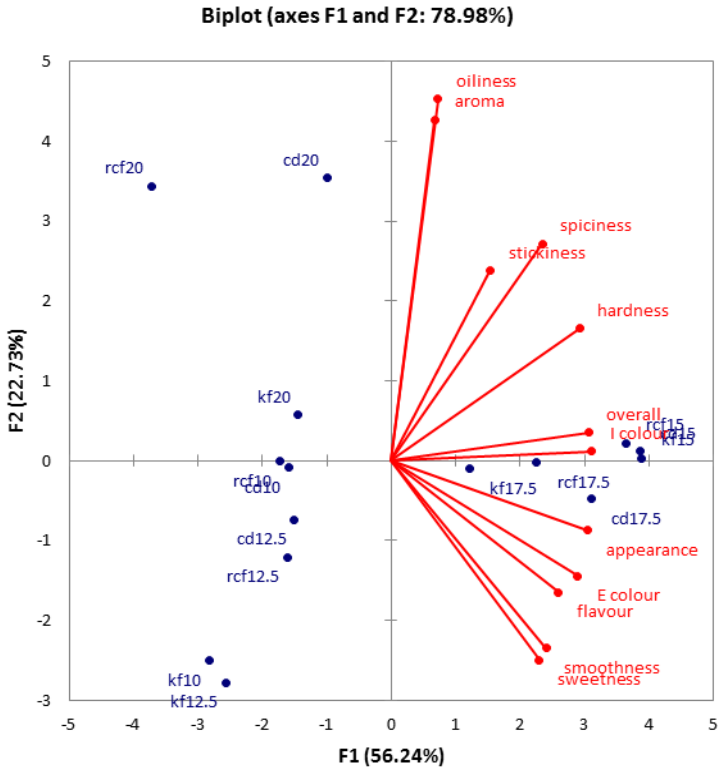

Figure 3. Principal component plot for *ofam* samples and their sensory attributes.

ofam containing high fibre flours need to be investigated to enhance the nutritional quality of the product.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Adi DD, Oduro IN, Tortoe C, Kwofie EM, Simpson BK (2018). Physicochemical characteristics and microbiological quality of senescent plantain products. Cogent Food and Agriculture 4:1441596.

Adi DD, Oduro IN and Tortoe Cn (2019). Consumer preference and quality expectations of senescent plantain products. Journal of Culinary Science and Technology pp. 1-16.

Agrahar-Murugkar D, Zaidi A, Kotwaliwale N, Gupta C (2016). Effect of egg-replacer and composite flour on physical properties, color, texture and rheology, nutritional and sensory profile of cakes. Journal of Food Quality 39(5):425-435.

Al-Haq MI, Sugiyama J (2004). Effect of degree of compression on texture profile parameters of pelican mango. Journal of Texture Studies 35:341-352.

Aziah AAN, Mim WL, Bhat R (2011). Nutritional and sensory quality evaluation of sponge cake prepared by incorporation of high dietary fiber containing mango (*Mangifera indica* var. Chokanan) pulp and peel flours. International Journal of Food Sciences and Nutrition 62(6):559-567.

Barrett A, Rosenberg S, Ross E (1994). Fracture intensity distributions during compression of puffed corn meal extrudates: Method for quantifying fracturability. Journal of Food Science 59(3):617-620.

Bourne M (2002). Food texture and viscosity: concept and measurement. Elsevier.

Dikeman CL, Fahey GC (2006). Viscosity as related to dietary fiber: a review. Critical Reviews in Food Science and Nutrition 46(8):649-63.

Dzomeku B, Darkey S, Bam R, Ankomah A (2007). Sensory evaluation of four ИПА tetraploid hybrids for kaakle (a local dish) in Ghana. Journal of Plant Sciences 2(6):640-643.

Edwige AEF, Severin KK, Rose-Monde M, Joseph KN, Sebastien NL (2014). Optimization of Dockounou Manufacturing Process Parameters. Sustainable Agriculture Research 3(526-2016-37788).

Fennema OR (1996). Food Chemistry, third ed/Ed. Marcel Dekker, New York.

Flore AEE, Séverin, KKA, Rose-Monde M, Essoh AE, Sébastien ANL (2013). Sensorial Characteristics of a senescent plantain empiric dish (Dockounou) produced in Côte d'Ivoire. Journal of Food Research 1(4):150.

Friedman HH, Whitney JE, Szczesniak AS (1963). The texturometer – a new instrument for objective texture measurement. Journal of Food science 28(4):390-396.

Gallagher E, Gormley T, Arendt E (2003). Crust and crumb characteristics of gluten free breads. Journal of Food Engineering

56(2-3):153-161.
Gallagher E, Gormley T, Arendt EK (2004). Recent advances in the formulation of gluten-free cereal-based products. Trends in Food Science and Technology 15(3-4):143-152.
Gómez M, Oliete B, Rosell CM, Pando V, Fernández E. (2008). Studies on cake quality made of wheat–chickpea flour blends. LWT-Food Science and Technology 41:1701-1709.
Kirk S, Sawyer R (1991). Pearson's composition and analysis of foods, Longman Group Ltd.
Lebesi DM, Tzia C (2011). Effect of the addition of different dietary fiber and edible cereal bran sources on the baking and sensory characteristics of cupcakes. Food Bioprocess Technology 4(5):710-722.
Lu TM, Lee CC, Mau JL, Lin SD (2010). Quality and antioxidant property of green tea sponge cake. Food Chemistry 119:1090-1095.
MacDougall D (2010). Colour measurement of food: principles and practice. In "Colour Measurement" (Elsevier) pp. 312-342.
Magwaza LS, Opara UL (2015). Analytical methods for determination of sugars and sweetness of horticultural products - A review. Scientia Horticulturae 184:179-192.
Mariotti M, Lucisano M (2014). Sugar and Sweetners. In "Bakery Product Science and Technology, pp. 199-221.
Marston K, Khouryieh H, Aramouni F (2016). Effect of heat treatment of sorghum flour on the functional properties of gluten-free bread and cake. LWT-Food Science and Technology 65:637-644.
Masoodi F, Sharma B, and Chauhan G (2002). Use of apple pomace as a source of dietary fiber in cakes. Plant Foods for Human Nutrition 57(2):121-128.
Mondal A, Datta A. (2008). Bread baking–a review. Journal of Food Engineering 86(4):465-474.
Nashat S, Abdullah M (2016). Quality evaluation of bakery products. In "Computer Vision Technology for Food Quality Evaluation (Second Edition)", Elsevier pp. 525-589.
Niba LL (2005). Carbohydrates: Starch. Hui YH Handbook of Food science, Technology and Engineering. Taylor and Francis 4.
Peressini D, Sensidoni A (2009). Effect of soluble dietary fibre addition on rheological and breadmaking properties of wheat doughs. Journal of Cereal Science 49(2):190-201.
Psimouli V, Oreopoulou V (2012). The effect of alternative sweetners on batter rheology and cake properties. Journal of Science of Food and Agriculture 92(1):99-105.
Purlis E (2010). Browning development in bakery products–A review. Journal of Food Engineering 99(3):239-249.
Reppas C, Greenwood DE, Dressman JB (1999). Longitudinal versus radial effects of hydroxypropylmethylcellulose on gastrointestinal glucose absorption in dogs. European Journal of Nutrition 8(3):211-219.
Rodríguez-García J, Puig A, Salvador A, Hernando I (2012). Optimization of a sponge cake formulation with inulin as fat replacer: structure, physicochemical, and sensory properties. Journal of Food Science 77(2):189-197.
Schemann M, Ehrlein HJ (1986). Postprandial patterns of canine jejunal motility and transit of luminal content. Gastroenterol 90(4):991-1000.
Severin KKA, Edwige A, Rose-Monde M, Koffi Y, Essoh AE, and Sebastien NL (2013). Physicochemical and nutritional characteristics assessement of two different traditional foods prepared with senescent plantain. African Journal of Food Science 7(3):51-55.
Stone H, Sidel JL (2004). Sensory Evaluation Practices. Amsterdam; Boston: Elsevier Academic Press.
Sumnu G (2001). A review on microwave baking of foods. International Journal of Food Science and Technology 36(2):117-127.
Szczesniak AS (2002). Texture is a sensory property. Food Quality and Preference 13(4):215-225.
Toyosaki T, Koketsu M (2007). Antioxidant effects of the water-soluble fraction of baked sponge cake made with silky fowl egg: comparison with White Leghorn egg. British Poultry Science 48(4):449-453.
Yolacaner ET, Sumnu G, Sahin S (2017). Microwave-assisted baking. In "The Microwave Processing of Foods. Elsevier pp. 117-141.
Zhou W, Therdthai N, Hui Y (2014). Introduction to baking and bakery products. Bakery Products Science and Technology pp. 1-16.

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Contribution of fish in improving micronutrients content in complementary foods for children aged 6 to 23 months in Lindi Rural District

Hope Masanja*, Theresia Jumbe and Renatha Pacific

Department of Food Technology, Nutrition and Consumer Sciences, Sokoine University of Agriculture, P. O. Box 3006, Morogoro, Tanzania.

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Lindi region has high stunting prevalence of about 35%, and one of the factors that cause stunting is inadequate intake of micronutrients for children under 2 years old. This study aimed at assessing contribution of fish in improving micronutrients, specifically vitamin A, zinc and iron contents in complementary foods for children aged 6 to 23 months old children in Lindi Rural District. A cross-sectional study was done; interviews were conducted on 212 caregivers with children aged 6 to 23 months at Mchinga Ward. Information collected includes demographic information and commonly consumed complementary foods for targeted children through the use of 24 h dietary recall. Also, laboratory analysis for zinc, iron, vitamin A contents and proximate composition were done for commonly consumed foods. About 89.2% of children were given fish-based complementary foods. On average, fish-based complementary foods had higher vitamin A concentrations (279 µg RE/100 g serving) compared to non-fish-based complementary foods (4 µg RE/100 g serving), but low in iron and zinc concentrations (0.66 and 0.067 mg/100 g serving, respectively) than non-fish-based complementary foods (0.74 and 0.074 mg/100 g serving respectively). Furthermore, fish-based complementary foods had higher proximate composition (except for % moisture content) compared to non-fish-based complementary foods.

Key words: Lindi, fish, complementary foods, children, micronutrients.

INTRODUCTION

Undernutrition is still a problem in developing countries, especially high prevalence of stunting which signifies chronic under nutrition in general. The number of stunted children has steadily increased from 50.6 million in 2000 to 58.7 million in 2017 (Development Initiatives, 2018). Undernutrition can permanently impair a child's physical and cognitive development. The damage often leads to poorer school performance, hence future income reductions. These children are also at increased risk of illness and disease in their adulthood (Wells et al., 2020). In developing countries dietary energy forms the biggest proportion of complementary foods for children, but with

*Corresponding author. E-mail: hopemasanja@gmail.com. Tel: +255 784 150 351.

low micronutrients levels causing micronutrient deficiency (Abeshu et al*.,* 2016). Meeting micronutrients requirements during the early days of life contributes to preventing and correcting stunting (Shafique et al*.,* 2016). Among others, adequate intake of vitamin A, zinc, iron and universal promotion of iodized salt is essential in stunting reduction (Dewey, 2016). Adequate intake of zinc has a positive effect on size growth, especially in children under 2 years of age (Liu et al*.,* 2018). Iodine and iron are known to be essential for metabolic rate, development of body structures and neuronal maturation, in case of deficiency in early life stages it can lead to brain damage in children (Georgieff, 2017). Deficiency of iron may also lead to anemia. Vitamin A intake is essential for the immune system and reduce the child's risk of contracting and dying from infections like measles, and diarrheal illnesses (Huang et al*.,* 2018). These micronutrients can be accessible to the child through breast milk and the complementary foods when breast milk alone is no longer sufficient to meet nutritional requirements. Hence, appropriate complementary foods can promote good nutritional status and growth in infants and young children (Aguayo, 2017). Also, complementary feeding strategies have been linked with a reduction in stunting in food insecure populations (Martinez, 2018). In Tanzania, unfortunately most complementary foods are usually cereal-based served with little or no vegetables, and often lacking animal proteins hence low in micronutrient levels (Makori et al*.,* 2018).

In coastal areas, fish is the major source of animal protein. It is an irreplaceable animal source especially for the species that are consumed as whole such as sardines (*dagaa*) as they provide essential nutrients including the micronutrients of high bioavailability which are found in limiting amounts in the diet (Tilami and Sampels, 2017). Some of the micronutrients available in fish include vitamin A, vitamin D, selenium, phosphorus, calcium, iron and zinc. Also they consist of polyunsaturated n-3 fatty acids which are essential in human nutrition as they are involved in many metabolic functions. Due to its availability and accessibility in coastal regions, promotion of fish-based complementary foods is important and its consumption can be used as an effective food-based strategy to enhance micronutrient intake in fishing communities. The main objective of this paper is to assess the micronutrient contribution of fish-based complementary foods compared to non-fish complementary foods commonly offered to children of age 6-23 months at Lindi. Lindi region is one among other coastal regions in Tanzania practicing fishing activities as part of their livelihood and has high prevalence of stunting of 35.2% for under-five years children which is more than the national prevalence of 34.7% (National Bureau of Statistics and ICF Macro, 2015). For all of the above, we assessed iron, zinc and vitamin A contents in fish and non-fish-based commonly used complementary foods in Lindi Rural District.

MATERIALS AND METHODS

A cross-sectional study was conducted in villages practicing fishing activity Mchinga A and Mchinga B, which are located along the Indian Ocean in Lindi Rural District at Mchinga Ward. A total of 212 mother-child pairs with children aged 6-23 months were randomly selected. Interviews were conducted among the selected mother-child pairs with the use of questionnaires as tool for data collection. The study involved mothers, since in Tanzanian culture, they are expected to be the ones who are responsible for planning meals and feeding their children. The questionnaire consisted of semi structured questions aimed at obtaining socio-demographic information of the mother and her child, and types of complementary foods consumed by children (both fish-based and non-fish-based) using the 24 h dietary recall for children through their caregivers. Mothers' socio-demographic information was important as they have influence on the choices they do for their children's feeding practices. Through interactive 24 h dietary recall, caregivers not only mentioned all foods and fluids consumed by their children but also ingredients and amounts used in meal preparation and quantities of consumed foods or drinks.

Sample identification, preparation and nutrient determination of common fish-based and non-fish-based complementary foods

The common types of fish-based and non-fish-based complementary foods consumed by the children aged 6-23 months were obtained from the 24 h dietary recall data. From this, information on foods with highest frequency for both fish-based complementary foods (Figure 2) and non-fish-based complementary foods (Figure 3) was obtained. About 17 food samples were prepared by 10 randomly recruited mothers using various locally obtained ingredients (Table 1) with amounts, preparation and cooking methods obtained from the 24 h dietary recall data.

Samples were then collected and transported to the Department of Food Technology, Nutrition and Consumer Sciences Laboratory in Sokoine University of Agriculture, Morogoro, Tanzania. Upon arrival, samples were stored in the laboratory freezer (-40°C) for 12 h. Samples were then ground to ensure homogeneity and subjected into procedures for (i) proximate analysis following Association of Official Analytical Chemists (1995) method No 925.10, (ii) for minerals content (iron and zinc) determination following Association of Official Analytical Chemists (1995) method No. 968.08, by Atomic Absorption Emission Spectrophotometer (AA 630-12) and total vitamin A for both β-carotene and retinol content were determined using ultra-violet visible spectrophotometer. Each analysis was conducted in duplicate.

Mineral contents

Minerals (zinc and iron) were analyzed following AOAC (1995) method No 925.10. 5 g of the homogenized water bath warmed sample was mixed with 10 ml concentrated nitric acid, slowly boiled and evaporated down to 5 ml on a hot plate and left to cool. The sample was then filtered using No. 1 Whatman filter paper into volumetric flask and diluted to 100 ml mark using distilled water. The samples were analyzed for iron and zinc using Shimadzu Atomic Absorption Spectrophotometer (AAS) UNICAM 919, England.

Vitamin A (Retinol)

10 ml of homogenized water bath warmed oil sample was taken

Table 1. Summary of cooked food samples for laboratory analysis.

Number of samples	Food sample
1	Unrefined maize porridge (UM)
2	Cassava porridge (C)
3	Refined maize porridge (RM)
4	Unrefined maize porridge, millet, beans and rice (UMMBR)
5	Unrefined maize porridge, millet, groundnuts and rice (UMMGR)
6	Boiled fish (*Dagaa*) with water and salt (BF-S)
7	Boiled fish (*Tasi*) with water and salt (BF-T)
8	Boiled fish (*Kibua*) with water and salt (BF-K)
9	Refined maize flour and water for stiff porridge with fish (*Dagaa*), tomatoes, coconut cream, onions and salt for stew (FSSP-S)
10	Refined maize flour and water for stiff porridge with fish (*Tasi*), tomatoes, coconut cream, onions and salt for stew (FSSP-T)
11	Refined maize flour and water for stiff porridge with fish (*Kibua*), tomatoes, coconut cream, onions and salt for stew (FSSP-K)
12	Fish (*Dagaa*) with irish potatoes, tomatoes, coconut cream, onions, salt and water (PTF-S)
13	Fish (*Tasi*) with irish potatoes, tomatoes, coconut cream, onions, salt and water (PTF-T)
14	Fish (*Kibua*) with irish potatoes, tomatoes, coconut cream, onions, salt and water (PTF-K)
15	Fish (*Dagaa*) with green banana, coconut cream, tomatoes, onions and salt (BNF-S)
16	Fish (*Tasi*) with green banana, coconut cream, tomatoes, onions and salt (BNF-T)
17	Fish (*Kibua*) with green banana, coconut cream, tomatoes, onions and salt (BNF-K)

**Dagaa* (*lupapa* type) - English named as Indian oil sardine (*Sardinella longiceps*); **Tasi* - English named as Rabbit fish (*Siganus sutor*); **Kibua* - English named as Indian mackerel (*Rastrelliger kanagurta*) (Food and Agriculture Organization, 1983); *The abbreviations will be used in the text.

into 22 ml screw cap test tube; then 1 ml of 5% pyrogallol with 1% ascorbic acid was added followed by 2 ml of 50% alcoholic potassium hydroxide solution and vortex mixed for 15 s followed by the ultrasonic agitation for 60 min at 45°C. Further, 2 ml of distilled water was added followed by the addition of 2 ml extraction mixture of n-Hexane: Ethyl acetate (90%:10%). The mixture was then vortex mixed for 15 s. The organic phase was transferred into another clean test tube (Lietz et al*.,* 2001). The extraction was repeated twice and organic phases combined which were then washed with 2 ml solution of sodium sulfate. The organic phase was then transferred to a clean test tube and evaporated to dryness. The dried extract was eluted with 2 ml absolute alcohol, vortex mixed for 15 min and absorbance read at 325 nm using X-Ma 3000 UV spectrophotometer. Sample concentrations were calculated using the following equation (Craft, 2008);

$$Rc = \frac{A \times El \times 10000}{E \times S \times Et}$$

Where; Rc = Retinol concentration (mg/L)
A = Sample absorbance as read at 325 nm using UV-Visible spectrophotometer (The machine calibrated using pure ethanol as blank sample)
El = Elution volume
E = Extinction coefficient of retinol in ethanol (1850)
S = Amount of sample taken for analysis
Et = Extraction volume.
10000 = conversion factor from % to mg/l

Vitamin A (β-carotene)

A measurement of 10 ml of water bath was warmed at 40°C. The samples were extracted with 150 ml cold acetone and poured into 30 ml petroleum ether (BP 40-60°C) layer, then washed with distilled water until free from any acetone (Rodriguez-Amaya and Kimura, 2004). Samples were then saponified for 12 h with 30 ml 60% Methanolic potassium hydroxide, washed with distilled water until free from potassium hydroxide by controlling the washings using phenolphthalein indicator. The clear extracted carotenoids were then passed through the activated anhydrous sodium sulphate, and collected into volumetric flask. Absorbencies were read at 450 nm sin UV-Visible spectrophotometer. Standard calibration plot was prepared by dissolving 10 mg of standard β-carotene into 100 ml dry petroleum ether, and actual concentration of the obtained standard solution was determined. From this, serial distributions were prepared and their absorbency read at 450 nm which were used to construct a standard plot. Sample concentrations were calculated using the obtained linear regression equation.

Data analysis

Collected data was entered and subjected to statistical analysis using Statistical Product and Service Solutions (SPSS) version 20 to compute for descriptive and inferential statistics. Descriptive statistics were computed including the frequencies, means and modes. Analysis of variance (ANOVA) was done for the laboratory results at 95% confidence interval ($P \leq 0.05$) to assess significance difference of vitamin A, iron and zinc among fish-based and non-fish-based complementary foods. Furthermore, contribution of commonly used complementary foods for children on meeting the recommended daily intake (RDI) for vitamin A, iron and zinc was assessed through percentage determination of vitamin A, iron and zinc concentration per serving contributed to the total RDI respectively.

RESULTS

Socio-demographic information of mother-child pair

A big proportion (98.1%, n = 206) of respondents were the biological mothers of the children (Table 2). Most

Table 2. Socio-demographic information of the mother-child pair.

Variable	Frequency	Percent
Age group distribution		
<20	29	13.9
20-29	97	47.1
30-39	66	31.7
<40	15	7.2
Child-caregiver relationship		
Mother	206	98.1
Others	4	1.9
Area of residence		
Mchinga 1	122	57.5
Mchinga 2	90	42.5
Marital status		
Married (monogamous)	121	57.1
Married (polygamous)	15	7.1
Widowed	1	0.5
Divorced	21	9.9
Single	54	25.5
Occupation		
Housewife	41	19.3
Farmer	145	68.4
Formally Employed	1	0.5
Self-employed	14	6.6
Farmer and self-employed	6	2.8
Farmer and livestock keeper	4	1.9
Average income per month (TSh)		
0	23	10.8
<100000	122	57.5
100000-199999	32	15.1
200000-299999	9	4.2
300000-399999	21	9.9
>=400000	5	2.4
Level of education of the caregiver		
Never gone to school	71	33.5
Primary school	121	57.1
Secondary school	19	9.0
High school	1	0.5
Age of within which caregivers finished their education		
Within 2 years	11	9.0
Within 3 to 5 years	33	27.1
More than 5 years	78	63.9
Sex of the children		
Male	100	47.2
Female	112	52.8

Table 2. Contd.

Age of the children		
6 to 8 months	51	24.2
9 to 11 months	48	22.7
12 to 23 months	112	53.1

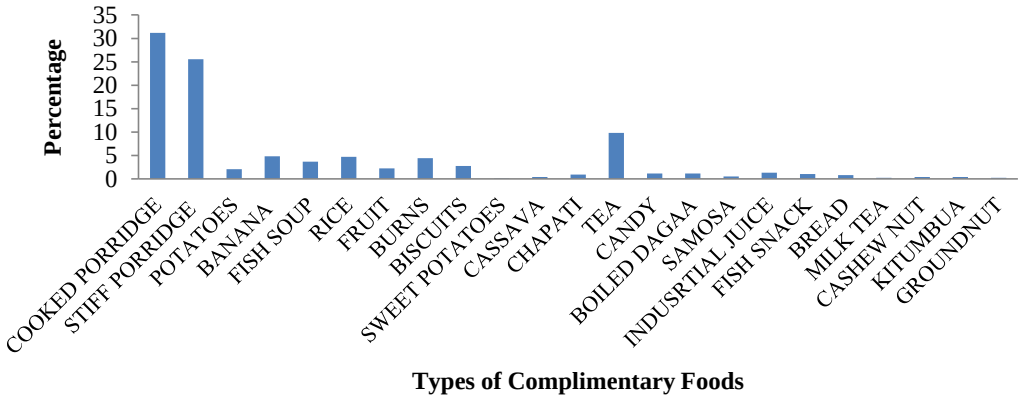

Figure 1. Frequency of type of complementary foods and snacks consumed by the children aged 6-23 months for the past 24 h in percentage (n=212).

mothers (78.8%) had an age range of 20-29 years with mean age of 27.9±0.8. Single parenting also existed in the area (25.5% single mothers), and the majority of the women were married in monogamous while a small proportion of respondents (7.1%) were married in a polygamous type of marriage. In terms of occupation levels, the majority (68.4%) were farmers, with most of them having their income less than 100,000 Tanzanian shillings (TSh) per month. The illiterate rate among the respondents was also high (33.5%) and the majority had just primary education (57.1%) with 78% having finished their education more than 5 years ago. Also, the mean household size was 4.9 ± 1.8 (range 2 to 12), with 68.6% of the households having members equal or less than 5. The mean age of the children is 13.9 ± 5.1 months with the age range of 12 to 23 months (53.1%, n = 212). More than half (52.6%) of these children were female.

24 h dietary recall

Porridge was found to be the main dish consumed by most of the children (31%) followed by maize stiff porridge with different relish (26%), but mostly fish relish (Figure 1). The higher the age the more varieties of foods consumed by the children. Children aged 6 to 8 months consumed a total of 24 varieties of complementary foods and snacks, those aged 9 to 11 months consumed 28 varieties of foods and snacks while those at age of 12 to 23 months consumed 32 varieties of foods and snacks. Among all varieties of food consumed, many children had consumed fish for the past 24 h, with *kibua*, *tasi* and *dagaa* being reported as the variety of fish mostly consumed (Figure 4). It was also observed that types of fish consumed increases as the age of the children increases. According to mothers and caregivers, about89.2% of children are fed with fish in their diets. Only few children were not given fish and age of the child was found to have association with fish consumption ($p < 0.05$), where large proportion of these children had the age of 6 to 8 months.

Many children (86.7%) were being served with fish-based complementary foods during the main meal, which is lunch and dinner. Only 0.5% of the children were served fish-based complementary food as a snack. Only 39% of the households had household members who are involved in any fish business, which has no association with child's fish consumption ($p>0.01$).

Proximate analysis

The analysis involved the food analysis for percentage protein, fiber, fat, ash, dry matter and moisture content. Carbohydrate percentage and total energy (kcal) was calculated based on the results obtained from the analyzed proximate parameters. In average fish-based complementary foods had higher proximate parameters mean values than non-fish-based complementary foods (Table 3).

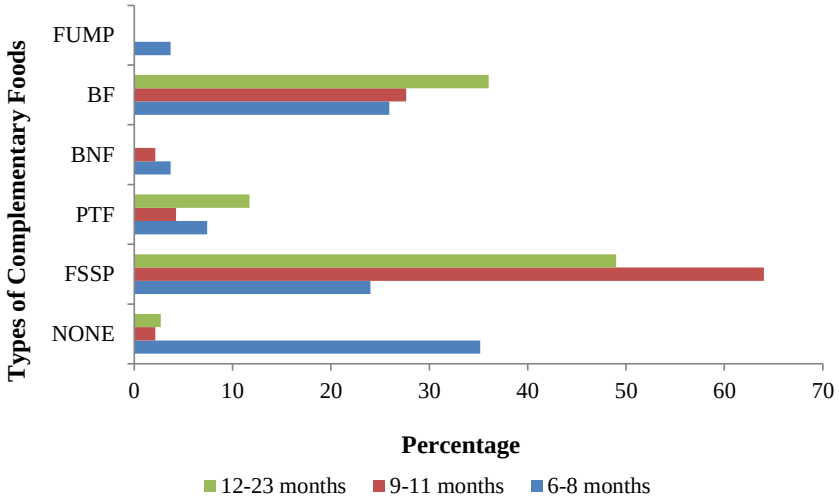

Figure 2. Percentage of children aged 6-23 months consuming various forms of fish based complementary foods (n=212). NONE= Not consuming any type of fish, FSSP= Fish with stiff porridge, PTF= Fish with Irish potatoes, BNF= Fish with green bananas, BF= Fish soup, FUMP= Fish with unrefined maize porridge.

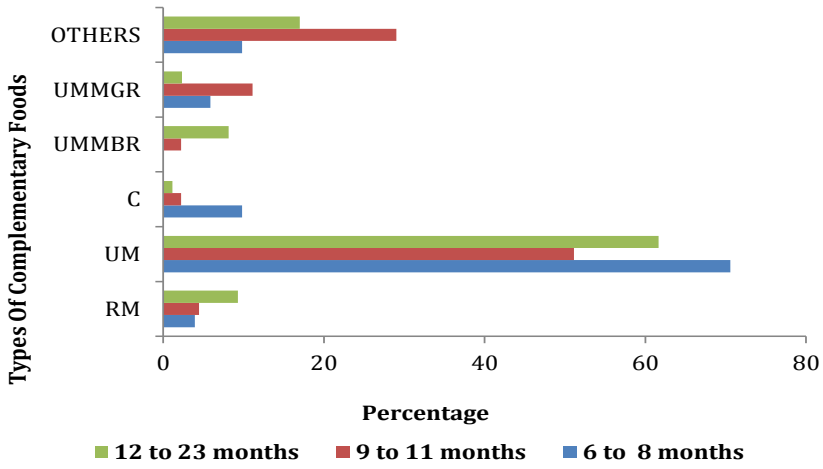

Figure 3. Percentage of children aged 6-23 months consuming various types of non-fish based complementary foods (n=212). RM = Refined maize porridge, UM = Unrefined maize porridge, C = Cassava porridge, UMMBR = Unrefined maize, millet, beans and rice porridge, UMMGR = Unrefined complementary foods.

Vitamin A concentration in cooked food samples

Mean vitamin A concentration in fish-based complementary foods was higher (279 µ RE) than in non-fish-based complementary foods (4 µ RE). High vitamin A concentration on fish-based complementary foods was more contributed by the retinol content from the fish. Significant difference ($p < 0.05$) of vitamin A concentration was observed between fish-based and non-fish-based complementary foods. Also, significant difference ($p < 0.05$) of vitamin A concentration was observed among non-fish-based complementary foods (UMMGR, UMMBR, C, RM and UM) and among fish-based complementary foods (FSSP, BF, PTF and BNF) (Table 4).

Iron concentration in cooked food samples

Iron was significantly higher on non-fish-based complementary foods (0.74 mg) than on fish-based complementary foods (0.66 mg). There was significant

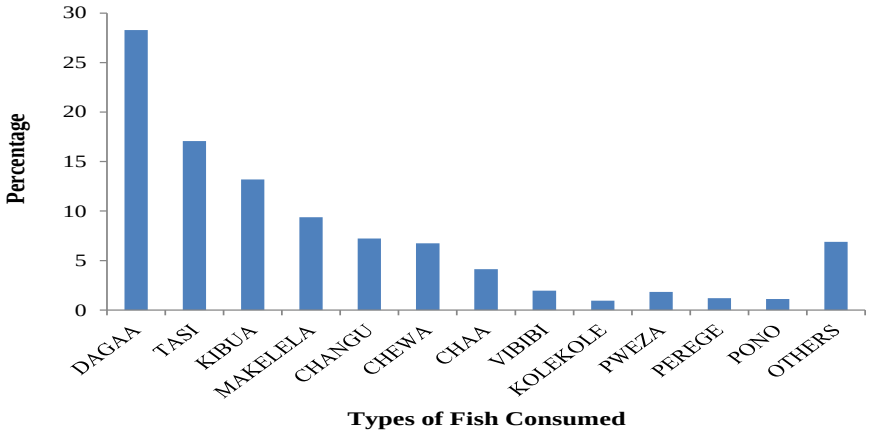

Figure 4. Frequency of type of fish consumed by the children aged 6-23 months in percentage (n=189).

Table 3. Proximate composition of commonly used complementary foods (per 100 g wet matter).

Sample name	% Crude Protein	% Crude Fiber	% Fat	%Ash	%Moisture Content	% Dry Matter	% Carbohydrate	Energy (Kcal)
Fish-based complementary foods								
BF-K	5.3±1.6^{abc}	4.8±0.7^{ab}	2.4±0.4^{a}	4.7±0.5^{a}	78.9±0.7^{efg}	21.1±0.7^{efg}	4.0±0.1 ^{abcd}	58.3±10.1^{cd}
BF-S	5.5±0.5^{ab}	3.6±0.6^{ab}	0.2±0.1^{bc}	3.6±0.1^{bc}	86.1±0.3^{d}	13.9±0.3 ^{h}	1.1±0.3^{d}	28.5±4.2^{efg}
BF-T	5.5±0.5^{ab}	5.6±0.1^{ab}	0.7±0.1^{b}	3.6±0.1 ^{b}	80.5±0.2^{e}	19.51±0.2 ^{g}	4.1±1.0^{abcd}	44.2±1.3^{def}
BNF-K	8.7±2.4^{a}	2.3±0.1 ^{b}	4.1±0.5^{de}	1.6±0.0^{de}	74.4±0.2 ^{j}	25.7±0.2^{b}	8.9±1.7^{abcd}	107.2±1.2^{a}
BNF-S	4.2±1.4^{abc}	3.4±1.1^{ab}	3.2±0.6^{d}	1.9±0.0^{d}	78.5±0.3^{efgh}	21.5±0.3^{defg}	8.9±3.4^{abcd}	80.4±2.6^{abc}
BNF-T	2.8±0.4^{bc}	3.0±0.1^{ab}	2.3±1.1^{d}	2.2±0.4^{d}	77.5±0.9 ^{fghi}	22.5±0.6^{cdef}	12.2±2.0^{ab}	80.8±3.1^{abc}
FSSP-K	4.5±2.4^{abc}	6.6±0.2^{ab}	3.2±0.1^{cd}	2.5±0.5^{cd}	75.8±0.4^{ij}	24.2±0.4^{bc}	7.4±3.3^{abcd}	76.0±4.9^{bc}
FSSP-S	3.6±1.6^{bc}	4.6±2.5^{ab}	0.3±0.3^{ab}	4.3±0.6^{ab}	79.6±0.7^{ef}	20.4±0.7 ^{fg}	7.7±3.4^{abcd}	47.7±8.9^{de}
FSSP-T	4.0±2.5^{abc}	7.2±0.7^{a}	2.8±1.3^{cd}	2.5±0.0^{cd}	71.3±0.6^{k}	28.7±0.6^{a}	12.3±2.6 ^{ab}	90.3±11.9 ^{ab}
PTF-K	2.9±0.8^{bc}	4.4±1.0^{ab}	0.9±0.0 ^{d}	2.3±0.1 ^{d}	76.9±0.6^{ghi}	23.1±0.6^{cde}	12.5±2.4 ^{a}	70±6.8^{bcd}
PTF-S	3.6±0.5^{bc}	4.5±1.3^{ab}	5.1±2.3 ^{d}	2.4±0.0 ^{d}	78.5±0.1^{efgh}	21.5±0.1^{defg}	5.9±3.1^{abcd}	84±6.5^{abc}
PTF-T	1.3±0.2^{bc}	5.5±1.7^{ab}	2.9±0.0 ^{d}	2.3±0.0 ^{d}	76.8±0.1 ^{hi}	23.2±0.1^{cd}	11.2±1.7 ^{abc}	76.4±6.8^{bc}
Non-fish-based complementary foods								
C	0.4±0.0 ^{c}	1.9±0.5 ^{b}	0.1±0.2 ^{f}	0.5±0.1 ^{f}	94.3±0.1^{a}	5.7±0.1^{k}	2.8±0.5^{c}	14±0.6^{g}
RM	1.3±0.5^{bc}	3.6±3.1^{ab}	0.2±0.0^{ef}	0.8±0.1^{ef}	90.3±0.6^{c}	9.8±0.6 ^{i}	3.8±3.7^{abcd}	22.4±17^{efg}
UM	3.4±0.8^{bc}	2.7±0.7^{ab}	0.1±0.1 ^{f}	0.1±0.0 ^{f}	92.5±1.2^{ab}	7.5±1.2^{jk}	1.1±1.1 ^{d}	19.2±0.0^{fg}
UMMBR	3.6±0.9^{abc}	1.9±0.1 ^{b}	0.1±0.2^{ef}	0.8±0.1^{ef}	90.1±0.4 ^{c}	9.9±0.4^{i}	3.5±0.5^{bcd}	29.0±0.3^{efg}
UMMGR	2.7±0.5^{bc}	2.7±0.1^{ab}	0.3±0.1^{de}	1.7±0.1^{de}	90.9±0.1^{bc}	9.1±0.1^{ij}	1.6±0.6 ^{d}	20.1±0.4^{efg}

BF = Fish soup, BNF = Fish with mashed bananas, FSSP = Fish with stiff porridge, PTF = Fish with mashed Irish potatoes, C = Cassava porridge, RM = Refined maize porridge, UM = Unrefined maize porridge, UMMBR = Unrefined maize, millet, beans and rice porridge, UMMGR = Unrefined maize, millet, groundnuts and rice porridge, -S = *Dagaa*, -T = *Tasi*, -K = *Kibua*. Results are presented as means and standard deviations. Analysis of variance (ANOVA) was used to find significant difference between samples (P<0.05). Means with a column with same superscripts are not significantly different from each other. %Carbohydrate = 100 - (%Crude protein + %Crude fibre + %Crude fat + %Ash content + %Moisture content) Energy (Kcal) = (fat x 9) + (protein x 4) + (carbohydrate × 4)

difference (p<0.05) of iron concentration among the non-fish-based complementary foods and among the fish-based complementary foods.

UM porridge contained the highest amount of iron concentration (1.25 mg ± 0.01 per 100 g) than the rest, while PTF-S contained the lowest quantity of iron content (0.22 mg ± 0.02 per 100 g). Unlike vitamin A, iron concentration was found to be in higher quantities on non-fish-based complementary foods compared to the fish-based complementary foods (Table 5).

Table 4. Difference of vitamin A concentration of commonly used complementary foods (µg /100 g wet basis).

Sample name	β-Carotene (µg /100 g RE)	Retinol (µg /100 g RE)	Vitamin A (µg 100 g RE)
Fish-based complementary foods			
BF-S	0.0	109.3	109.3±0.5^{k}
BF-T	0.0	103.3	103.3±0.5^{l}
BF-K	0.0	212.1	212.1±0.6^{i}
BNF-S	80.9	337.8	418.7±0.1^{b}
BNF-T	53.0	256.9	149.2±0.7^{j}
BNF-K	54.3	534.9	311.2±0.6e
FSSP-S	129.8	135.9	265.7±0.1^{g}
FSSP-T	69.1	429.5	498.6±0.0^{a}
FSSP-K	52.5	316.8	369.3±0.5^{d}
PTF-S	70.0	317.7	387.7±0.9^{c}
PTF-T	66.2	151.7	217.9±0.8^{h}
PTF-K	54.3	252.4	306.7±0.6^{f}
Average			279.1
Non-fish-based complementary foods			
C	4.9	0.0	4.9±0.1^{n}
RM	1.5	0.0	1.5±0.3^{o}
UM	7.6	0.0	7.6±0.3^{m}
UMMBR	2.5	0.0	2.5±0.3^{o}
UMMGR	2.9	0.0	2.9±0.3^{o}
Average			3.9

BF = Fish soup, BNF = Fish with mashed bananas, FSSP = Fish with stiff porridge, PTF = Fish with mashed irish potatoes, C = Cassava porridge, RM = Refined maize porridge, UM = Unrefined maize porridge, UMMBR = Unrefined maize, millet, beans and rice porridge, UMMGR = Unrefined maize, millet, groundnuts and rice porridge, -S = *Dagaa*, -T = *Tasi*, -K = *Kibua*.

Zinc concentration in cooked food samples

Zinc concentration was found to be higher on non-fish-based complementary foods (0.077 mg/100 g) than on fish-based complementary foods (0.073 mg/100 g). Significance difference ($p<0.05$) between fish-based complementary foods and non-fish-based complementary foods for zinc concentration was observed. Furthermore, significant differences ($p < 0.05$) of zinc concentration among the non-fish-based complementary foods and among the fish-based complementary foods were obtained. Non-fish-based complementary foods had higher amount of zinc except for sample C and RM. Also, sample UM, FSSP-T and BNF-S had the highest amount of zinc content than the rest of the complementary foods (Table 5).

Contribution of commonly used complementary foods for children on meeting the recommended daily intake (RDI) for vitamin A, iron and zinc

On average, all fish-based complementary foods met the vitamin A RDI for children aged from 6 to 23 months correspondingly, by either consumed once, twice or thrice per day unlike the non-fish-based complementary foods (Table 6). Only one fish-based complementary food BNF-S was able to meet the iron RDI while three non-fish-based complementary foods met the iron RDI, unrefined maize porridge (UM); unrefined maize, millet, beans and rice porridge (UMMBR), and unrefined maize, millet, groundnuts and rice porridge (UMMGR) (Table 7). For the mentioned complementary foods to be able to meet the iron RDI, they must be fully consumed two times a day, except for BNF-S and UMMGR which are supposed to be consumed three times a day (Table 7). Zinc was observed to be very low in both fish-based and non-fish-based complementary foods as no complementary food was able to meet zinc RDI (Table 8).

DISCUSSION

Demographics and 24 h dietary recall

Different studies (Mekonnen et al., 2017: Udoh and Amodu, 2016) showed the existence of demographic characteristics effect towards child's feeding practices. Many caregivers had only primary education with most of them having completed primary school 5 years ago. Low education level among the female caregivers is also associated with child's exclusive breastfeeding, meal

Table 5. Difference of iron and zinc concentration among commonly used complementary foods (mg/100 g wet basis).

Sample name	Iron (mg/100 g) ± standard deviation	Zinc (mg/100 g) ± standard deviation
Fish-based complementary foods		
BF-S	0.53±0.05 ^{de}	0.06±0.01 ^{bcd}
BF-T	0.34±0.02 ^{fg}	0.04±0.02 ^{cd}
BF-K	1.26± 0.01 ^{a}	0.11±0.01 $^{a\ b}$
BNF-S	0.31±0.02 ^{gh}	0.04±0.00 ^{cd}
BNF-T	0.95±0.03 ^{b}	0.13±0.05 ^{a}
BNF-K	0.83±0.01 ^{c}	0.09±0.01 ^{abcd}
FSSP-S	0.36±0.04 ^{fg}	0.05±0.01 ^{cd}
FSSP-T	0.82±0.04 ^{c}	0.09±0.00 ^{abc}
FSSP-K	1.26±0.02 ^{a}	0.13±0.02 ^{a}
PTF-S	0.22±0.02 ^{hi}	0.03±0.01 ^{d}
PTF-T	0.55±0.03 ^{d}	0.07±0.00 ^{abcd}
PTF-K	0.55±0.03 ^{d}	0.03±0.00 ^{cd}
Average	0.66	0.07
Non-fish-based complementary foods		
C	0.19±0.01 ^{i}	0.03±0.00 ^{cd}
RM	0.44±0.03 ^{ef}	0.04±0.00 ^{cd}
UM	1.25±0.01 ^{a}	0.13±0.00 ^{a}
UMMBR	1.03±0.00 ^{b}	0.11±0.04 ^{ab}
UMMGR	0.78±0.02 ^{c}	0.08±0.00 ^{ab}
Average	0.74	0.08

BF = Fish soup, BNF = Fish with mashed bananas, FSSP = Fish with stiff porridge, PTF = Fish with mashed irish potatoes, C = Cassava porridge, RM = Refined maize porridge, UM = Unrefined maize porridge, UMMBR = Unrefined maize, millet, beans and rice porridge, UMMGR = Unrefined maize, millet, groundnuts and rice porridge, -S = *Dagaa*, -T = *Tasi*, -K = *Kibua.*

diversification and meeting the recommended minimum number of meals (Duan et al*.,* 2018). Even though no significant association was observed between the caregivers' average income and feeding practices, caregivers' poor accessibility to foods in markets which may be due to low household income less than 100,000 TSh per month can also affect the child's feeding practices, since availability and accessibility of various food materials is important for diversification of foods.

All the children under the study were already introduced to complementary foods as expected since they are all from the age of 6 months and above (Pan American Health Organization, and World Health Organization, 2003). It is also recommended for complementary foods to be provided 2-3 times per day at 6-8 months of age and 3-4 times per day at 9-11 and 12-24 months of age, with additional nutritious snacks (such as a piece of fruit) offered 1-2 times per day, as desired for the average healthy breastfed infant. If energy density or amount of food per meal is low, or the child is no longer breastfed, more frequent meals may be required. On average, all age groups tend to be fed three times per day as required. But those aged 12 to 23 months did not meet the recommendations as they were not given healthy snacks between meals. During this period, they need more frequency of eating nutritious foods including the health snacks like fruits so as to satisfy the nutrients demands for their growth and health in general.

In different studies (Abeshu et al*.*, 2016: Kulwa et al*.,* 2015), it has been reported that porridge is most common used form of complementary food in developing countries. This has been observed at Mchinga as well, the commonly consumed form of complementary food is porridge with the addition of salt in it. In which, unrefined maize porridge (UM) found to be the most commonly used kind of complementary food for children aged 6 to 23 months. Followed by cassava porridge (C) for the children aged 6 to 8 months, porridge containing a mixture of unrefined maize, millet, groundnuts and rice flour for children aged 9 to 11 months, and porridge containing a mixture of unrefined maize, millet, beans and rice flour for the children aged 12 to 23 months. Then followed by the consumption of stiff porridge (*ugali*) with other side dishes, and very few who consumed bananas, potatoes and rice. All food materials used to prepare the porridge for the children are cereals as reported in other developing countries that dietary energy forms a big proportion of complementary foods (Abeshu et al*.,* 2016). The feeding practice at the study area may be influenced by agricultural production as it is reported that cassava,

Table 6. Percentage of vitamin A content contributed by fish-based complementary foods and non-fish-based complementary foods on meeting the RDIs.

RDI (mcg RE)	6-8 Months			9-11 Months			12-23 Months		
	350			350			400		
Sample	Average weight of food consumed per meal (g)	Vitamin A Concentration from 1 serve (µg)	% Contribution to RDIs from 1 Serve	Average weight of food consumed per meal (g)	Vitamin A Concentration from 1 serve (µg)	% Contribution to RDIs from 1 Serve	Average weight of food consumed per meal (g)	Vitamin A Concentration from 1 serve (µg)	% Contribution to RDIs from 1 Serve
Fish-based complementary foods									
BF-S	60.9	161.79	46	90.2	239.63	68	151.4	402.22	101
BF-T	61.9	308.65	88	90.2	449.76	129	151.4	754.93	189
BF-K	62.9	232.27	66	90.2	333.08	95	151.4	559.07	140
BNF-S	128	139.91	40	178	194.56	56	230	147.56	37
BNF-T	135	139.45	40	180	185.93	53	229	142.55	36
BNF-K	138	292.73	84	182	386.06	110	236	301.21	75
FSSP-S	111	430.34	123	178	690.10	197	240	930.47	233
FSSP-T	125	272.40	78	182	396.61	113	256	557.87	139
FSSP-K	130	398.69	114	185	567.37	162	275	843.39	211
PTF-S	115	481.46	138	160	669.85	191	212	887.56	222
PTF-T	132	196.98	56	178	265.62	76	228	340.23	85
PTF-K	137	426.28	122	186	578.74	165	235	731.21	183
Non-fish-based complementary foods									
UMMBR[2]	187.1	4.74	1	227.4	5.76	2	295.0	7.47	2
UMMGR[2]	187.1	5.41	2	227.4	6.57	2	295.0	8.53	2
RM[2]	187.1	2.74	1	227.4	3.33	1	295.0	4.32	1
UM[2]	187.1	14.16	4	227.4	17.20	5	295.0	22.32	6
C[2]	187.1	9.15	3	227.4	11.12	3	295.0	14.42	4

FSSP = Fish with stiff porridge, BF = Fish soup, PTF = Fish with mashed irish potatoes, BNF = Fish with mashed bananas, UMMBR = Unrefined maize, millet, beans and rice porridge, UMMGR = Unrefined maize, millet, groundnuts and rice porridge, RM = Refined maize porridge, UM = Unrefined maize porridge, C = Cassava porridge, -S = *Dagaa*, -T = *Tasi*, -K = *Kibua*.

maize, sorghum and pulses (pigeon and cowpeas) are common food crops produced at Lindi, with few people engaged in livestock keeping while fishing is for only those living along the coast (Jones, 2017).

Fish consumption

World Health Organization (2004) advised meat, poultry, fish or eggs to be eaten daily or as often as possible, since they are rich sources of many nutrients such as iron and zinc. At Mchinga generally, almost all households consume fish, only very few households do not consume fish due to economic reasons. Children are being provided with both fish-based and non-fish-based complementary foods. They consume fish mostly in forms of relish or soup. Children's fish consumption in fishing communities has been observed to be higher as reported in several studies (Bandoh and Kenu, 2017; Wake and Geleto, 2019), compared to other reports of fish consumption studies among children in developing countries (Gibson et al., 2020; Mekonnen et al., 2017). Therefore, high fish consumption in this study area could be attributed to the fact that it is a fishing community. Furthermore, age of the child was found to have significant association with child's fish consumption. Hence, few numbers of

Table 7. Percentage of iron content contributed by fish-based complementary foods and non-fish-based complementary foods on meeting the RDIs.

	6-8 Months			9-11 Months			12-23 Months		
RDI (mg)		**11**			**11**			**6**	
Sample	**Average weight of food consumed per meal (g)**	**Iron Concentration from 1 serve (mg)**	**% Contribution to RDIs from 1 Serve**	**Average weight of food consumed per meal (g)**	**Iron Concentration from 1 serve (mg)**	**% Contribution to RDIs from 1 Serve**	**Average weight of food consumed per meal (g)**	**Iron Concentration from 1 serve (mg)**	**% Contribution to RDIs from 1 Serve**
Fish-based complementary foods									
BF-S	60.9	0.50	5	90.2	0.74	7	151.4	1.24	21
BF-T	61.9	0.78	7	90.2	1.14	10	151.4	1.91	32
BF-K	62.9	0.22	2	90.2	0.32	3	151.4	0.54	9
BNF-S	128	0.43	4	178	0.60	5	230	0.45	8
BNF-T	135	1.70	15	180	2.27	21	229	1.74	29
BNF-K	138	0.73	7	182	0.96	9	236	0.75	13
FSSP-S	111	0.61	6	178	0.98	9	240	1.32	22
FSSP-T	125	0.68	6	182	1.00	9	256	1.40	23
FSSP-K	130	0.29	3	185	0.41	4	275	0.61	10
PTF-S	115	1.09	10	160	1.52	14	212	2.02	34
PTF-T	132	1.09	10	178	1.47	13	228	1.89	32
PTF-K	137	0.43	4	186	0.59	5	235	0.74	12
Non-fish-based complementary foods									
UMMBR[2]	187.1	1.47	13	227.4	1.78	16	295.0	3.02	50
UMMGR[2]	187.1	1.92	17	227.4	2.33	21	295.0	2.31	39
RM[2]	187.1	0.82	7	227.4	1.00	9	295.0	1.30	22
UM[2]	187.1	2.34	21	227.4	2.85	26	295.0	3.69	62
C[2]	187.1	0.36	3	227.4	0.44	4	295.0	0.57	10

FSSP = Fish with stiff porridge, BF = Fish soup, PTF = Fish with mashed Irish potatoes, BNF = Fish with mashed bananas, UMMBR = Unrefined maize, millet, beans and rice porridge, UMMGR = Unrefined maize, millet, groundnuts and rice porridge, RM = Refined maize porridge, UM = Unrefined maize porridge, C = Cassava porridge, -S = *Dagaa*, -T = *Tasi*, -K = *Kibua*.

children aged 6-8 months were reported not to consume fish-based complementary foods due to the fear of accidental fish bone eating which will result in injuries. They instead provide them with other foods especially the staples. Most mothers cannot provide fish meals to their children especially when they are not in season because of limited availability and high cost of the fish during that season. Unfortunately, this is also the case even when they are in season, that fish may be available but the household economy may be low so they cannot purchase them.

Proximate composition

In general, fish-based complementary foods had more percentage of energy content per 100 g serving compared to the non-fish-based complementary foods (Table 3). Fat content has contributed much to the total energy in fish-based complementary foods which might be due to the presence of fish and coconut milk as ingredients. Types of fish used in this study especially *Dagaa* (*Sardinella longiceps*) have been reported to have adequate amount of fat content (Mohanty et al., 2019), as well as coconut cream has been

Table 1. Percentage of zinc content contributed by fish-based complementary foods and non-fish-based complementary foods on meeting the RDIs.

RDI (mg)	6-8 Months			9-11 Months			12-23 Months		
	5			5			6.5		
Sample	Average weight of food consumed per meal (g)	Zinc Concentration from 1 serve (mg)	% Contribution to RDIs from 1 Serve	Average weight of food consumed per meal (g)	Zinc Concentration from 1 serve (mg)	% Contribution to RDIs from 1 Serve	Average weight of food consumed per meal (g)	Zinc Concentration from 1 serve (mg)	% Contribution to RDIs from 1 Serve
Fish-based complementary foods									
BF-S	60.9	0.06	1.1	90.2	0.08	1.7	151.4	0.14	2.2
BF-T	61.9	0.08	1.6	90.2	0.12	2.3	151.4	0.19	3.0
BF-K	62.9	0.03	0.6	90.2	0.04	0.9	151.4	0.07	1.1
BNF-S	128	0.05	1.1	178	0.07	1.5	230	0.10	1.5
BNF-T	135	0.16	3.1	180	0.21	4.2	229	0.27	4.1
BNF-K	138	0.09	1.7	182	0.11	2.3	236	0.15	2.3
FSSP-S	111	0.08	1.6	178	0.13	2.5	240	0.17	2.6
FSSP-T	125	0.04	0.9	182	0.06	1.3	256	0.09	1.4
FSSP-K	130	0.03	0.7	185	0.05	1.0	275	0.07	1.1
PTF-S	115	0.15	3.0	160	0.21	4.2	212	0.28	4.2
PTF-T	132	0.11	2.3	178	0.15	3.1	228	0.20	3.0
PTF-K	137	0.06	1.1	186	0.08	1.5	235	0.10	1.5
Non-fish-based complementary foods									
UMMBR[2]	187.1	0.21	4.2	227.4	0.25	5.1	295.0	0.33	5.1
UMMGR[2]	187.1	0.14	2.9	227.4	0.18	3.5	295.0	0.23	3.5
RM[2]	187.1	0.07	1.3	227.4	0.08	1.6	295.0	0.10	1.6
UM[2]	187.1	0.24	4.8	227.4	0.29	5.9	295.0	0.38	5.9
C[2]	187.1	0.06	1.2	227.4	0.08	1.5	295.0	0.10	1.5

FSSP = Fish with stiff porridge, BF = Fish soup, PTF = Fish with mashed Irish potatoes, BNF = Fish with mashed bananas, UMMBR = Unrefined maize, millet, beans and rice porridge, UMMGR = Unrefined maize, millet, groundnuts and rice porridge, RM = Refined maize porridge, UM = Unrefined maize porridge, C = Cassava porridge, -S = *Dagaa*, -T = *Tasi*, -K = *Kibua*.

reported to have high-fat content per 100 g serving (Ahmed et al., 2019). Also, high carbohydrate contents in fish-based complementary foods might have contributed to non-fish food materials since fish has very low carbohydrate content (Moxness, 2019).

Protein is an important nutrient for proper growth of children; thus, it is essential to ensure it is consumed in required amounts. BNF-K has the highest amount of protein followed by fish soup (BF) dishes. It has been reported in different studies (Sonavane et al., 2017; Moxness, 2019) that among other fish from Indian ocean *Kibua (Rastrelliger kanagurta*) has high amount of protein (19.2%).

The high amount of proteins may be highly contributed by the fish variety used as well as amount of fish contents on those foods (Bogard et al., 2015). Generally, the fish-based complementary foods had higher amounts of all proximate parameters with most of them complying with standards set by Food and Agriculture Organization and World Health Organization (2017) except for moisture content

than the non-fish-based complementary foods (Table 3).

Vitamin A, iron and zinc concentrations and their contribution to RDI

Since most of the children consumed fish-based complementary foods within 24 h, fish consumption may be the main reason for the complementary foods meeting vitamin A RDI. Chakraborty et al. (2014) reported that marine fish are rich in fat-soluble vitamins, including vitamins A, D, E, and K, which are required in human metabolism. Also, fish-based complementary foods were found with higher amounts of vitamin A than non-fish-based complementary foods, mainly contributed by the retinol content as it has been also reported by Vilain et al. (2016). Furthermore, it was observed that PTF-T, PTF-S, BNF-K and BNF-S if totally consumed were able to meet the vitamin A RDI for children from 6 to 23 months in a single serving per day (Table 6). Their consumption should be emphasized to children followed by PTF-K. Also the combination of animal and plant sources of vitamin A contributes to the good result of vitamin A content in foods (Table 4), since animal source foods can fill multiple micronutrient gaps at a lower volume of intake than plant source foods (Zhang et al*.,* 2016). In addition, in different studies *dagaa* and *tasi* have also been reported with higher vitamin A content compared to *kibua*. Mohanty et al*.* (2016) reported about *dagaa* (*S. longiceps*), Wahyuningtyas et al*.* (2017) reported *Tasi (Siganus sutor)* while Moxness (2019) reported about *kibua (R. kanagurta*) having 346.4, 187.27 and 100 µg/100 g of vitamin A content, respectively.

Despite *dagaa, tasi* and *kibua* having significant amounts of vitamin A as reported by other studies, single serving of *dagaa* soup (BF-S) and *tasi* soup (BF-T) did not meet the RDI for vitamin A of the children at any age group except for *kibua* soup (BF-K) which met vitamin A RDI of for children aged 9-11 months old. Since water content is an important determinant of levels of other food components (Abeshu et al., 2016), high moisture content in fish soup samples than the other prepared food samples (Table 2) might have affected concentrations of nutrients in foods, with vitamin A included. It seems like the high proportion of water added during cooking of the soups diluted nutrients concentration of the foods. Complementary foods such as BF-S, BF-T and BF-K had no vitamin A plant source, which also contributed to their low concentration of vitamin A. Consequently, fish-based complementary foods had the best vitamin A concentration. Thus, if fish contributed high ratio in formulating a meal, it is possible to formulate complementary foods with sufficient amount of vitamin A.

Fish-based complementary foods have been observed to have high iron concentration than non-fish-based complementary foods as in some other studies. Unlike in this study, even though the iron concentration increases in complementary foods with the age, two servings per day of unrefined maize porridge (UM) and UMMGR if completely consumed can meet the iron RDI only for 12 to 23 months children while it has to be three serving per day of BF-T, UMMBR and BNF-S in order to meet iron RDI for children of that age group (Table 7). No food sample, either fish-based or non-fish-based met iron or zinc RDI on a single serving per day.

Kibua fish has been reported to have 3.2 mg/100 g of iron and 1.3 mg/100 g of zinc (Moxness, 2019). In this study, *dagaa* and *tasi* types of fish might have higher concentration of iron than *kibua* fish as it is observed on fish-based complementary foods with *dagaa* and *tasi* having higher iron concentration per 100 g serving than those complementary foods with *kibua*. *Dagaa* has been reported to have high concentration of minerals, but the concentration is highly contributed by calcium content as it is being consumed whole together with bones (Palani et al., 2014).

Among non-fish-based complementary foods, those with unrefined maize as one of their ingredients (UM, UMMBR and UMMGR) were observed to have higher iron and zinc content than those without unrefined maize (RM and C). Zinc concentration was significantly higher ($p<0.05$) in UM than RM, mainly contributed by the presence of whole maize grains which improved zinc content as explained by Suri and Tanumihardjo (2016). Large proportion of the minerals in maize tends to be lost during milling process. Milling process removes the germ with many nutrients leaving mainly the starchy, and the remainder contains only about 20% of the zinc content. Furthermore, in this study UM contained highest amount of zinc followed by UMMBR and UMMGR. Since UMMGR has the lower amount of zinc than UMMBR, there is a possibility that the high quantities of zinc in UMMBR are contributed by the presence of beans (Ramírez-Ojeda et al., 2018). However, even if there is high iron quantity, its absorption is questionable as unrefined plant-based staple foods are often rich in phytate that can bind and significantly reduce absorption of non-haem iron (Gibson et al*.,* 2018).

Having complementary foods whether fish-based or non-fish-based with high iron concentration are enough to meet the children's RDI, indicated that mothers can prepare complementary foods for their children with adequate iron content within their households. It is more efficient to promote and improve the fish-based complementary foods since legumes and cereals are accompanied with high quantities of anti-nutritional factors (Bora, 2014), unless processing of removing/reducing them is done (Suri and Tanumihardjo, 2016).

Zinc concentration in the complementary foods remains very low as indicated by the low contribution of zinc to the RDI for children based on low concentration of zinc per serving and low concentration per meal for each age group (Table 8). Zinc concentration has always been a

concern in complementary foods for children since it fails to meet the RDIs (Osendarp et al*.,* 2016). Fish-based complementary foods contribute significantly on meeting the micronutrients RDI (Bogard et al*.,* 2015: Byrd et al*.,* 2020), except for zinc in this study.

Conclusion

In general, this study indicated that fish-based complementary foods contribute significantly on studied micronutrients' concentration except for zinc. Fish-based complementary foods provide adequate amount of vitamin A as required for the targeted children unlike the non-fish-based complementary foods. However, only some complementary foods if eaten twice or thrice a day can meet the iron RDI. Zinc is found to be very low in both fish-based and non-fish-based complementary foods. It is therefore possible to formulate at home fish-based complementary foods that meets iron and vitamin A RDI for the children age 6 to 23 months. For the case of zinc, fish proportion included in a meal should be increased and/or other good sources of zinc such as seeds should also be given to children in order to meet zinc RDI.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Abeshu MA, Lelisa A, Geleta B (2016). Complementary Feeding : Review of Recommendations, Feeding Practices and Adequacy of Homemade Complementary Food Preparations in Developing Countries - Lessons from ethiopia. Frontiers in Nutrition 3(41):1-9.

Aguayo VM (2017). Complementary feeding practices for infants and young children in South Asia. A review of evidence for action post-2015. Maternal and Child Nutrition 13(2):1-13.

Ahmed S, Hoque MM, Zzaman W, Thakur MU, Hossain MM (2019). Study on physicochemical and anti-oxidant properties of coconut cream extracted from two BARI varieties. International Food Research Journal 26(1):153-160.

Association of Official Analytical Chemists (AOAC) (1995). Official Methods of Analysis. Official Association of Analytical Chemists, Washington DC. 820pp.

Bandoh DA, Kenu E (2017). Dietary diversity and nutritional adequacy of under-fives in a fishing community in the central region of Ghana. BioMed Central Nutrition 3(2):1-6.

Bogard JR, Hother AL, Saha M, Bose S, Kabir H, Marks GC, Thilsted SH (2015). Inclusion of small indigenous fish improves nutritional quality during the first 1000 days. Food and Nutrition Bulletin 36(3):276-289.

Bora P (2014). Anti-Nutritional Factors in Foods and their Effects. Journal of Academia and Industrial Research 3(6):285-290.

Byrd KA, Thilsted SH, Fiorella KJ (2020). Fish nutrient composition: a review of global data from poorly assessed inland and marine species. Public Health Nutrition 24(3):476-486.

Chakraborty K, Joseph D, Chakkalakal SJ (2014). Interannual and Seasonal Dynamics in Amino Acid, Mineral and Vitamin Composition of Epinephelus diacanthus. Journal of Biology and Earth Science 4(1):91-104.

Craft N (2008). Laboratory Procedure Manual. Craft Technologies Inc., North Carolina 45 p.

Development Initiatives (2018). 2018 Global Nutrition Report: Shining a light to spur action on nutrition. Bristol, UK: Development Initiatives Poverty Research Ltd. 166pp.

Dewey KG (2016). Reducing stunting by improving maternal, infant and young child nutrition in regions such as South Asia: evidence, challenges and opportunities. Maternal and Nutrition 12(1):27-38.

Duan Y, Yang Z, Lai J, Yu D, Chang S, Pang S, Jiang S, Zhang H, Bi Y, Wang J, Scherpbier RW, Zhao L, Yin S (2018). Exclusive Breastfeeding Rate and Complementary Feeding Indicators in China: A National Representative Survey in 2013. Nutrients 10(2):249

Food and Agriculture Organization (FAO) (1983). Species Catalogue. Fisheries Synopsis. Food and Agriculture Organization of the United Nations, Rome 43 p.

Food and Agriculture Organization and World Health Organization (FAO/WHO) (2017). Guidelines on formulated complementary foods for older infants and young children CAC/GL 8-1991. Available at: http://www.fao.org/fao-who-codexalimentarius/sh-proxy/en/?lnk=1&url=https%253A%252F%252Fworkspace.fao.org%252Fsites%252Fcodex%252FStandards%252FCXG%2B8-1991%252FCXG_008e.pdf

Georgieff MK (2017). Iron assessment to protect the developing brain. The American Journal of Clinical Nutrition 106(6):1588S-1593S.

Gibson RS, Raboy V, King JC (2018). Implications of phytate in plant-based foods for iron and zinc bioavailability, setting dietary requirements, and formulating programs and policies. Nutrition Reviews 76(11):793-804.

Gibson E, Stacey N, Sunderland TCH, Adhuri DS (2020). Dietary diversity and fish consumption of mothers and their children in fisher households in Komodo District, eastern Indonesia. Plus ONE 15(4):e0230777.

Huang Z, Liu Y, Qi G, Brand D, Zheng SG (2018). Role of Vitamin A in the Immune System. Journal of Clinical Medicine 7(9):258.

Jones AD (2017). Critical review of the emerging research evidence on agricultural biodiversity, diet diversity, and nutritional status in low- and middle-income countries. Nutrition Reviews 75(10):769-782.

Kulwa KBM, Mamiro P S, Kimanya ME, Mziray R, Kolsteren PW (2015). Feeding practices and nutrient content of complementary meals in rural central Tanzania : implications for dietary adequacy and nutritional status. BioMed Central Pediatrics 15(171):1-11.

Lietz G, Henry CJK, Mulokozi G, Mugyabuso JKL, Ballart A, Ndossi GD, Lorri W (2001). Comparison of the effects of supplemental red palm oil and sunflower oil on maternal vitamin A status 1 - 3. American Journal of Clinical Nutrition 74(4):501-509.

Liu E, Pimpin L, Shulkin M, Kranz S, Duggan CP, Mozaffarian D, Fawzi W (2018). Effect of Zinc Supplementation on Growth Outcomes in Children under 5 Years of Age. Nutrients 10(3):377.

Makori N, Kassim N, Matemu AO, Kinabo J (2018). Factors associated with stunting in Dodoma Region, Tanzania. African Journal of Food, Agriculture, Nutrition and Development 18(3):13842-13860.

Martinez B, Webb MF, Gonzalez A, Douglas K, Grazioso MP, Rohloff P (2018). Complementary feeding intervention on stunted Guatemalan children: a randomised controlled trial. BMJ Paediatrics Open 2(1):1-8.

Mekonnen TC, Workie SB, Yimer TM, Mersha WF (2017). Meal frequency and dietary diversity feeding practices among children 6 - 23 months of age in Wolaita Sodo town , Southern Ethiopia. Journal

of Health, Population and Nutrition 36(18):1-8.
Mohanty BP, Ganguly S, Mahanty A, Mitra T (2019). Fish in human health and nutrition. Advances in Fish Research 7:189-218.
Mohanty BP, Sankar TV, Ganguly S, Mahanty A, Anandan R, Chakrabarty K (2016) Micronutrient composition of 35 food fishes from India and their significance in human nutrition. Biological Trace Element Research 174:448-458.
Moxness AK (2019). Nutrient composition of 19 marine fish species from Sri Lanka and their potential contribution to food and nutrition security. Dissertation for Award of MSc Degree at University of Bergen, Norway pp. 44-53.
National Bureau of Statistics and ICF Macro (2015). Tanzania Demographic and Health Survey and Malaria Indicator Survey. National Bureau of Statistics, Dar es Salaam, Tanzania 65 p.
Osendarp SJM, Broersen B, van Liere MJ (2016). Complementary Feeding Diets Made of Local Foods Can Be Optimized, but Additional Interventions Will Be Needed to Meet Iron and Zinc Requirements in 6- to 23-Month-Old Children in Low- and Middle-Income Countries. Food and Nutrition Bulletin 37(4):544-570.
Palani KM, Ruba AA, Jeya SR, Shanmugam SA (2014). Proximate and major mineral composition of 23 medium sized marine fin fishes landed in the thoothukudi Coast of India. Journal of Nutrition and Food Sciences 4(1):1-7.
Pan American Health Organization, and World Health Organization (2003). Guiding Principles for Complementtary Feeding of the Breastfed Child. Pan American Health Organization, Washington DC. 40 p.
Ramírez-Ojeda AM, Moreno-Rojas R, Cámara-Martos F (2018). Mineral and trace element content in legumes (lentils, chickpeas and beans): Bioaccesibility and probabilistic assessment of the dietary intake. Journal of Food Composition and Analysis 73:17-28.
Rodriguez-Amaya DB, Kimura M (2004). HarvestPlus Handbook for Carotenoid Analysis. HarvestPlus Technical Monograph, Washington DC. 63 p.
Shafique S, Sellen DW, Lou W, Jalal CS, Jolly SP, Zlotkin SH (2016). Mineral- and vitamin-enhanced micronutrient powder reduces stunting in full-term low-birth-weight infants receiving nutrition, health, and hygiene education: a 2 × 2 factorial, cluster-randomized trial in Bangladesh. The American Journal of Clinical Nutrition 103(5):1357-1369.
Sonavane AE, Koli JM, Patange SB, Naik SD, Mohite AS (2017). Proximate composition and fatty acid profiling of indian mackerel (*Rastrelliger kanagurta*) off Ratnagiri, West Coast of India. International Journal of Pure and Applied Biosciences 5(4):920-924.
Suri DJ, Tanumihardjo SA (2016). Effects of different processing methods on the micronutrient and phytochemical contents of maize: From A to Z. Comprehensive Reviews in Food Science and Food Safety 15(5):912-926.
Tilami SK, Sampels S (2017). Nutritional Value of Fish: Lipids, Proteins, Vitamins, and Minerals. Fisheries Science and Aquaculture 26(2):1-13.
Udoh EE, Amodu OK (2016). Complementary feeding practices among mothers and nutritional status of infants in Akpabuyo Area, Cross River State Nigeria. SpringerPlus 5(1):2073.
Vilain C, Baran E, Gallego G, Samadee S (2016). Fish and the Nutrition of Rural Cambodians. Asian Journal of Agriculture and Food Sciences 4(1):2321-1571.
Wahyuningtyas LA, Nurilmala M, Sondita MFA, Taurusman AA, Sudrajat AO (2017). Nutritional profile of Rabbitfish (Siganus spp .) from the Kepulauan Seribu (Thousand Islands), Jakarta, Indonesia. International Food Research Journal 24(2): 685-690.
Wake AA, Geleto TC (2019). Socio-economic importance of Fish production and consumption status in Ethiopia. International Journal of Fisheries and Aquatic Studies 7(4):206-211
Wells JC, Sawaya LS, Wibaek R, Mwangome M, Poullas MS, Yajnik CS, Demaio A (2020). The double burden of malnutrition: aetiological pathways and consequences for health. The Lancert 395(10217):75-88.
World Health Organization (2004). Feeding the non-breastfed child 6-24 months of age. World Health Organization, Geneva. 31 p.
Zhang Z, Goldsmith PD, Winter-Nelson A (2016). The Importance of Animal Source Foods for Nutrient Sufficiency in the Developing World: The Zambia Scenario. Available at https://doi.org/10.1177/0379572116647823

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Evaluation of cooking time and organoleptic traits of improved Dolichos (*Lablab purpureus* (L.) sweet) genotypes

David Ngure[1*], Miriam Kinyua[2] and Oliver Kiplagat[2]

[1]International Maize and Wheat Improvement Center (CIMMYT), P. O. Box 1041-00621, Nairobi, Kenya.
[2]Department of Biotechnology, School of Agriculture and Biotechnology, University of Eldoret P. O. Box 1125-30100, Eldoret, Kenya.

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In Lablab bean, cooking time and organoleptic qualities are major factors that influence its adoption and consumption. Its production in Kenya has been constrained by low yielding varieties, pests, poor agronomy and varieties with non-preferred taste and flavor. This study was initiated to evaluate cooking time and organoleptic traits of six Dolichos genotypes, (G2, B1, M5, LG1, W7 and G2), that had been bred at the University of Eldoret and two checks (Local Variety and DL1002). Cooking time and organoleptic studies were carried out on-farm in Meru County, Ruiri sub location using an organized farmer group (Ruiri farmers group) that comprised of ten panelists (seven women and three men). There was a high significant difference (P ≤ 0.001) among the six improved genotypes and the two checks in terms of cooking time and sensory attributes evaluated. Cooking time ranged from 87 to 159 min, with genotype M5 taking the shortest time (87 min) and local variety taking the longest time (159 min) to cook, respectively. In overall acceptability, genotypes G2, G1, M5 and B1 were highly rated because of their short cooking time and good organoleptic attributes. High variability among the genotypes evaluated could be exploited even further in breeding programs to produce genotypes that take even less time to cook and with even better organoleptic characters for easy adoption by farmers.

Key words: Lablab *(Lablab purpureus)*, cooking time, organoleptic traits.

INTRODUCTION

Dolichos (*Lablab purpureus* (*L.*) Sweet) (2n = 22) is a grain legume, adapted to most tropical environments: a wide range of rainfall, temperature and altitudes (Ravinaik et al., 2015; Rai, 2010). Across Africa subsistence farmers grow it for human consumption for vegetable (flowers, immature pods and mature grains) (Ngure et al., 2021; Uday et al., 2017), green manure, cover crop and concentrate feed for livestock (Hassan and Joshi, 2019; Maass et al., 2010).

Changes in climatic conditions have necessitated a worldwide interest in searching for new and potential uses of unconventional legumes. Pengelly and Maass (2001) concluded that because of its already well-established uses as a pulse, vegetable and forage, lablab is a priority genus in developing multi-purpose legumes in both commercial and small holder farming systems in the

*Corresponding author. E-mail: davynja@yahoo.com.

tropics. Cooking time and sensory quality are two important traits when selecting dry bean varieties for consumption but have largely been overlooked by breeders in favor of yield and other traits (Bassett et al., 2017). The cooking of most legumes involves several processes to render them palatable, digestible, and accessible for nutrient availability (Bergeson et al., 2016). As a result, cookability and organoleptic traits of beans are important attributes that affect the performance, selection and acceptance of bean varieties developed by breeders (Shivachi et al., 2012). Like other legumes, Lablab seeds contain anti-nutritional factors; trypsin and chymotrypsin inhibitors, tannins, phytohemagglutinins (lectins), lathyrogens, cyanogenic glycosides and goitrogenic factors, saponins and alkaloids (Wanjekeche et al., 2003; Vijayakumari et al., 1998). These anti-nutritional factors limit the usage of the legume, unless they are eliminated through processing e.g. by pre-soaking and subsequent discarding of the liquid and/or by heat treatment at relatively elevated temperatures (Wanjekeche et al., 2003). Prolonged cooking has a negative impact on beans; reducing their nutritive value especially vitamins and certain amino acids therefore results to the underutilization of the bean (Urga and Fufa, 2009).

Sensory factors are a major determinant of the consumers' subsequent purchasing behavior (Mkanda et al., 2007). Some of the most important characteristics considered in selecting dry bean varieties for production and consumption are fast food cooking and good flavor quality traits (Shivachi et al., 2012). In India for example, lablab is valued for its nutritional and sensory attributes (Venkatachalam et al., 2007). Cookability and organoleptic qualities are important attributes affecting performance, selection and acceptance of bean varieties developed by breeders (Shivachi et al., 2012). According to Coelho et al. (2009), prolonged cooking has been listed as one of the major factors responsible for underutilization of beans in many diets. Therefore, the improvement of locally adapted varieties is vital (Nene, 2006). This will minimize nutrient loss, reduce expenditure on fuel and shorten cooking time as well as help to fight food insecurity if successfully integrated in the farming system. Previous studies have shown that cooking time is an important trait in breeding of common beans especially where 96% of the beans consumed are prepared at household level (Shivachi et al., 2012; Jacinto-Hernandez et al., 2003).

Apart from cooking time, sensory characteristics such as appearance, texture and taste contribute to consumers' choice of a particular bean variety (Mkanda, 2007; Sanzi and Attienza, 1999). Descriptive sensory evaluation identifies, describes, and quantifies sensory attributes of a food material or product using human subjects. Sensory attributes that influence acceptance of cooked beans are visual appearance, texture and flavour-taste and aroma (Mkanda et al., 2007) as they contribute to consumers' like or dislike of certain bean varieties. Consumer sensory evaluation is a process of evaluating opinion of a particular product in terms of specific sensory attributes. An example of a participatory farmer evaluation form used in this study is as described in Supplementary Table 1 where farmers were expected to fill the form after examining each genotype.

Appearance: It is most important to consumers since they have certain expectations on how food should look like (Parker, 2002). It is divided into color and geometric (shape and size) attributes.

Texture: This is a quality felt with fingers, tongue and teeth. According to Mkanda et al. (2007), fast cooking beans have soft texture that is preferred by most consumers.

Flavor: It comprises of odor and taste. It is defined as a perceived attribute resulting from integrated responses to a complex mixture of stimuli on several senses, smell, taste, touch sigh and even hearing (reference?). Flavor, like appearance and texture, is a quality factor that influences the decision to purchase and consume a food product.

Over the years, farmers in Kenya preferred other legumes over lablab bean because of the bitter taste (Wanjekeche et al., 2000). Prolonged cooking time also increases the cost of utilizing the bean due to increase in amount of fuel needed (Shivachi et al., 2012). Odor of the lablab was also reported to affect acceptance (Kim and Chung, 2008). Similarly, a study on common bean reported that bitter taste contributes to consumers' dislike of some bean varieties (Mkanda et al., 2007). Studies are being conducted to improve Dolichos production in Kenya with a primary aim of identifying and evaluating various genotypes to come up with stable and well adapted cultivars for release and possible commercialization. Therefore, there is a need to carry out cooking time and organoleptic studies on improved lablab genotypes by the breeder, with the aid of the consumers/farmers, to ascertain whether he or she has achieved this objective. At the University of Eldoret Biotechnology Department, a breeding program was initiated to breed for the improvement of sensory and organoleptic traits (cooking time and taste) as well as high yielding *Lablab* varieties. Therefore, the objective of this study was to evaluate the diversity of the six improved Dolichos genotypes bred at University of Eldoret based on cooking time and sensory attributes.

MATERIALS AND METHODS

Genetic material

The genotypes used in the current study comprised of 6 lines that had been bred at University of Eldoret (W7, M5, B1, G1, G2 and LG1) to improve their yield, cooking time and taste and two commercial checks (DL1002 and a local land race (Local variety) collected from farmers' field in Meru county, Ruiri Village). The

Table 1. Description of the genotypes used in the study.

Entry	Genotype code	Seed color
1	LG1	Black
2	G2	Black
3	W7	Black
4	M5	Brown
5	G1	Black
6	B1	Dotted (Brown with black dots)
7	Local variety	Black
8	DL1002	Black

genotypes were selected based on yield, adaptability and ability to withstand pests and other diseases. The genotypes are as described in Table 1.

Study site

Cooking time and organoleptic studies were carried out on-farm in Meru County, Ruiri sub location using an organized farmers group (Ruiri farmers self-help group). This study site was selected because of the popularity of the crop in the region as well as the familiarity of the crop by the farmer group as Dolichos is part of their stable diet.

Experimental design and statistical analysis

In cooking time, cooking of the 8 genotypes was done to ascertain the cooking time of each genotype at a farm in Ruiri-Meru County in a Completely randomized design (CRD) with three tasting replicates. Organoleptic evaluation was also laid in a CRD where the coded samples were presented to the panel at random for evaluation. The taste panel consisted of 7 women and 3 men from the Ruiri farmers group in Meru County. Female formed the majority of the panelists' since they are usually involved in preparation of meals therefore are likely to be more sensitive to taste than men (Shivachi et al., 2012; Kigel, 1999). The data was subjected to statistical analysis using Genstat discovery 13th edition. Means were separated using Duncan's Multiple Range Test (DMRT) of the same software.

Cooking time

Saucepans 'sufurias' used in the experiment were of same size and were made of stainless steel with tight fitting lids. Heating system used was charcoal since it was the most convenient in the study site. A quarter (¼) Kgs of each genotype was weighed, cleaned and cooked in accordance with Gisslen (2007) protocol with few modifications in terms of the quantity of water, source of heat and quantity of grains used. All the eight genotypes were coded differently to avoid bias when scoring.

After the eight "jiko's" lit, one and a half liters of water was put in each saucepan and let to boil. Water from all the source pans was let to boil before the seeds were put in to take care of errors that may have arisen due to the different intensities from the source of heat. Once the water in all the source pans was boiled, each ¼ kg seed genotype was poured into the separate saucepans simultaneously and then covered with tight fitting lids of the same size and then timing started. During the cooking process, the samples remained covered with water and it was added intermittently as its level dropped until the grains were fully cooked to acceptable tenderness. Tenderness was determined using the method of Njoku and Ofuya (1989), by subjectively pressing the beans in between fingers until no hard material was found as traditionally done. One person was allowed to determine the tenderness of all the genotypes; this was to take care of errors that could have arisen due to various people having different textures on their fingertips as well as different strengths when pressing the beans. Samples were allowed to cook for the first sixty minutes. For the next thirty minutes sampling was done at an interval of ten minutes and at intervals of five minutes for the rest of the cooking time. The cooking time was recorded for the genotypes that had cooked to the required tenderness. This was calculated from the initiation of cooking until 80% of the grains were cooked. Three sample replicates of each genotype were cooked separately and each cooking time recorded. An average from the three readings was then calculated and recorded as the cooking time for each genotype.

Organoleptic tests

Before sensory evaluations were made, a panel of reviewers was trained to rate different attributes using the determined hedonic scales (Supplementary Table 1). After cooking the seeds to the acceptable tenderness, organoleptic tests were done. The panelists were trained on what they were expected to do and how they were to carry out the scoring. The attributes evaluated included: appearance, texture, taste, and overall acceptability. Appearance (size and shape) was rated by sight, texture by rubbing gently between the thumb and index fingers of the hand and in the mouth and taste in the mouth. Evaluations were done through quantitative descriptive analysis. The panelist indicated the intensity of the specified characteristic (Appearance, Taste and Texture), by checking an appropriate category and ordering them using five descriptive terms (1= Very bad, 2= Bad, 3= Fair, 4= Good and 5= Very good) (Supplementary Table 1). The cooked samples used for tasting were code blinded from the panelist and served on ten plates then given to the taste panel for evaluation. One sample was evaluated at a time by all panelists. They rated each sample depending on the intensity of the sensation perceived. After testing and scoring one sample, the panelists were given water for rinsing the plate and their mouths before proceeding to the next sample.

RESULTS

Cooking time

There was a significant difference in cooking time ($P \leq 0.001$) among the genotypes evaluated (Table 2). Cooking time for the genotypes ranged from 87 to 159 min with genotypes M5 taking the shortest time to cook

Table 2. Mean cooking time.

Genotype	Cooking time
W7	131.67^{e}
G2	117.0^{d}
M5	87.67^{a}
B1	99.33^{b}
LG1	107.67^{c}
G1	121.0^{d}
Local Variety	159.33^{g}
DL1002	154.0^{f}
Grand mean	122.21
$MS_{(Genotype)}$	1900.7***
$MS_{(error)}$	2.6
SD	256.64
CV (%)	2.1

Table 3. Means for organoleptic traits.

Entry	Genotype	Appearance	Taste	Texture	Acceptability
1	**W7**	4^{cd}	3.4^{bc}	3.8^{bc}	3.8^{bc}
2	**G2**	4.4^{de}	4.1^{de}	4.3^{cd}	4.3^{de}
3	**M5**	3.4^{ab}	4.6^{e}	4^{bc}	4^{cd}
4	**B1**	3.8^{bc}	4^{cde}	4.3^{cd}	4^{cd}
5	**LG1**	3.3^{ab}	3.6^{bcd}	3.5^{b}	3.5^{b}
6	**G1**	4.9^{e}	4^{cde}	4.8^{d}	4.5^{e}
7	**Local Variety**	3.1^{a}	2.6^{a}	2.9^{a}	2.9^{a}
8	**DL1002**	4^{cd}	3.3^{ab}	3.9^{bc}	3.7^{bc}
	Grand mean	3.8	3.7	3	3.8
	$MS_{(Genotype)}$	2.9***	3.1***	2.5***	2.1***
	$MS_{(error)}$	0.5	0.7	0.6	0.4
	CV (%)	13.6	18.5	15.7	10.9

N/B*** = Significant at P ≤ 0.001. Means followed by the same letter are not significantly different, according to Duncan's Multiple Range Test (DMRT).

while the local variety taking the longest time to cook. Five out of eight genotypes had cooking time lower than the general mean (122.21 min), all of them being the new varieties. Genotype M5 took an average of 87 min to cook which is less than 1 h and 30 min, genotypes B1, LG1, G2 and G1 took an average of 99, 107, 117 and 121 min to cook respectively, which is within 2 h. However, genotypes W7, DL1002 and Local variety took an average of 131, 154 and 159.33 min to cook which is more than 2 h and above the average mean.

Organoleptic traits

The results obtained from the organoleptic traits, that is, appearance, taste, texture and acceptability, evaluated were highly significant, due to the differences in their means at P ≤ 0.001 (Table 3). The local variety was ranked lowest in all the traits evaluated whereas genotype G2 and G1 were ranked highly in all the traits evaluated. Despite genotype W7 being ranked highly in appearance, it was ranked average in terms of acceptability. There was a deviation from the expected, that brown genotypes would be ranked highly for appearance, where some brown genotypes B1 and M5 were ranked poorly and given low scores for appearance, 3.75 and 3.38, respectively. Genotypes G1, G2, M5 and B1 received the highest overall acceptability scores of 4.54, 4.25, 4.0 and 4.0, respectively. This is due to the fact that they were highly scored in all of the traits evaluated except for genotype M5 and B1 which received low scores of 3.37 and 3.75 for appearance. This high level of significance in the organoleptic traits evaluated (P ≤ 0.001) depicts the importance of organoleptic

evaluation and thus should also be incorporated in other breeding programs as an important aspect in breeding and selection.

DISCUSSION

The reduction in cooking time has important implications for fuel wood requirements as majority of households rely on charcoal for cooking (Bergeson et al., 2016). There was a notable significant difference between the new genotypes and the checks (a local variety and DL1002) with the new genotypes taking a shorter cooking time as indicated by the results in Table 2. There was significant variation in cooking time among the eight genotypes ranging from 87 to 159 min. The cooking times recorded in this study are lower than findings form, Shivachi et al. (2012) who reported cooking time of thirteen genotypes to be between 70-197 min. Bassett et al. (2017) reported cooking times of 389 dry bean genotypes ranged from 16.7 to 68.9 min. Comparatively, the two checks (DL1002 and Local variety) took relatively long time to cook than the new improved genotypes. This was expected since the new genotypes had been bred to improve on their cooking time as well as organoleptic traits. The shortest cooking time was 87 min recorded by M5 which is a brown seeded genotype followed by B1, that recorded 99 min, and which is also brown seeded but has black dots and the longest cooking time of 159 min was recorded by Local variety which is black seeded, and a common land race grown by farmers in Ruiri-Meru.

Variation in cooking time is caused by many factors among them: genetic makeup of the genotypes, energy source used, type of water used, size and age of the beans among others (Shivachi et al., 2012). However, because most of these factors that is, heat supply, water type, source of heat, age and size of bean, were kept constant during the experimentation, it can therefore be concluded that the difference in cooking time among the genotypes could be attributed to their genetic makeup (Bitjoka, 2008; David and Konesh, 2004; Ngwira and Mwangwela, 2001). The black seeded genotypes took longer to cook than the brown seeded genotypes, this finding also concurred with findings from Shivachi et al. (2012). This result could be attributed to high anti nutrient levels in their seed coats.

Maass and Usongo (2007) and Pengelly and Maass (2001) related lablab color to anti nutrient levels and found dark seeded types to contain high amounts of these substances than white or cream seeded types. A large amount of heat is thus required to eliminate these compounds resulting in prolonged cooking of these genotypes (Shivachi et al., 2012). Adeboye (2006) and Fasoyiro et al. (2005) also concluded that dark seeded pigeon pea and mucuna varieties took longer time to cook owing to large amounts of anti-nutritional factors contained in their seed. From the organoleptic results gotten we can also conclude that anti nutritional factors are responsible for bitter taste, that is, dark/black genotypes received low scores for the taste attributes. These genotypes are thus associated with extended cooking time to eliminate their bitter taste. Osman (2007) also made similar observations.

All organoleptic traits evaluated were highly significant ($P \leq 0.001$) for the four traits evaluated. From the findings, it was clear that the sensory panelist had clear preference when it came to the specific genotypes. A major finding from the panelist was that the quality traits of appearance, taste and texture are fundamental and greatly affect consumers' preference for particular lablab genotypes. With regards to appearance, genotype G2 was rated highest and Local variety was lowest. This may be attributed to the fact that G2 has uniform, round and well filled seeds as opposed to the local variety that has flat and the seeds are not well filled and thus not appealing. In terms of taste, genotype M5 was rated highest while the local variety was rated lowest (Table 3). This could be attributed to the anti-nutritional content of the genotypes, since M5 is brown seeded as opposed to the Local variety which black seeded. These results were similar to Shivachi et al. (2012) and Mkanda et al. (2007) who reported that black seeded genotypes were more bitter than the brown seeded genotypes. In a study by Kimani et al. (2017), sensory tests showed significant differences for the bitter taste ($P \leq 0.05$).

In pulse, white or cream genotypes are highly preferred to dark once because the latter, contain relatively high amounts of anti-nutritional factors giving them a bitter taste (Shivachi et al., 2012). In terms of texture, B1 was rated highest while Local variety was rated lowest. Genotype G1 was rated the highest and local variety lowest in terms of the overall acceptability, Table 3. This could be attributed to the fact that despite the seeds being black in color, they are large, smooth, uniform size and well filled, thus the farmer preference. Local variety was ranked least in nearly all the traits that were evaluated. This was a clear indication that most of the genotypes that are grown by farmers need to be improved.

Organoleptic traits, that is, appearance, texture and taste, affect the general acceptance of the lablab genotypes and that farmers adopt genotypes based on all these factors that is, desirable agronomic attributes like growth habit, yield and adaptation. Similar observations have also been sighted by Kankwatsa and Muzira (2018) and Kinyua et al. (2008). From these findings therefore, new genotypes especially beans need to be subjected to both cooking time and organoleptic trait evaluations to ascertain their overall acceptability by the farmers who are the end users of these varieties.

CONCLUSION AND RECOMMENDATION

Results from cooking time showed that improved

genotypes took less time to cook than the two checks, therefore the overall objective of this study was achieved. The organoleptic study showed that sensory traits of appearance, texture and taste greatly affect consumers' choice and thus influencing the adaptability of bean varieties. In this study, anti-nutritional factors were neither qualified nor quantified, and thus need further investigation to ascertain their contribution to cooking time.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Bassett AN, Cichy KA, Daniel Ambechew D (2017). Cooking time and sensory analysis of a dry bean diversity panel. Publications from USDA-ARS / UNL Faculty. 1665. Available at: https://digitalcommons.unl.edu/usdaarsfacpub/1665.

Bergeson TL, Opio C, MacMillan PD (2016). Crop ash filtrate influence on cooking time and sensory preferences for dried black beans (Phaseolus vulgaris L.). African Journal of Food Science 10(8):132-142.

Bitjoka L (2008). PC-based instrumentations system for the study of bean cooking kinetic. Journal of Applied Sciences 8(6):1103-1107.

Coelho MMC, Vargas PV, Souza AC, Tereina T, Santos JCP (2009). Cooking quality of common beans as influenced by the nitrogen levels and time of application. International Journal of Agricultural Biology 11(3).

David Y, Konesh JS (2004). Phytate from edible beans: Chemistry, processing and health benefits. World food publishers.

Fasoyiro SB, Ajibade RS, Soka JO, Ashaye OA, Obatolu VA, Farinde EO, Afolabi OO (2005). Physical characteristic and effects of processing methods on pigeon pea varieties. Journal of Food Agriculture and Environment 3(3&4):59-61.

Gisslen W (2007). Professional cooking. 6th edition. Wiley and sons INC.

Hassan Md.M, Joshi N (2019). Hydrothermal effects on physiochemical, sensory attributes vitamin C and antioxidants activity of frozen immature *Dolichos lablab*. Heliyon 6(1):e03136.

Kankwatsa P, Muzira R (2018). Agronomic Performance and Sensory Evaluation of Lablab (*Lablab purpureus* L. Sweet) Accessions for Human Consumption in Uganda. Open Access Library Journal 5(3):1.

Kigel J (1999). Culinary and nutritional quality of *Phaseolus vulgaris* seeds as affected by environmental factor. Faculty of Agricultural, Food and Environmental Sciences, Hebrew University of Jerusalem.

Kim JS, Chung HY (2008). Characterization of volatile components in Field bean (Lablab) obtained by simultaneous steam distillation and solvent extraction. Journal of Nutrition and Food Sciences 13:18-22.

Kimani E, Matasyoh J, Kinyua, GM Wachira, FN (2017). Characterization of volatile compounds and flavour attributes of *Lablab purpureus* bean accessions. African Journal of Biotechnology 18(24):518-530.

Kinyua MG, Orwa D, Kimani E, Kamotho G (2008). Survey of Dolichos bean (*Lablab purpureus*) Production systems, Utilization, Marketing and the collection and Characterization of gemplasm in Kenya. Proceeding of the International Dolichos meeting, Arusha, Tanzania 8th March 2008.

Maass BL, Knox MR, Venkatesha SC, Angessa TT, Ramme S, Pengelly BC (2010). Lablab purpureus - A crop lost for Africa? Tropical Plant Biology 3(3):123-135

Maass LB, Usongo FM (2007). Changes in seed characteristics during the domestication of lablab bean (*Lablab purpureus*) L. Sweet.) Papilionoideae). Australian Journal of Agricultural Research 58(1):9-19

Mkanda AV, Amanda M, Henriëtte L de Kock (2007). Relating consumer preferences to sensory and physicochemical properties of dry beans (*Phaseolus vulgaris*). Journal of the Science of Food and Agriculture 87(15):2868-2879.

Nene YL (2006). Indian pulses through the millennia. Asian-Agricultural History 10(3).

Ngure D, Kinyua M, Kiplagat O (2021). Morphological and microsatellite characterization of improved Lablab purpureus genotypes. Journal of Plant Breeding and Crop Science 13(2):23-34.

Ngwira MM, Mwangwela AM (2001). Culinary characteristics of selected bean varieties in Malawi. Processing of bean seed workshop, Arusha, Tanzania. January 12-14 (2001).

Njoku HO, Ofuya CO (1989). Effect of pretreatment in the cooking time of the African yam bean. Journal of Food Science 3:758-759.

Osman M (2007). Effect of different processing methods, on nutrient composition, antinutrional factors, and *in vitro* protein digestibility of *Dolichos lablab* bean [*Lablab purpuresus* (L) Sweet]. Pakistan Journal of Nutrition 6(4):299-303.

Pengelly B, Maass L (2001). Lablab purpureus (L.) Sweet-Diversity, potential use and determination of a core collection of this multipurporse tropical legume. Genetic Resources and Crop Evolution 3(48):261-271.

Rai N, Ashish K, Singh K, Singh M, Datta D, Rai M (2010). Genetic relationship among Lablab (Lablab purpureus) genotype cultivars from different races based on quantitative traits and Random Amplified Polymorphic DNA (RAPD) marker. African Journal of Biotechnology 9(2):137-144.

Ravinaik K, Hanchnamani CN, Patil MG, Imamsaheb SJ (2015). Evaluation of dolichos genotypes (Dolichos lablabL.) under North eastern dry zone of Karnataka. The Asian Journal of Horticulture 10:49-52.

Sanzi CM, Attienza DRJ (1999). Sensory analysis of beans (*Phaseolus vulgaris* L.) Biotechnology, Agronomy and Social Environment 3:201-204.

Shivachi A, Kinyua MG, Kiplagat KO, Kimurto PK, Towett BK (2012). Cooking time and sensory evaluation of selected Dolichos (Lablab purpureus) genotypes. African Journal of Food Science and Technology 3(7):155-159.

Jacinto-Hernandez C, Azpiroz-Rivero S, Acosta-Gallegos JA, Hernandez-Sanchez H, Bernal-Lugo I (2003). Genetic analysis and random amplified polymorphic DNA markers associated with cooking time in common bean. Crop science 43(1):329-332.

Uday KHR, Gowda BM, Ramesh S, Vasundhara M (2017). Characterization and Identification of Dolichos Bean (*Lablab purpureus* L. sweet) Recombinant Inbred Lines (RIL) with High Pod Yield and High Pod Fragrance. International Journal of Pure Applied Biosciences 5(6):428-436.

Urga K, Fufa H (2009). Effects of balancing and soaking some physical characteristics of grass pea (*Lathyrus sativus*). Journal of Agriculture and food science.

Venkatachalam L, Sreedhar RV, Bhagyalakshmi N (2007). Genetic analyses of micropropagated and regenerated plantlets of banana as assessed by RAPD and ISSR markers. *In vitro* Cell Developmental

Biology in Plants 43:267-274.
Vijayakumari K, Siddhuraju P, Pugalenthi M, Janardhanan K (1998). Effect of soaking and heat processing on the levels of antinutrients and digestible proteins in seeds of *Vigna aconitifolia* and *Vigna sinensis*. Food Chemistry 63(2):259-264.
Wanjekeche E, Mwangi J, Kamidi M, Powon P, Khaemba J (2000). Farmer participation in the evaluation of grain legumes in North-Western Kenya. In: KARI. Participatory technology development for soil management by small holders in Kenya. Proceedings of the 2nd Scientific Conference of the Soil Management and Legume Research Network Projects, Mombasa, Kenya, 39 p.
Wanjekeche E, Wakasa V, Mureithi JG (2003). Effect of germination, alkaline and acid soaking and boiling on the nutritional value of mature and immature Mucuna (*Mucuna pruriens*) beans. Tropical and Subtropical Agroecosystems 1:183-192.

Supplementary Table 1. Participatory farmer evaluation form.

Genotype code …….
Evaluator's name …… Date……

Trait	Score/Rank
Inavyoonekana/ Appearance	
Cooking time	
Ladha/ Taste	
Texture	
Kukubalika/ Overall adaptability	

KEY

1- Mbaya sana	1- Very bad
2- Mbaya	2- Bad
3- Inaridhisha	3- Fair
4- Nzuri	4-Good
5- Nzuri sana	5- Very good

Maoni/ comments

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……

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Quality assessment of Ugali blended with orange-fleshed sweet potato to alleviate vitamin A deficiency in Tanzania

Roman M. Fortunatus[1*], Amarat H. Simonne[2] and Richard J. Mongi[3]

[1]Department of Food Science and Technology, University of Dar es Salaam, Dar es Salaam, Tanzania.
[2]Family, Youth and Community Sciences Department, University of Florida/IFAS, Gainesville, FL 32611, United States.
[3]College of Health Sciences, University of Dodoma, Dodoma, Tanzania.

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Approximately 38% of Tanzanian children have vitamin A deficiency (VAD), and the majority of them do not have access to vitamin A-fortified foods. Orange-fleshed sweet potato (OFSP), a new crop in Tanzania, is rich in β-carotene, and could be a cheaper solution for VAD. The objectives of this study were to develop a type of Ugali (stiff maize porridge) fortified with OFSP, to correlate its β-carotene content (using colour measurement), and to assess its proximate composition and consumer acceptability. Ugali was prepared using maize flour with various amounts of added OFSP (0, 30, 50, 70 and 100%). Samples of Ugali with more OFSP had higher colour values (a* and b*) that imply the increase in β-carotene as the OFSP amount increased. The proximate compositions of Ugali with different amounts of OFSP were different (*P*<0.05). All samples that were made with the mixture of OFSP and maize flour have shown to have higher sensory scores than those with 100% maize or 100% OFSP; Ugali with 50% OFSP was most favourably rated by Tanzanian consumers. This sample was selected as a potential possibility for everyday consumption since it was shown to potentially supply more than 50% of the RDA of provitamin A for a specific age group. This supplementation method may be simple, affordable, and effective in reducing VAD in Tanzania.

Key words: β-carotene, colour parameters, proximate composition, total carotenoids.

INTRODUCTION

Micronutrient deficiencies are one of the major growing health problems in the world (Magee and McCann, 2019); more than two billion people are at risk of vitamin A, iron, and iodine deficiencies (Ramakrishnan, 2002). At least half of children aged 6 months to 5 years worldwide suffer from one or more micronutrient deficiencies (CDC, 2014). Low serum retinol concentration (<0.70 μmol.L^{-1}), an indication of vitamin A deficiency (VAD), affects an estimated 190 million preschool-age children and 19.1 million pregnant women globally (WHO, 2009). This problem is more pronounced in developing countries especially in Africa, Asia and in low-income populations in Latin America, the Caribbean (López de Romaña et al., 2015), and Europe (Darmon et al., 2002).

*Corresponding author. E-mail: romanmmanda@yahoo.com or asim@ufl.edu.

In Tanzania, vitamin and mineral deficiencies significantly contribute to more than 27,000 infant and 1600 maternal deaths annually (World Bank, 2012) with hidden hunger index of 35 (Ritchie and Roser, 2017) in a score of 100. According to the 2010 Tanzania Demographic and Health Survey, about 38% of children between 6 and 59 months had VAD (NBS and ICF, 2011) and a demographic health survey of 2015 showed that only 41% of the children aged 6-59 months has received vitamin A supplementation 6 months before the survey (Ministry of Health et al., 2016). Tanzania and other sub Saharan Africa have shown a decline in poverty condition. However, in 2018 about 26% (14 million) of the Tanzanian population lived below the poverty line (equivalent to about US $1.9-2 a day) (World Bank, 2020). Of these, more than 80% resided in rural areas, and could not afford a quality diet (UNICEF, 2020). According to Lyana and Manimbulu (2014), maize (white corn) is the major staple food crop in many parts of Tanzania. Maize flour is used for Ugali (stiff porridge) preparation in about 91% of households in Tanzania, and Ugali is the most frequently consumed food in Tanzania (Muhihi et al., 2013). Maize comprises 41% of the weekly calorie intake of households in Tanzania (NBS and ICF, 2011). It is a carbohydrate-rich food (25.6%) and is one of the major Tanzanian staple foods (Lukmanji et al., 2008). Vitamin A in food is found as retinol (preformed vitamin A) or as provitamin A carotenoids. Preformed vitamin A is found exclusively in animal foods, including eggs and milk, fish and fish oils, and animal livers (Ross et al., 2020). These foods are too expensive for poor communities (van den Berg et al., 2000); hence, the primary source of provitamin A in these communities is β-carotene (or other provitamin A carotenoids) from plant sources. Micronutrient supplements are often given to populations with severe micronutrient deficiencies, but the intervention is expensive, and for it to be effective, it must be repeated every six months (WHO, 1998). Therefore, the success of using these supplements is limited in developing countries. A successful program for the iodification of table salt in Tanzania has been accomplished, but fortification programs for other foods (wheat, cooking oil, and maize flour) have only started in recent years (NBS and ICF, 2011). Large proportions of the population cannot afford and/or get fortified food. One way to reduce the prevalence of VAD in Tanzania and other developing counties could be to add β-carotene from locally available food sources to improve the nutritional quality of flour used to prepare Ugali, a common staple food (De-Regil et al., 2011). For instance, orange-fleshed sweet potato (OFSP), which is rich in provitamin A, could be an affordable choice for fortification since it has proven to improve total body vitamin A stores as effectively as supplementation (Gannon et al., 2014). This product could thus reach a greater population and help to eliminate micronutrient deficiencies (Low et al., 2017). Colour parameter methods, from objective colour measurements (that is, CIE L* a*b*, hue, and chroma), have been successfully used for estimating the amount of coloring compounds, such as lycopene and other carotenoids, in many plants. For instance, the lycopene content in tomatoes from HPLC analyses correlates well with colour parameters in linear regression (R^2 = 96%) (Arias et al., 2000). Other researchers explored the relationship between carotenoid content and the colour of winter-type squash flowers and flesh (Fransis, 1962; Seroczyńska et al., 2006); these revealed a weak relationship, indicating that the a* parameter was the strongest (Seroczyńska et al., 2006). Another study correlating specific carotenoid contents in pumpkins and squash (*Cucurbita* species) flesh (by HPLC) and colour parameters revealed strong correlations between a* and total carotenoids and b* and lutein. These researchers concluded that this technique (colour parameter measurement) can be used as an "easy-to-use and inexpensive method" for estimating carotenoid contents in large numbers of samples from breeding programs (Itle and Kabelka, 2009). Simonne et al. (1993) correlated colour parameters and specific carotenoid contents (from HPLC data) in sweet potato and found that β-carotene content was highly correlated with hue angle, especially in sweet potatoes with yellow to deep orange (r =-0.99) and conclude that colour parameters can be used for the estimation of β-carotene. Since most of the laboratories in developing countries have limited access to advanced technologies for β-carotene analysis (that is, HPLC), this study utilized a simple method of colour measurement to estimate β-carotene (from sweet potato) content in Ugali. Orange-fleshed sweet potato is among the bio-fortified staples bred for high provitamin A carotenoid content (CIP, 2006). It has emerged as one of the most promising plant source of β-carotene for reducing vitamin A deficiency prevalence (Hagenimana et al., 1999; Tumwegamire et al., 2004; Low et al., 2017; Bao and Fweja, 2020); OFSP can supply about 50% per 100 g of the daily vitamin A requirement (Low et al., 2001) (Recommended daily allowance is 400-1300 $\mu g.day^{-1}$ RAE depending on age, sex and health status). In this study, formulated mixtures of maize flour and boiled OFSP were mixed in different amounts to obtain a ratio that provided the optimum level of provitamin A in Ugali. The objectives of this study were (i) to develop fortified Ugali using locally available raw food materials that are rich in provitamin A, that is, OFSP; (ii) to utilize colour measurement as a tool to estimate ß-carotene levels in mixture; and (iii) to assess the nutritional composition and evaluate the chemical and physical properties and consumer acceptability of this Ugali.

MATERIALS AND METHODS

Initial work to optimize analytical methods (colour and β-carotene, moisture), and Ugali preparation was accomplished at the

University of Florida Food Safety and Quality Research Laboratory (UF-FSQL) in Gainesville, Florida, USA. Most other subsequent work (including sample preparation, chemical analysis, sensory evaluation, and texture analysis) was conducted at the Department of Food Technology, Nutrition and Consumer Sciences laboratory at the Sokoine University of Agriculture (SUA), Morogoro, Tanzania. Colour measurements were conducted at the International Institute of Tropical Agriculture (IITA) in Mikocheni, Dar es Salaam, Tanzania. The consumption study to estimate Ugali intake was conducted in Morogoro town with five volunteer consumer households (N =15) near the SUA campus in Morogoro.

Orange-fleshed sweet potato (*Ipomea batatas* Lam) [OFSP] used in the initial study to optimize analytical methods (colour and β-carotene, moisture) and in the Ugali preparation were purchased from local grocery stores in Gainesville, Florida. While the variety information was not available, the supply was uniform enough for the purpose of the initial study. The average root weight was 514.7 g before peeling and 408.6 g after peeling (79.4% recovery). OFSP (Jewel variety) for the subsequent studies were purchased locally in Tabora, Tanzania in three batches of 100, 100, and 300 kg. OFSP of similar maturities were transported to a lab at SUA in Morogoro, Tanzania. At the SUA laboratory, the OFSP were sorted according to the USDA grading system (USDA, 2005). OFSP of U.S. Extra No. 1 grade were selected and average sweet potato root weight was about 181 g.

Maize flour (8 kg, Maseka Instant Corn Masa mix) for the preliminary study at UF-FSQL was purchased from a local grocery store in Gainesville, FL. Maize flour (about 20 kg, Ndaiga Super Sembe, Ndaiga Milling Morogoro-Tanzania) for the actual study at SUA was purchased from a local grocery store at the SUA campus and sieved in a stainless steel testing sieve with an aperture of 1 mm and a wire diameter of 0.56 mm (Tokyo Screen Co. Ltd, Japan).

All chemicals were of analytical grade and were purchased from the Techno Net Scientific Ltd. store, Mwenge, Dar es Salaam, Tanzania. Acetone, petroleum ether, sulphuric and hydrochloric acid, sodium hydroxide, diethyl ether, and boric acid (Carlo Ebra Reagents, Val De Ruil-France), anhydrous sodium sulfate (Uni-Chem Chemical Reagent, Belgrade-Serbia), sodium chloride (Nentech Ltd., Brixworth, Northants-UK), protein analysis catalysts (copper sulphate: potassium sulphate: selenium = 10: 10: 1) and indicators (Bromocresol Green/Methyl Red, mixed indicator solution; Sigma-Aldrich, Louis USA), *β*-carotene standard [Fulka BioChemika (22040 standard with purity of >97.0% HPLC), Buchs-Switzerland].

Preparation of OFSP for Ugali fortification

The OFSP for sensory evaluation as well as for Ugali preparation were prepared from sorted samples one day after reaching the laboratory. The OFSP were washed with tap water, rinsed with distilled water, peeled with a kitchen knife, and cut into uniform cubes (1 × 1 × 1 cm). The sweet potato cubes (about 2 kg average for each batch) were then fully immersed in boiling water (1: 2 OFSP: water (w/v) at 100°C for 15 min in a 5 L stainless steel pot. The boiling time of 15 min under this condition was previously determined at the University of Florida, following a boiling time study at 100°C. Boiling time was recorded after water with sweet potato reached 100°C (about 7 min). Water was drained off, and the pot with boiled OFSP was kept in a water bath filled with tap water at room temperature (26°C) to cool for about 10 min. The cooled OFSP was blended with a mixer blender (Pigeon Appliances Pvt Ltd., India) at setting number 2 for 1 min. For raw OFSP, cubes were blended with this blender at this condition and used for colour, texture and proximate analysis. The boiled and blended OFSP was then ready for either sensory evaluation, mixing with maize flour for preparing Ugali, or for chemical analysis.

Preparation of Ugali and Ugali with OFSP

Ugali was prepared according to Nyotu et al. (1986) with minor modifications as to the composition of Ugali (to add OFSP) and the cooking time. Water was boiled (100°C) then maize flour was added to the boiling water (1: 2.8 w/v maize flour: water) while stirring. This mixture was stirred for 5 to 10 min until a uniform consistency and stiffness was obtained. Ugali with OFSP was prepared by adding boiled OFSP to boiling water together with maize flour while stirring. The amount of OFSP, maize flour, and water was adjusted based on the moisture ratio of boiled OFSP and maize to obtain five combinations with increments of 0, 30, 50, 70 and 100% OFSP that were coded as A, B, C, D and E, respectively. These ratios together with cooking times were formulated through the preliminary studies done at UF-FSQL.

Sensory evaluation

Ugali was evaluated by a consumer panel (n=181) at the food science sensory evaluation lab at SUA. Participants were recruited in accordance with the University of Florida Institutional Review Board for Human Subjects (#2015-U-1123). All panelists were students of SUA with average age of 23 years old (the maximum age was 37 and the minimum was 19). Each panelist was given five samples (5 g each; samples were served at 26°C and coded with 3-digit random numbers) of Ugali prepared with different amounts of OFSP (0 to 100%), as described previously. Panelists were asked to evaluate each sample based on appearance, texture, flavor, and overall preference, using a 9-point hedonic scale where 9 was anchored with “like extremely” and 1 was anchored with “dislike extremely” (Ihekoronye and Ngoddy, 1985). In addition, the panelists were asked to rank the samples (1-5) based on their preference. Sensory evaluation was conducted on three different days with 40, 40, and 101 panelists. Samples from the same batch that was used for the sensory evaluation were also used for chemical and physical analyses. The samples for chemical and physical analyses were sealed in minimum-oxygen freezer bags that were wrapped with aluminium foil and stored at -18°C at the Food Technology, Nutrition and Consumer Sciences Department laboratory of SUA until the time of experiments (not more than a week).

Consumption study to estimate *β*-Carotene intake from fortified Ugali

In order to estimate amounts of *β*-carotene intake from OFSP-fortified Ugali during a normal meal, 5 consumer households were recruited to participate in a consumption study. None of the members of these households were involved with any sensory evaluation described previously. These consumer households (with a combined 15 total members) were randomly chosen from a pool of volunteers who were willing to participate. The Ugali with 50% OFSP was selected for the consumption study, based on the results of the sensory evaluation. During a week-long period selected families were provided with the fortified Ugali (1.2 $kg.family^{-1}.meal^{-1}$) three times. The members of the family were to consume the Ugali along with typical meal accompaniments (e.g. fried fish, roasted beans, boiled amaranth, boiled sweet potato leaves or roasted meat) in their home. The serving sizes were based on the amount each person needed to reach satiety (without restriction) that was weighed by top scale balance (Citizen Bench Scale, 12R988, India).

According to Burri (2011), bioaccessible β-carotene from OFSP can be calculated as follows:

$$\begin{aligned} &Bioaccessible\ \ \beta-carotene \\ &=\beta-carotene\ in\ OFSP\times\ fraction\ retained\ after\ cooking\ and\ storage \\ &\times\ Bio\ accessible\ \ fraction \end{aligned} \quad (1)$$

The bioaccessibility of *β*-carotene in blended foods containing OFSP flour has been measured using *in vitro* digestion. The *in vitro* bioaccessibility of *β*-carotene from heat-processed OFSP was observed and accessible *all*-trans-*β*-carotene was 24 and 41% without fat (Bengtsson et al., 2009). Porridge with maize: soybean: OFSP flours (30: 35: 35) had a bioaccessibility of 16% *all*-trans carotenoids and 30.3% 13-*cis* carotenoids. Boiled puree of OFSP had a bioaccessibility of 9.9% for *all*-trans carotenoids and 43.5 for 13-*cis* carotenoids (Bechoff et al., 2011). Burri (2011) stated that the bioaccessibility of β-carotene is 25%. The retinol equivalency ratio was estimated to be 12 µg β-carotene: 1-µg retinol for women and children with good Vitamin A status (West et al., 2002) as shown in Equation 2 while the Recommended Daily allowance is as shown in Equation 3.

$$RE\ (\mu g.g^{-1}) = \frac{\beta-carotene\ (\mu g.g^{-1})\times Bio\ accessible\ \ fraction\ (0.25)}{12} \quad (2)$$

$$RDA consumed.meal^{-1} = \frac{Vita\,minA\ (\mu g.g^{-1})}{RAE\ (\mu g.g^{-1})}\times 100 \quad (3)$$

For this study, an additional introduction letter from SUA and a permit to conduct research with households was needed for each household, in addition to the UF-IRB.

β-Carotene analysis

The methodology for *β*-carotene analysis at SUA was optimized based on the preliminary experiments that were done at the University of Florida Food Safety and Quality Research Laboratory. Based on these preliminary experiments, *β*-carotene in sweet potato and sweet potato-fortified Ugali was analyzed according to a method described by Kimura et al. (2007), with minor modifications to the amount of solvents used (acetone and petroleum ether). Approximately 2 g of samples were weighed (electronic balance, Contech Instrument Ltd.) into glass tubes and 5 mL of cold acetone (refrigerated at 4°C for about 2 h) was added. The mixture was then homogenized with a homogenizer (Polytron, Omni mixer Homogenizer, Special model, Omni International Inc., USA) for 1 min at 3600 rpm. Extractions (with acetone) were done five times until a colorless residue was obtained and the final total volume of the extract was 25 mL. The supernatant (acetone extract) was pipetted into a 250-mL separatory funnel (containing 50 mL of petroleum ether) for partitioning. The mixture in the separatory funnel was allowed to separate for approximately 3 min and the lower aqueous phase was discarded. The petroleum ether phase was washed 3 to 4 times with 20 mL of distilled water (Wagtech International Ltd Berkshire UK). To prevent emulsion, washing was done slowly along the walls of the funnel without shaking, and when emulsion occurred, saturated sodium chloride (NaCl) solution was added to prevent formation of an emulsion. The petroleum ether phase was collected in 25, 50, or 100 mL volumetric flasks, depending on expected β-carotene amount in the solvent phase. Residual water was removed by passing the extract through a small funnel with glass wool containing about 15 g anhydrous sodium sulfate. The volumes of carotenoid solution were then adjusted to 25, 50, or 100 mL (raw OFSP) with petroleum ether, and absorbance readings were taken using a UV-VIS Spectrophotometer (Biomate 6 UV VIS Thermo Scientific) at 450 nm. The total carotenoid content (β-carotene) of the stock solution was verified according to Davies (1976), using the absorption $A^{1\%}_{1\ cm}$ of β-carotene in petroleum ether (that is, 2592) and found to be 98%. The total carotenoid was calculated as all trans-β-carotene since 80-90% of the carotenoid in OFSP is β-carotene (Bengtsson et al., 2008).

$$Total\ carotenoids\ (\mu g.g^{-1}) = \frac{Absorbance * Total\ extract\ volume(mL) * 10^4}{Specific\ extinction\ \ coefficien\ t\ (2592) * sample\ \ weight\ (g)}$$

β-carotene standard was used to prepare the stock solution of 100 μg.mL^{-1}. *β*-carotene of the samples was calculated from a standard curve obtained from 0.4, 0.8, 1.7, 3.3, 6.7 and 13.3 μg.mL^{-1}. *β*-carotene concentration was expressed on a fresh weight basis to synchronize the results with sensory panelists' assessment of the product as a wet product. Precautionary measures to prevent artifact formation and losses of carotenoids during analysis were rigorously followed such as completion of the analysis within the shortest possible time, protection from direct light, high temperatures was avoided, exclusion of oxygen and the use of high-purity solvents (Kimura et al., 2007).

Determination of proximate composition of samples

Proximate composition [moisture (AOAC, 2000), ash (AOAC, 2000) #942.05, crude fiber (AOAC, 2000) #978.10, fat (AOAC, 2000)#920.390, protein (Thiex et al., 2002) and carbohydrate (calculated by difference)] analysis was carried out in duplicate on the raw OFSP, boiled OFSP, and Ugali samples. Slight modification was done on protein analysis by the use of slight different ratio of the catalyst mixture as shown in the chemical supplies list.

Colour

Colour measurement in the preliminary study at UF-FSQL was done using a Minolta Chroma meter (Konica CR- 400 Tokyo Japan), while the subsequent colour analysis was done at IITA with a PCM+ Chroma meter with settings at Ist LAB C10 CIELAB 1:1:1. Approximately 20 g of each sample from three batches, each with one boiled OFSP, one raw OFSP, and four Ugali with different levels of OFSP, were analyzed. Samples were wrapped in very low-density polyethylene transparent material, and the measurements (L*, a* and b*) coordinates were read and recorded in ten different locations (Simonne et al., 1993).

Statistical analysis

The statistical comparison of data was performed by one-way analysis of variance (ANOVA) using R software in R Studio (Version 3.5.0 © 2018 RStudio, Inc) to determine differences among samples; ANOVA assumptions were validated by normality and homogeneity of the variance by Shapiro-Wilk normality test, Bartlett test of homogeneity of variances, respectively while independence of variance by residuals against fitted values plots. Independent variables were five samples (at three replicates) of Ugali, while dependent variables were colour parameters (ten measurements (L*, a*, b* coordinates and Chroma*), *β*-carotene (ug.g^{-1}), proximate composition (moisture, ash, crude fiber, fat, protein, and carbohydrate) and firmness. Sensory scores (appearance, texture, flavor, and overall preference) were analyzed by two-way analysis of variance, where panelists (n = 181) and

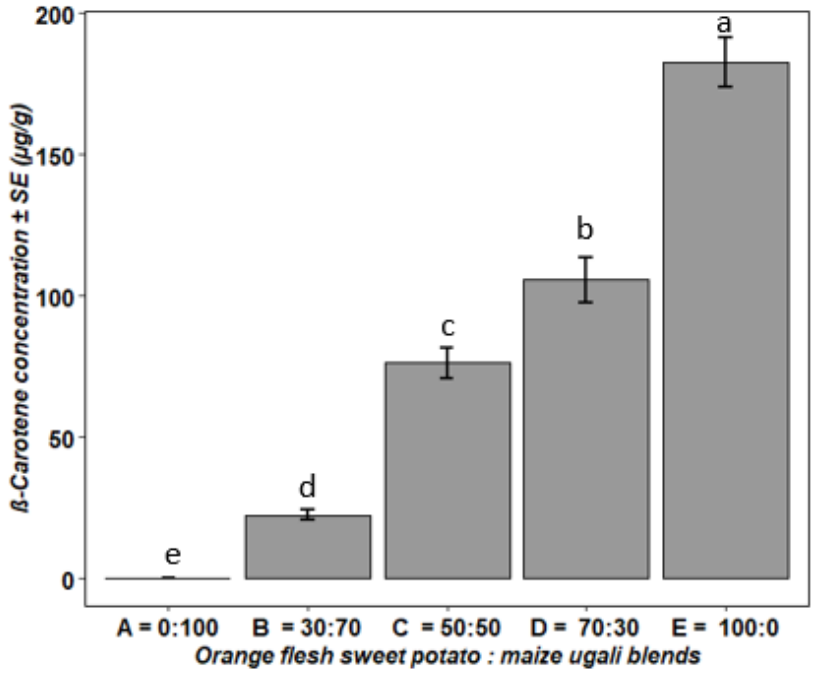

Figure 1. Mean β-carotene concentration (µg/g) (wet basis) ±standard error (n=6) of ugali of maize/OFSP ugali blends. Samples sharing the same superscript letter are not significantly different at 5% significant level according to Tukey's HSD multiple ranks test.

attributes were independent factors. Ranking scores were analyzed by Friedman's test. The correlation coefficients and their probability levels were obtained from linear regression analysis. The means of sensory scores from different attributes (appearance, texture, flavor, and overall preference), regardless of the sample to which they belonged, were ranked from 1st to 20th; overall Rank Sum Index (ORSI) for the samples was calculated by adding the ranks for each attribute from a given sample (Simonne et al., 1999). Determination of significance of differences (mean separation) among chemical, physical and sensory scores was obtained by Tukey's HSD multiple ranks test. P values of 0.05 were considered significant; p values less than 10^{-8} were expressed as ≤ 0.001.

RESULTS AND DISCUSSION

Addition of boiled OFSP in the samples significantly increased the β-carotene concentration in the Ugali samples ($p \leq 0.001$) (Figure 1). A similar trend was observed in other OFSP fortified products, such as flatbread (Tadesse et al., 2015), chapatti, mandazi, and buns (Hagenimana et al., 1998) and yellow maize ogi porridge (Ukom et al., 2019). Sample D (70% OFSP: 30% maize) has a similar β-carotene concentration to that of the raw OFSP (112.3±2.24 μg/g).

The higher β-carotene content of boiled OFSP may result from higher extractability of β-carotene from the OFSP tissues. It has been found that processed OFSP has significantly higher ($P< 0.05$) bioaccessible β-carotene, as compared to the raw forms. Bioaccessibility varies with processing treatments in this order: raw <baked < steamed/boiled < deep fried (Tumuhimbise et al., 2009). As early as 1948, it was reported that homogenization improves the bioavailability of β-carotene of carrots for humans (Van Zeben and Hendriks, 1947).

The colour of the OFSP-fortified Ugali samples was measured with a Chroma meter and L*, a* and b* coordinates were recorded. Results showed that L* coordinate (values) differed significantly among all samples ($p \leq 0.001$). As the proportion of OFSP increased, the lightness (L*) decreased (Figure 2). This is because maize flour is white in colour, and as the proportion of this flour decreases, the whiteness in the sample decreases. In general, samples with a higher proportion of OFSP had higher a* and b* values.

The results of this study show that as the β-carotene increased, the intensity of the orange colour increased also (Figure 2). Of the sensory attributes that related to the carotenoid content, the most visible to consumers is the colour (orange), and this visible trait can influence marketing and promotion (Tomlins et al., 2010). Regression equations for the prediction of β-carotene based on a*, b*, and Chroma*, based on this study, are shown in Table . The results of this study are consistent with previous studies on correlation of colour parameters and carotenoid contents in sweet potatoes (Simonne et al., 1993; Ameny and Wilson, 1997).

This study shows a very high negative correlation between β-carotene and L* due to varying proportions of maize flour in the Ugali samples (Table 1). The correlation

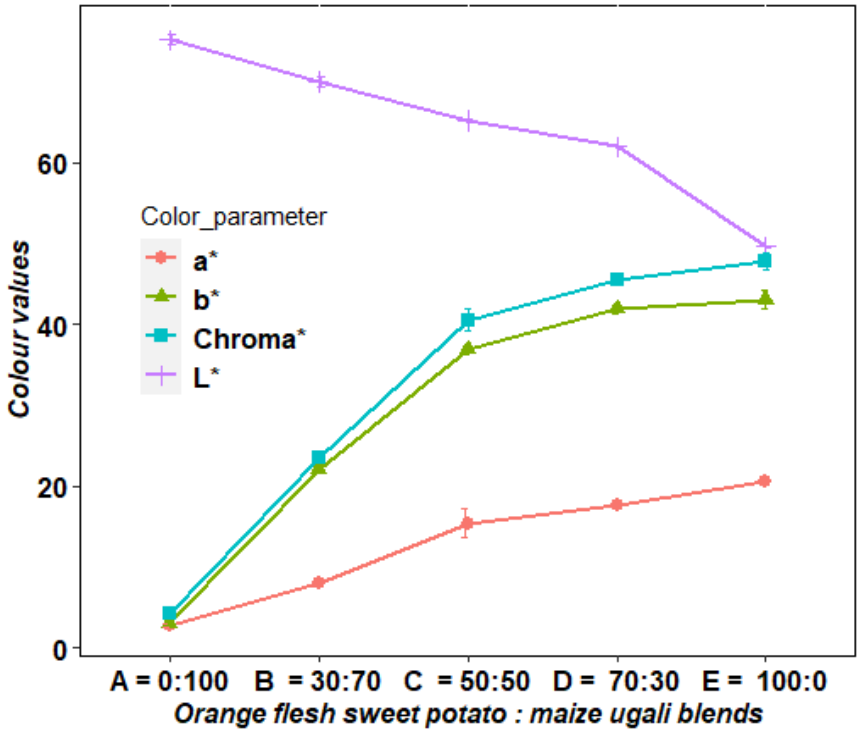

Figure 2. Colour parameters (L*, a*, b* and Chroma) ±standard error (n=30) of ugali prepared with varying portions of OFSP.

correlation between β-carotene and b* was lower compared to a*; however, the relationship between β-carotene and a* or b* in this study was low when compared with the study done by Bengtsson et al. (2009) (r = 0.96 β-carotene and a*). Yet the correlation is higher when compared with Takahata et al. (1993) (r = 0.897 β-carotene and a*) and Simonne et al. (1993) (r = 0.73 β-carotene and a*, r = 0.57 β-carotene and b*).

The result of the proximate composition of Ugali from maize: OFSP blends are shown in Table 2. Results show that crude fiber content increased as the amount of OFSP increased ($p \leq 0.001$); a similar trend was observed by Zegeye et al. (2015). Very low amount of crude fat (0.04-0.16%) was found in the samples, this might be a result of using maize flour from deshelled grains, negligible fat content in OFSP and exclusion of addition fat/oil in preparation of Ugali.

The presence of % ash content (0.2-0.9%) in the samples is an indication of the presence of an important element for human nutrition. Percent carbohydrate differed significantly in all the samples ($p \leq 0.001$); the presence of a high amount of carbohydrate indicates that the samples prepared can provide energy to the body when consumed. It has been found that OFSP is a good source of energy and can supply energy of 293 to 460 Kj per 100 g (Hagenimana et al., 2001), this amount was comparable to the samples in this study except samples A, B and C. Sample C was found to have a significantly higher value of energy (545 Kj) than other samples due to high carbohydrate content which resulted by its lower moisture content. Lower values of energy in raw OFSP and sample E (377.1 and 272.1 Kj, respectively) resulted from their higher values of moisture content and lower protein content.

A consumer panel (n=181) consisting of SUA students aged 19 to 37 evaluated the Ugali products. The results in Table 3 show that most of the panelists preferred samples with no blending, that is, samples A and E. Sample E (100% OFSP: 0% maize Ugali) was the significantly preferred sample ($p < 0.05$), based on ORSI. In general, the addition of OFSP resulted in higher preference in the samples studied (excluding sample A). The panelists accepted all samples; this indicates that the developed samples can be introduced at the household level to fight against vitamin A deficiency. Stiff porridge has a bland taste because it is commonly prepared from unseasoned maize meal without any other ingredients or additives (Calvin, 2014).

A moderate positive correlation between ORSI and β-carotene (r = 0.612) was observed because most of the panelists preferred non-fortified samples to the fortified samples. When 100% maize Ugali (traditional) was removed from the regression calculation, the correlation was highly positive (r = 0.958).

Females preferred samples with higher amounts of OFSP than males (Figure 3); this may be due to the

Table 1. Best fit regression equation and correlation coefficients for β-carotene with colour space values of maize/OFSP ugali blends (0, 30, 50, 70 and 100%).

Pair of relationship	Regression equation	Spearman correlation coefficient (r)	*P* value
β-carotene and L*	β-carotene = -6.9785* L* + 526.8881	-0.9328	≤0.001
β-carotene and a*	β-carotene = 8.649*a* - 33.935	0.9413	≤0.001
β-carotene and b*	β-carotene = 3.5392*b* - 26.6789	0.8879	≤0.001
β-carotene and Chroma*	β-carotene = 3.3579 *Chroma* -31.2127	0.9181	≤0.001

Table 2. Proximate analysis ±Standard Error (n=6) of ugali, raw OFSP and maize/OFSP ugali blends.

Sample	%Fiber	%Fat	%Protein	%Moisture content	%Ash	%Carbohydrate	Energy (Kj)
Raw OFSP	1.1±0.04^{a}	0.1±0.016^{a}	1.7±0.04^{d}	76.1±0.38^{b}	0.9±0.18^{a}	20.2±0.35^{c}	377.1±7.86^{e}
A	0.5±0.10^{c}	0.1±0.02^{a}	4.0±0.14^{bc}	69.9±0.68^{d}	0.2±0.05^{c}	25.4±0.59^{b}	495.5±10.04^{b}
B	0.5±0.05^{c}	0.2±0.06^{a}	4.9±0.19^{a}	67.6±0.48^{de}	0.2±0.02^{c}	26.6±0.63^{ab}	534.2±7.20^{ab}
C	0.8±0.06^{ab}	0.1±0.01^{a}	4.3±0.20^{ab}	66.2±0.44^{e}	0.3±0.01^{c}	28.3±0.53^{a}	545.4±9.23^{a}
D	0.7±0.04^{bc}	0.3±0.30^{a}	3.5±0.16^{c}	73.2±1.12^{c}	0.3±0.02^{bc}	21.9±1.26^{c}	437.5±16.58^{c}
E	1.0±0.06^{a}	0.1±0.0 ^{a}	1.5±0.11^{d}	82.1±0.36^{a}	0.6±0.02^{ab}	14.6±0.29^{d}	272.1±6.09^{e}

Means within columns followed by standard error then different letters are significantly different (*P*< 0.05) according to Tukey's HSD multiple ranks test.

Table 3. Sensory evaluation scores for the samples (n=181 panelists) of ugali and maize/OFSP ugali blends.

Sample	Appearance	Flavor	Texture	Overall acceptability	Ranking	ORSI^{+}
A	7.5±0.13^{ab}	6.9±0.13^{b}	7.1±0.13^{ab}	7.1±0.13^{b}	2.9±0.12^{b}	51
B	6.7±0.14^{c}	6.3±0.15^{c}	6.7±0.13^{bc}	6.6±0.14^{c}	3.4±0.10^{a}	19
C	7.1±0.12^{bc}	6.3±0.15^{c}	6.5±0.14^{c}	6.5±0.14^{c}	3.3±0.09^{a}	22
D	7.4±0.10^{ab}	6.9±0.12^{b}	6.9±0.12^{bc}	6.9±0.12^{bc}	3.0±0.09^{ab}	45
E	7.6±0.13^{a}	7.7±0.11^{a}	7.5±0.14^{a}	7.7±0.11^{a}	2.3±0.12^{c}	73

Means within columns followed by standard error then different letters are significantly different (*P*< 0.05) according to Tukey's HSD multiple ranks test. $^{+}$Overall Rank Sum Index (ORSI) for the samples, calculated by adding the ranks for each attribute (Simonne et al., 1999); Responses are based on a 9-point hedonic scale; samples were ranked based on preference from 1-5 (1 means most preferred).

increased sweetness and visual appearance of OFSP. Tadesse et al (2015) observed a similar trend; the degree of preference increased with the substitution level of OFSP flour in the formulations of flatbread prepared from blends of maize and OFSP. This study also suggested that the trend might be due to the fact that the sweetness increases as OFSP amounts increase. Samples were orange in colour, and brightness increased with the increase in the proportion of OFSP, which could be a reason for the demonstrated preference differences.

In order to estimate β-carotene intake from fortified Ugali as retinol activity equivalent (RAE), five consumer households (n =15 total members) were recruited to consume Ugali with 50% OFSP: 50% Maize at their regular meal. Results showed that adultsbetween19 and 51 years might typically consume servings of Ugali up to 305.8 g for males (n=2) and 197.9 g for females (n=6) (Table).

Based on these studies, Table shows the summary of calculated retinal equivalent provided by sample C (50% OFSP: 50% Maize) supplied to five households. This sample was estimated to give 54% RAE/meal of RDA/day for males (n=2) and 44.9% for female (n=6) for adults (aged 19-50 years).

Ugali is consumed with different accompaniments that usually contain fat/oil; hence, the absorption of this amount of β-carotene as RAE will be considered to be at its maximum, since fat/oil enhances absorption of β-storage, intracellular location, and the intactness of the cellular matrix. Beta-carotene in sweet potato storage roots is found in lipid droplets or bound to a protein that is released during cooking, thereby enhancing its

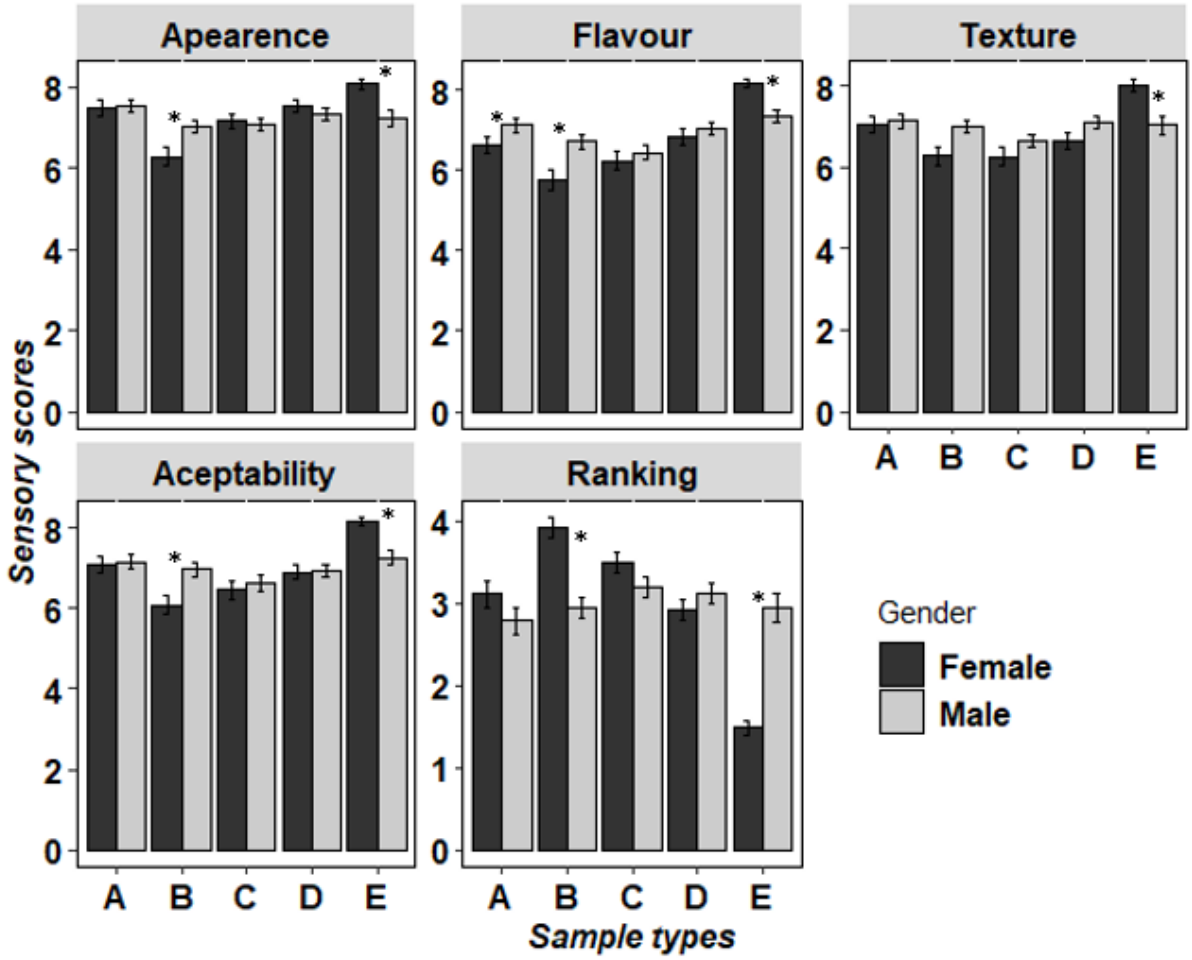

Figure 3. Sensory evaluation scores and consumer preference (ranking) based on gender (n=98 males and 83 females) of ugali and maize/OFSP ugali blends.* Bar graphs of the same sample with asterisk indicate statistical difference based on gender ($p < 0.05$) according to t-test. Samples were ranked based on preference from 1-5 (1 means most preferred).

Table 4. Percent RDA of retinol activity equivalent (RAE) provided by the sample C (50% OFSP ugali) based on age and gender.

Age group (years)	Number of participants		Average of amount consumed (g) from three meals		Amount of bioavailable consumed RAE (µg-meal^{-1})		RDA Vitamin A µg /day RAE (USDHHS and USDA, 2015)		Percent RAE consumed.meal^{-1} of RDA	
	M	F	M	F	M	F	M	F	M	F
4-8	1	1	162.1	69.9	257.3	110.9	400	400	64.3	27.7
9-13	2	-	156.2	-	248.0	-	600	600	41.3	-
14-18	-	2	-	193.0	-	306.5	900	700	-	43.8
19-50	2	6	305.8	197.9	485.6	314.2	900	700	54.0	44.9
51+	1	-	335.0		531.9	-	900	700	59.1	-

bioavailability (Hof et al., 2000). It is concluded that absorption of *β*-carotene is enhanced by fat/oil present in the food (Bechoff et al., 2011; Dimitrov et al., 1988; Hof et al., 2000; West et al., 2002). Ugali does not contain oil/fat by itself, but it is usually consumed with a variety of accompaniments, such as meat, vegetables, beans, and fish, that have fat.

The current study measured β-carotene using a

spectrophotometer. Improved technologies such as HPLC should be used in the future to provide more reliable results that can show changes in β-carotene, together with its isomers, in Ugali. Performing a larger consumer level study may give a more reliable estimate of the Retinol Equivalent consumed when eating fortified Ugali. Finally, studies that measure retinol changes in the blood after consumption of the developed fortified Ugali for a recommended time period should also be done in the future.

Conclusion

This is the first study to utilize colour measurement as a tool to correlate ß-carotene levels in OFSP fortified Ugali. Supplementing OFSP in maize Ugali resulted to increase in β- carotene content. The developed samples of Ugali showed a 20 to 28% carbohydrate content that can be used as a source of energy to the body. Sample with 50% OFSP and 50% maize Ugali was estimated to give at least half (50%) of recommended daily allowable of bioavailable retinol activity equivalent per meal to adults (19 to 50 years). This study provided information on development of fortified Ugali using a new locally (Tanzania) available crop (ORSP) to increase provitamin A activity. In addition, the results revealed that the final product had acceptable nutritional composition and chemical and physical properties and consumer acceptability.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Ameny MA, Wilson, PW (1997). Relationship between hunter colour values and β-carotene contents in white-fleshed African sweetpotatoes (*Ipomoea batatas Lam*). Journal of the Science of Food and Agriculture 73(3):301-306.

Association of Official Analytical Chemist (AOAC) (2000). Official methods of analysis (18th ed.).

Arias R, Lee TC, Logendra L, Janes H (2000). Correlation of lycopene measured by HPLC with the L*, a*, b* colour readings of a hydroponic tomato and the relationship of maturity with colour and lycopene content. Journal of Agricultural and Food Chemistry 48(5):1697-1702.

Bao B, Fweja L (2020). Evaluation of the potential of freshly bred orange-fleshed sweet potato varieties in combating vitamin A deficiency. Tanzania Journal of Science 46(1):1-8.

Bechoff A, Poulaert M, Tomlins KI, Westby A, Menya G, Young S, Dhuique-Mayer C (2011). Retention and bioaccessibility of β-carotene in blended foods containing orange-fleshed sweet potato flour. Journal of Agricultural and Food Chemistry 59(18):10373-10380.

Bengtsson A, Namutebi A, Alminger ML, Svanberg U (2008). Effects of various traditional processing methods on the all-trans-β-carotene content of orange-fleshed sweet potato. Journal of Food Composition and Analysis 21(2):134-143.

Bengtsson, Anton, Larsson Alminger M, Svanberg U (2009). *Invitro* bioaccessibility of β-carotene from heat-processed orange-fleshed sweet potato. Journal of Agricultural and Food Chemistry 57(20):9693-9698.

Burri BJ (2011). Evaluating Sweet potato as an intervention food to prevent vitamin A Deficiency. Comprehensive Reviews in Food Science and Food Safety 10(2):118-130.

Calvin O (2014). Physical properties of dry-milled maize meals and their relationship with the texture of stiff and thin porridge. African Journal of Food Science 8(8):435-443.

CDC (2014). IMMPaCt: Micronutrient Facts | DNPAO | CDC. http://www.cdc.gov/immpact/micronutrients/

International Potato Center (CIP) (2006). Report. "McKnight Foundation CCRP East African Regional Sweetpotato Project Annual Report," International Potato Center, Nairobi, April 2005-March 2006.

Darmon N, Ferguson EL, Briend A (2002). A cost constraint alone has adverse effects on food selection and nutrient density: An analysis of human diets by linear programming. The Journal of Nutrition 132(12):3764-3771.

Davies BH (1976). Carotenoids. In Chemistry and biochemistry of plant pigments (T. W. Goodwin). London: Academic Press. https://link.springer.com/chapter/10.1007/978-3-642-66632-2_11

De-Regil LM, Suchdev PS, Vist GE, Walleser S, Peña-Rosas JP (2011). Home fortification of foods with multiple micronutrient powders for health and nutrition in children under two years of age. In The Cochrane Collaboration (Ed.), Cochrane Database of Systematic Reviews. John Wiley & Sons, Ltd. http://doi.wiley.com/10.1002/14651858.CD008959.pub2

Dimitrov NV, Meyer C, Ullrey DE, Chenoweth W, Michelakis A, Malone W, Boone C, Fink G (1988). Bioavailability of beta-carotene in humans. The American Journal of Clinical Nutrition 48(2):298-304.

Fransis FJ (1962). Relationship between flesh colour and pigment content in squash. Proceedings of the American Society for Horticultural Science 81(408):14.

Gannon B, Kaliwile C, Arscott SA, Schmaelzle S, Chileshe J, Kalungwana N, Mosonda M, Pixley K, Masi C, Tanumihardjo SA (2014). Biofortified orange maize is as efficacious as a vitamin A supplement in Zambian children even in the presence of high liver reserves of vitamin A: A community-based, randomized placebo-controlled trial. The American Journal of Clinical Nutrition 100(6):1541-1550.

Hagenimana V, Carey EE, Gichuki ST, Oyunga MA, Imungi JK (1998). Carotenoid contents in fresh, dried and processed sweetpotato products. Ecology of Food and Nutrition 37(5):455-473.

Hagenimana V, Low J, Anyango M, Kurz K, Gichuki ST, Kabira J (2001). Enhancing vitamin a intake in young children in Western Kenya: Orange-fleshed sweet potatoes and women farmers can serve as key entry points. Food and Nutrition Bulletin 22(4):376-387.

Hagenimana V, Oyunga MA, Low J, Njoroge SM, Gichuki ST, Kabira J (1999). The Effects of Women Farmers' Adoption of Orange-Fleshed Sweet Potatoes: Raising Vitamin A Intake in Kenya | ICRW. http://www.icrw.org/publications/effects-women-farmers-adoption-orange-fleshed-sweet-potatoes-raising-vitamin-intake-ken

Hof KH van het, West CE, Weststrate JA, Hautvast JGAJ. (2000). Dietary Factors That Affect the Bioavailability of Carotenoids. The Journal of Nutrition 130(3):503-506.

Ihekoronye AI, Ngoddy PO (1985). Integrated Food Science and Technology for the Tropics. Macmillan.

Itle RA, Kabelka EA. (2009). Correlation Between L*a*b* Colour Space Values and Carotenoid Content in Pumpkins and Squash (*Cucurbita* spp.). HortScience 44(3):633-637.

Kimura M, Kobori CN, Rodriguez-Amaya DB, Nestel P (2007). Screening and HPLC methods for carotenoids in sweetpotato, cassava and maize for plant breeding trials. Food Chemistry 100(4):1734-1746.

López de Romaña D, Olivares M, Brito A (2015). Introduction: Prevalence of micronutrient deficiencies in Latin America and the Caribbean. Food and Nutrition Bulletin 36(2 Suppl):S95-S97.

Low J, Walker T, Hijmans R (2001). The potential impact of orange-fleshed sweet potatoes on vitamin A intake in Sub-Saharan Africa. A Paper Presented at a Regional Workshop on Food Based Approaches to Human Nutritional Deficiencies 9-11. http://cipotato.org/wp-content/uploads/publication%20files/booklets/002221.pdf

Low JW, Mwanga ROM, Andrade M, Carey E, Ball AM (2017). Tackling vitamin A deficiency with biofortified sweetpotato in sub-Saharan Africa. Global Food Security 14:23-30.

Lukmanji Z, Hertzmark E, Mlingi N, Assey V, Ndossi G, Fawzi W (2008). Tanzania Food Composition Tables (1st ed.). Muhimbili University of Health and Allied Sciences (MUHAS), Dar es Salaam - Tanzania, Tanzania Food and Nutrition Centre (TFNC), Dar es Salaam - Tanzania and Harvard School of Pubic Health (HSPH), Boston, USA. http://cdn1.sph.harvard.edu/wp-content/uploads/sites/30/2012/10/tanzania-food-composition-tables.pdf

Lyana AZ, Manimbulu, N (2014). Culture and Food Habits in Tanzania and Democratic Republic of Congo. Journal of Human Ecology 48(1):9-21.

Magee PJ, McCann MT (2019). Micronutrient deficiencies: Current issues. Proceedings of the Nutrition Society 78(2):147-149.

Ministry of Health, Zanzibar MoH, NBS, Zanzibar OCGS, ICF. (2016). Tanzania Demographic and Health Survey and Malaria Indicator Survey 2015-2016. https://dhsprogram.com/publications/publication-fr321-dhs-final-reports.cfm

Mitra S (2012). Nutritional Status of Orange-Fleshed Sweet Potatoes in Alleviating Vitamin A Malnutrition through a Food-Based Approach. Journal of Nutrition and Food Sciences 02(08).

Muhihi A, Gimbi D, Njelekela M, Shemaghembe E, Mwambene K, Chiwanga F, Malik VS, Wedick NM, Spiegelman D, Hu FB, Willett WC (2013). Consumption and acceptability of whole grain staples for lowering markers of diabetes risk among overweight and obese Tanzanian adults. Globalization and Health 9:26.

NBS, ICF (2011). Tanzania Demographic and Health Survey 2010. National Bureau of Statistics (NBS) [Tanzania] and ICF Macro.

Nyotu HG, Alli I, Paquette G (1986). Soy supplementation of a maize based Kenyan food (ugali). Journal of Food Science 51(5):1204-1207.

Ramakrishnan U (2002). Prevalence of micronutrient malnutrition worldwide. Nutrition Reviews 60(5 Pt 2):S46-S52.

Ritchie H, Roser M (2017). Micronutrient Deficiency. Our World in Data. https://ourworldindata.org/micronutrient-deficiency

Ross AC, Hodges JK, Wei C, Li Y (2020). Vitamin A. In Essential and Toxic Trace Elements and Vitamins in Human Health (pp. 202-214). Elsevier. https://doi.org/10.1016/B978-0-12-805378-2.00016-4

Seroczyńska A, Korzeniewska A, Sztangret-Wiśniewska J, Niemirowicz-Szczytt K, Gajewski M (2006). Relationship between carotenoids content and flower or fruit flesh colour of winter squash (Cucurbita maxima Duch.). Folia Horticulturae 18(1):51-61.

Simonne AH, Kays SJ, Koehler PE, Eitenmiller RR (1993). Assessment of β-carotene content in sweetpotato breeding lines in relation to dietary requirements. Journal of Food Composition and Analysis 6(4):336-345.

Simonne E, Boozer R, Simonne A (1999). Yield, ear characteristics, and consumer acceptance of selected white sweet corn varieties in the Southeastern United States. HortTechnology 9(2):289-293.

Tadesse TF, Nigusse G, Kurabachew H (2015). Nutritional, microbial and sensory properties of flat-bread (Kitta) prepared from blends of maize (*Zea mays L*.) and orange-fleshed sweet potato (*Ipomoea batatas L*.) flours. International Journal of Food Science and Nutrition Engineering 5(1):33-39.

Takahata Y, Noda T, Nagata T. (1993). HPLC determination of beta-carotene content of sweet potato [*Ipomoea batatas*] cultivars and its relationship with colour values. Japanese Journal of Breeding (Japan). http://agris.fao.org/agris-search/search.do?recordID=JP9500057

Thiex N., Manson H, Anderson S, Persson JÅ (2002, March). Determination of Crude Protein in Animal Feed, Forage, Grain, and Oilseeds by Using Block Digestion with a Copper Catalyst and Steam Distillation into Boric Acid: Collaborative Study [Text]. http://aoac.publisher.ingentaconnect.com/search/article?option1=tka&value1=crude+protein&operator9=AND&option9=publications&value9=aoac&sortDescending=true&sortField=default&pageSize=10&index=1

Tomlins K, Rees D, Coote C, Bechoff A, Okwadi J, Masingue J (2010). Sweet potato utilization, storage, small-scale processing and marketing in Africa. In Sweet potato: Post harvest aspects in food, feed and industry. Nova Science Publishers Inc..

Tumuhimbise GA, Namutebi A, Muyonga JH (2009). Microstructure and *in vitro* beta carotene bioaccessibility of heat processed orange fleshed sweet potato. Plant Foods for Human Nutrition 64(4):312-318.

Tumwegamire S, Kapinga R, Zhang D, Crissman C, Agili S (2004). Opportunities for promoting orange-fleshed sweetpotato as a mechanism for combat vitamin-a deficiency in Sub-Saharan Africa. African Crop Science Journal 12(3):241-252.

Ukom AN, Adiegwu EC, Ojimelukwe PC, Okwunodulu IN (2019). Quality and sensory acceptability of yellow maize ogi porridge enriched with orange-fleshed sweet potato and African yam bean seed flours for infants. Scientific African 6:e00194.

UNICEF (2020). Sustainable Development Goals and children in Tanzania: Sustainable Changes start with Children P 164. https://www.unicef.org/tanzania/reports/sustainable-development-goals-and-children-tanzania

USDA (2005). United States Standards for Grades of Sweetpotatoes. United States Department of Agriculture. https://www.ams.usda.gov/grades-standards/sweetpotatoes-grades-and-standards

USDHHS, USDA (2015). 2015-2020 Dietary Guidelines for Americans (8th ed.).

Van den Berg H, Faulks R, Granado HF, Hirschberg J, Olmedilla B, Sandmann G, Southon S, Stahl W (2000). The potential for the improvement of carotenoid levels in foods and the likely systemic effects. Journal of the Science of Food and Agriculture 80(7):880-912.

Van Zeben W., Hendriks TF (1947). The absorption of carotene from cooked carrots. Internationale Zeitschrift Fur Vitaminforschung. International Journal of Vitamin Research. Journal International De Vitaminologie 19(3-4):265.

West CE, Eilander A, van Lieshout M (2002). Consequences of Revised Estimates of Carotenoid Bioefficacy for Dietary Control of Vitamin A Deficiency in Developing Countries. The Journal of Nutrition 132(9):2920S-2926S.

World Health Organization (WHO) (1998). Distribution of vitamin A during national immunization days. http://apps.who.int/iris/handle/10665/65502

World Health Organization (WHO) (2009). Global prevalence of vitamin A deficiency in populations at risk 1995-2005: WHO global database on vitamin A deficiency. http://apps.who.int/iris/handle/10665/44110

World Bank (2012). Action plan for the provision of vitamins and minerals to the Tanzanian population through the enrichment of staple foods (No. 69991; pp. 1-57). The World Bank. http://documents.worldbank.org/curated/en/2012/01/16408192/action-plan-provision-vitamins-minerals-tanzanian-population-through-enrichment-staple-foods

World Bank (2020). Sub-Saharan Africa. World bank group. databank.worldbank.org › poverty › Global_POVEQ_SSA

Zegeye M, Singh P, Challa A, Jemberu Y (2015). Development of maize based orange - fleshed sweet potato flat bread for lactating Mothers at Hawassa Zuria Woreda, SNNPRS, Ethiopia. 2015(55):183-190.

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