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STUDIES ON THE PROXIMATE COMPOSITION AND TRADITIONAL POST-HARVEST PRACTICES OF SELECTED CROPS IN SOUTHERN NIGERIA

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ABSTRACT
This study was carried out to evaluate the nutrient composition of five selected crops (viz; *Bambara nut*, *Bread fruit*, *Bush mango*, *Cocoyam*, and *sweet potato*); and their traditional post-harvest practices. Three different states viz; Rivers, Ebonyi and Akwa-Ibom states were chosen for this study. The crops selected for this study are perceived to be underutilized in the selected study areas, hence, the need to investigate the primary factors mitigating the maximum utilization of these crops. The samples were analysed for proximate composition (moisture, ash, crude fibre, crude fat, crude protein, and carbohydrate) using AOAC standard methods. Data on the traditional post-harvest practices were collected directly from the farmers using structured questionnaire which contained relevant questions based on the objectives of the study. Results of the proximate composition revealed that these crops have rich nutrient composition. However, the overall nutrient composition of these crops varied across the three states. The protein content of bread fruit was 2.50±0.00% in the samples obtained from Rivers state; 14.20±0.00% in the samples obtained from Ebonyi state and 10.25±0.07% in the samples obtained from Akwa-Ibom state. The traditional post-harvest practices associated with these crops differed, with some practices peculiar to the root tubers (cocoyam and sweet potato) while others to the legumes (Breadfruit and Bambara nut) and Bush mango (a fruit). Deductively, poor postharvest handling practices, lack of improved storage facilities restrain the commercialization of these underutilized crops. Hence, the adoption of improved post-harvest technologies would enhance the utilization of these crops.

Keywords: Nutrition, Post-harvest technologies, Storage, Underutilized, Crops, Traditional

INTRODUCTION
Recently, there has been a continuous decline in the availability of certain food crops which are considered essential because of their rich nutritional composition and other numerous economic values. Although these crops are particularly important, they have almost gone into extinction; worst of all, there is little research attention on most of these selected crops (Tan *et al*., 2020). This could be because of ignorance of their nutritional value, lack of proper post-harvest handling and storage facilities, urbanization (which has led to the cutting down of many economic trees) and lack of trained workforce in the cultivation of these crops.
Bambara nut (*Vigna subterranea*) is a legume predominantly grown in Africa (Tan *et al*., 2020); however, it can also be found at low levels in Thailand, Indonesia, and Malaysia (Mayes *et al*., 2019). Bambara nut is considered as a balanced food because of its rich nutritional composition (Halimi *et al*., 2019). Some production constraints such as lack of improved agronomic practices, processing and improved seed system have been identified as major setbacks affecting the full utilization of this food crop (Tan *et al*., 2020). Bambara nut is often dried to enhance its durability during storage.
Bread fruit is a starchy fruit predominantly grown in Nigeria, Ghana, and some other countries in West Africa (Runsewe-Abiodun *et al*., 2018). Two species of bread fruit were sampled in this study, viz: *Artocarpus altilis* and *Treculia africana*. *Artocarpus altilis* was predominantly found in south-south Nigeria (Akwa-Ibom and Rivers State) while *Treculia africana* was more predominant in south-eastern Nigeria (Ebonyi state). Both species are very nutritious and can be eaten boiled, cooked, fried, or roasted.
Bush mango (*Irvingia gabonensis*) is a large tropical African tree which grows wild in the forest. It is an economic tree which serves various purposes such as medicinal, food and timber. The fruit of *Irvingia gabonensis* has similar morphology with that of a mango fruit; a fleshy, yellowish, & edible mesocarp and a relatively hard endocarp known as the kernel.
Cocoyam (*Colocasia esculenta*), is an especially important root crop, cultivated especially for its edible corms (Si *et al*., 2018). Apart from the edible corms which contain about 70% of starch, the leaves are also used locally for soup making and wrapping ready-to-eat foods. Cocoyam farmers are mostly subsistent farmers who grow cocoyam mostly for their small households. The short shelf life of cocoyam may be a major hindrance to the commercialization of cocoyam.
Sweet potato (*Ipomoea batatas* (L.) Lam), is a very essential economic crop which serves several purposes ranging from poverty reduction to increasing food security (El Sheikha & Ray, 2017). It has a rich nutrient composition, good taste, and texture and this has been widely reported by several researchers (Mu *et al*., 2017; Truong *et al*., 2018; Zulkifli *et al*., 2021). There are different varieties of sweet potato in terms of flesh colour, white cream, yellow and purple. Sweet potato can be boiled, roasted, processed into chips, flour (for baking purposes) and can also be used as a soup thickener (Truong *et al*., 2018).
This research work was conducted to evaluate the nutrient composition of five selected crops (viz; Bambara nut, breadfruit, bush mango, cocoyam, and sweet potato); as well as investigate the traditional post-harvest practices for these crops. The crops selected for this study are perceived to be underutilized especially in the chosen geographic zone, hence, the need to investigate the mitigating factors responsible for the underutilization of these crops. This aims at improving the already existing post-harvest technologies as well as innovate new technologies that will extend the shelf life and improve nutrient retention of the food crops during storage.

MATERIALS AND METHODS

Study area

The study was conducted in Southern Nigeria. Three states viz; Rivers, Ebonyi & Akwa-Ibom State were mapped out for this study. Rivers state is a low-lying pluvial southern state in Nigeria situated between Latitude 4.8396ºN and Longitude 6.9112ºE (Ngex, 2016). The inland part of the state consists of tropical rain forest and towards the coast, the typical Niger Delta environment features many mangrove swamps. Ebonyi state is a mixture of eastern prototypes comprising of semi-savannah grassland with forests and swamps. Being in an agrarian area, the people of Ebonyi State are predominantly farmers. The state is situated between Latitude 6.2649ºN and Longitude 8.0137ºE (ESG, 2021). Akwa-Ibom is a southern state, located in the South-Southern part of the country. The state lies between latitude 4.9057ºN and Longitude 78537ºE (NIPC, 2020). Akwa-Ibom is bordered on the east by Cross River State, on the west by Rivers State and Abia State, and on the South by the Atlantic Ocean. A multistage purposive sampling procedure was used for this study.

Proximate analysis

The moisture content was determined by drying at 130 °C in a laboratory oven, until a constant weight was attained. For total ash determination, the food samples were weighed and converted to dry ash in a muffle furnace at 550 °C for incineration. The crude fat content was determined by extraction with petroleum ether, using a Soxhlet apparatus. Kjeldahl method was used for crude protein determination. All these determinations were carried out according to AOAC (2019). Carbohydrate content was determined by calculating the difference between the sums of all the proximate compositions from 100 %.

Data collection and analysis

Data were collected from farmers of these underutilized crops in the three states through the use of structured questionnaire which contained relevant questions on cultural practices, post-harvest handling methods, processing and storage problems; based on the objectives of this study. Four communities were selected in each state, making it a total of twelve communities in the three states. Meanwhile, the snow-ball sampling technique was used to sample 10 farmers of all the selected underutilized crops in a community and a total of 40 farmers in a state and 120 respondednts in the three states selected for the study. The dependent variable for the study was analysis of cultural practices and post-harvest handling which was measured at nominal level. Descriptive statistics such as frequency, percentage and mean were used and inferential statistics such as chi-square was used to establish a relationship between socio-economic characteristics of the respondents and their storage methods.

Statistical analyses were performed using SPSS 20.0.0, SPSS Inc. by Analysis of Variance (ANOVA) and mean calculated and separated using the Duncan's test when significant ($P<0.05$).

RESULTS AND DISCUSSION

Proximate composition of the selected crops

Among the three states (Akwa-Ibom, Ebonyi and Rivers State) sampled in this survey, Bambara nut was found only at Ebonyi state. Table 1 revealed that Bambara nut is an energy giving food crop with an enormous amount of carbohydrate (54.12±0.04%) and protein (23.06±0.00%). The moisture content (8.63±0.04%) was relatively low, and this reveals the durability of the crop under good storage conditions.

Table 1: Proximate composition of Bambara nut

Parameters (%)	Moisture	Ash	Fat	Fibre	Protein	Carbohydrate
Ebonyi	8.63±0.04	3.15±0.00	4.88±0.04	6.18±0.04	23.06±0.00	54.12±0.04

Means±SD

There was a significant ($p<0.05$) difference in moisture, fat, fibre, protein, and carbohydrate content of the bread fruit across the three states (Table 2). However, no significant ($p<0.05$) difference was recorded in the ash content of the bread fruit across the three states. Bread fruit samples collected from Rivers state and Akwa-Ibom state had significantly high moisture content compared to the bread fruit sample collected from Ebonyi state (Table 2).

Table 2: Proximate composition of Bread fruit

Parameters (%)	Moisture	Ash	Fat	Fibre	Protein	Carbohydrate
Rivers	61.90±0.06^{b}	1.35±0.14^{a}	0.24±0.01^{a}	3.55±0.03^{a}	2.50±0.00^{a}	30.47±0.16^{b}
Ebonyi	28.35±0.07^{a}	1.30±0.00^{a}	6.78±0.04^{c}	5.38±0.04^{b}	14.20±0.00^{c}	44.00±0.00^{c}
Akwa-Ibom	66.09±0.02^{c}	1.17±0.03^{a}	1.08±0.04^{b}	6.33±0.04^{c}	10.25±0.07^{b}	15.10±0.13^{a}

Means±SD and means followed by the same superscript letter(s) within the column are not significantly different according to Duncan Post Hoc test at 5% level of probability

Meanwhile, there was a significant ($p<0.05$) difference between the moisture, fibre and protein content of Bush mango obtained from Ebonyi and that obtained from Akwa-Ibom, while no significant ($p<0.05$) difference was recorded between the moisture, fibre and protein content of Bush mango obtained in Rivers and that obtained from Ebonyi State (Table 3). There was a significant ($p<0.05$) difference in fat and carbohydrate content of Bush mango across the three states. Significant ($p<0.05$) difference was recorded in ash content of Bush mango obtained in Rivers state and that obtained in Akwa-Ibom state (Table 3).

Table 3: Proximate composition of Bush mango

Parameters (%)	Moisture	Ash	Fat	Fibre	Protein	Carbohydrate
Rivers	5.61±0.14^{a}	2.20±0.71^{b}	41.45±0.04^{b}	4.68±0.04^{a}	8.41±0.01^{a}	37.66±0.04^{b}
Ebonyi	5.66±0.01^{a}	2.08±0.04^{ab}	42.43±0.04^{c}	4.68±0.04^{a}	8.48±0.04^{a}	36.69±0.01^{a}
Akwa-Ibom	6.15±0.07^{b}	2.02±0.28^{a}	37.43±0.04^{a}	5.63±0.03^{b}	9.54±0.02^{b}	39.24±0.01^{c}

Means±SD and means followed by the same superscript letter(s) within the column are not significantly different according to Duncan Post Hoc test at 5% level of probability

The moisture content of cocoyam samples collected from the three states were very high with the highest moisture content recorded in the samples collected from Akwa-Ibom state (77.45%). The crude fat and crude protein content were relatively very low (Table 4). However, the carbohydrate content was high compared to other proximate compositions, indicating that cocoyam is primarily a starchy food. Significant ($p<0.05$) difference was observed in moisture, ash, fat, fibre, protein, and carbohydrate content of cocoyam across the three states (Table 4).

Table 4: Proximate composition of cocoyam.

Parameters (%)	Moisture	Ash	Fat	Fibre	Protein	Carbohydrate
Rivers	74.13±0.04^{b}	1.38±0.11^{a}	0.16±0.01^{a}	1.45±0.07^{a}	0.44±0.01^{a}	22.45±0.01^{b}
Ebonyi	62.45±0.07^{a}	1.90±0.00^{b}	0.35±0.07^{b}	2.03±0.04^{b}	0.70±0.04^{c}	32.58±0.03^{c}
Akwa-Ibom	77.45±0.07^{c}	2.15±0.07^{c}	0.51±0.01^{c}	5.03±1.72^{c}	0.63±0.12^{b}	14.24±0.06^{a}

Means±SD and means followed by the same superscript letter(s) within the column are not significantly different according to Duncan Post Hoc test at 5% level of probability

Significant ($p<0.05$) difference was observed in moisture, fibre, protein, and carbohydrate content of cream fleshed sweet potato across the three states (Table 5). There was a significant ($p<0.05$) difference between the ash content of cream fleshed sweet potato obtained from Rivers state and that obtained from Akwa-Ibom state (Table 5). However, no significant ($p<0.05$) difference was observed between the ash content of cream fleshed sweet potato obtained from Rivers state and that obtained from Ebonyi state and between that obtained from Ebonyi and Akwa-Ibom state. No significant ($p<0.05$) difference was observed in the fat content of sweet potato across the three states (Table 5).

Table 5: Proximate composition of Cream fleshed sweet potatoes

Parameters (%)	Moisture	Ash	Fat	Fibre	Protein	Carbohydrate
Rivers	69.84±0.11^{c}	1.03±0.04^{a}	0.35±0.05^{a}	4.27±0.03^{c}	0.88±0.00^{a}	23.64±0.23^{a}
Ebonyi	68.75±0.07^{b}	1.09±0.01^{ab}	0.45±0.07^{a}	4.13±0.04^{b}	1.14±0.00^{b}	24.45±0.16^{b}
Akwa-Ibom	60.55±0.07^{a}	1.16±0.04^{b}	0.55±0.07^{a}	3.13±0.04^{a}	1.55±0.07^{c}	33.07±0.15^{c}

Means±SD and means followed by the same superscript letter(s) within the column are not significantly different according to Duncan Post Hoc test at 5% level of probability

Post-harvest activities/challenges

Table 6 indicates that 67.8% of the farmers in the study area used sun-drying method (for the five crops) before storage and 3.8% of the farmers used roasting method (for bread fruit and bush mango). However, 28.4% of cocoyam and sweet potatoes farmers had no drying method before storage. The implication of these drying methods (sun-drying and roasting) is the negative impact on hygiene and retention of nutrient value. Sun drying crops in an open air environment exposes them to flies, dust and other environmental contaminants while roasting has tendency of reducing nutrient value if the temperature used is very high and not properly regulated.

Table 6: Distribution of farmers according to the method of drying before storage of crops (N= 288)

Crops	Sun drying F (%)	Roasting F (%)	None F (%)
Bambara nut	20 (6.9)	0 (0)	0 (0)
Bread Fruit	18(6.3)	7(2.4)	0 (0)
Bush mango	50 (17.4)	4(1.4)	0 (0)
Cocoyam	69 (24.0)	0 (0)	43 (14.9)
Sweet potatoes	38 (13.2)	0 (0)	39 (13.5)
Total	195 (67.8)	11 (3.8)	82 (28.4)

Source: NSPRI Field Survey, 2021

Table 7 indicates that 39.6% of the farmers (of the five crops) acknowledged animal interference during drying. Due to the open air drying method adopted by majority of the farmers, it was easy for domestic animals and birds to eat up the crops during the drying process. Rain and dust were also mitigating factors in the drying process with 62.8% of the farmers acknowledging the interruption of the drying process by rain and 23.3% of farmers acknowledging the interference of dust which comes in contact with crops during drying. The implication of this, is on the quality of the crops after drying which may not be of good quality due to the external interferences during the drying process.

Table 7: Distribution of farmers according to the interference during drying of crops (N= 288)

Factors	Crops	Yes F (%)	No F (%)
Animals	Bambara nut	13 (4.5)	7 (2.4)
	Bread fruit	11 (3.8)	14 (4.9)
	Bush-mango	17 (5.9)	37 (12.8)
	Cocoyam	42 (14.6)	70 (24.3)
	Sweet potato	31 (10.8)	46 (16)
	Total	**114 (39.6)**	**174 (60.4)**
Rain	Bambara nut	20 (6.9)	0 (0)
	Bread fruit	15 (5.2)	10 (3.5)
	Bush-mango	50(17.4)	4 (1.4)
	Cocoyam	64 (22.2)	48 (16.7)
	Sweet potato	32 (11.1)	45 (15.6)
	Total	**181 (62.8)**	**104 (37.2)**

Dust	Bambara nut	2 (0.7)	18 (6.3)
	Bread fruit	5 (1.7)	20 (6.9)
	Bush-mango	24 (8.3)	30 (10.4)
	Cocoyam	24 (8.3)	88 (30.6)
	Sweet potato	12 (4.2)	65 (22.6)
	Total	**67 (23.3)**	**221 (76.7)**

Source: NSPRI Field Survey, 2021

About seventeen percent (16.7%) of bambara nut farmers stored bambara nuts using warm wood ash, 33.3% used bags and airtight containers while 16.7% of these bambara nut farmers had no storage method (Table 8). Few (10.7%) bread fruit farmers used bags and airtight containers for storage, 4% of them spread on the floor, while majority (74.7%) had no storage method. Bagging was the most adopted storage method by bush mango farmers, with 45.4% of these farmers adopting this method. A good number (33.3%) of them stored in airtight containers while 21.3% of these bush mango farmers had no storage method (Table 8). Cocoyam was commonly stored by spreading the corms on the floor, with 24.1% of cocoyam farmers adopting this method. Few (8%) of the cocoyam farmers used a local barn for storage. The trench method was also practiced by very few (2.4%) of these farmers. Majority (65.5%) of the cocoyam farmers had no post-harvest storage method. The most common storage method for sweet potato was spreading the tubers on the floor and this was adopted by 40.3% of the farmers. Very few (10.4%) of these farmers stored sweet potato in local barns, while majority (49.3%) had no storage method (Table 8).

Table 8: Distribution of farmers according to Post Harvest storage of selected food crops (N= 288)

Crops	Method of Storage	Yes F (%)	No F (%)
Bambara nut	Spray with warm wood ash	10(16.7)	10(16.7)
	Bagging	20(33.3)	0(0)
	Airtight Container	20(33.3)	0(0)
Bread fruit	Spread on floor	3(4)	22(29.3)
	Bagging	8(10.7)	17(22.7)
	Airtight Container	8(10.7)	17(22.7)
Bush mango	Bagging	49(45.4)	5(4.6)
	Airtight Container	36(33.3)	18(16.7)
Cocoyam	Local barn	27(8)	85(25.3)
	Spread on the floor	81(24.1)	31(9.2)
	Trench	8(2.4)	104(31)
Sweet potato	Local barn	16(10.4)	61(39.6)
	Spread on the floor	62(40.3)	15(9.7)

Source: NSPRI Field Survey, 2021

Table 9 reveals that 11.8% of bread fruit, bush mango, cocoyam and sweet potato farmers experienced mould growth on the crops during storage while 88.2% of these farmers had no complains concerning this. Bambara nut farmers did not experience mould growth during storage. Insect infestation was a major problem for bambara nut farmers and less of an issue for farmers of the other crops (Table 9). Majority of the farmers of bread fruit, bush-mango, cocoyam and sweet potato (6.9%, 11.5%, 37.5% and 26% respectively) experienced spoilage during storage. Bambara nut received a zero vote on this, revealing the durability of this crop during storage. A handful of the farmers of bread fruit & cocoyam (2.4% and 2.1% respectively) experienced germination of these crops during storage. Meanwhile, majority of sweet potato farmers experienced germination of their crops during storage (Table 9). No incidence of germination during storage was recorded by bambara nut and bush mango farmers.

Table 9: Distribution of farmers according to the challenges experienced during storage of crops (N= 288)

Challenges	Crops	Yes F (%)	No F (%)
Mould	Bambara nut	0 (0)	20 (6.9)
	Bread fruit	13 (4.5)	12 (4.2)
	Bush-mango	8 (2.8)	46 (16)
	Cocoyam	4 (1.3)	108 (37.5)
	Sweet potato	9 (3.1)	68 (23.6)
	Total	34 (11.8)	254 (88.2)
Insect infestation	Bambara nut	19 (6.6)	1 (0.3)
	Bread fruit	2 (0.7)	23 (8)
	Bush-mango	12 (4.2)	42 (14.6)
	Cocoyam	11 (3.8)	101 (44.3)
	Sweet potato	7 (2.4)	70 (24.3)
	Total	51 (17.7)	237 (82.3)

Spoilage	Bambara nut	0 (0)	20 (6.9)
	Bread fruit	20 (6.9)	5 (1.7)
	Bush-mango	33 (11.5)	21 (7.3)
	Cocoyam	108 (37.5)	4 (1.4)
	Sweet potato	75 (26)	2 (0.7)
	Total	236 (81.9)	52 (18.1)
Germination	Bambara nut	0 (0)	20 (6.9)
	Bush-mango	0 (0)	54 (18.8)
	Bread fruit	7 (2.4)	18 (6.3)
	Cocoyam	6 (2.1)	106 (36.8)
	Sweet potato	43(14.9)	34 (11.8)
	Total	56(19.4)	232 (80.6)

Source: NSPRI Field Survey, 2021

Discussion

Proximate composition of the selected underutilized crops

The ash, crude protein and fibre content of Bambara nuts obtained in this study concurs with the findings of Muhd et al. (2018) who reported that the ash, crude protein and fibre content of raw Bambara nuts were 4.31%, 20.32%, and 4.79% respectively. The percentage ash content reveals an appreciable quantity of minerals in Bambara nut. It has also been reported that Bambara nut contains potassium, magnesium, phosphorus, zinc, and iron (Oyeyinka *et al*., 2019; Hussin *et al*., 2020; Qaku *et al*., 2020). The percentage protein of Bambara nut obtained in this study are also similar to the findings of Yao et al. (2015), who reported a percentage protein content of 19% in a landrace, Ci12 bambara groundnut grown in Côte d'Ivoire. Meanwhile, Adebowale *et al*. (2011) reported that most of the protein content in Bambara nut are storage proteins. The high protein content obtained signifies that Bambara nut is a good source of plant-based protein, hence can be useful in combatting protein-energy malnutrition in rural communities. The percentage fat content of Bambara nut obtained in this study concurs with previous reports that the oil content of Bambara nut falls within the range of 3 to 7.5% (Minka & Bruneteau, 2000; Emendu & Emendu, 2014). The high percentage carbohydrate content of Bambara nut obtained concurs with previous findings (Adebowale & Lawal, 2002; Sirivongpaisal, 2008) and confirms its rich carbohydrate composition. The relatively low moisture content (8.63±0.04%) shows that Bambara nut may have a long post-harvest shelf life if stored under appropriate conditions.

The significant differences in the moisture content of the bread fruit native to Rivers and Akwa-Ibom States (*Artocarpus altilis*) compared to that native to Ebonyi State (*Treculia africana*) could be due to the difference in the bread fruit specie (Bennett & Isaiah, 2022). The breadfruit native to Ebonyi state had a significantly (P<0.05) lower moisture content (28.35±0.07%), compared to that obtained from Rivers State (61.90±0.06%) and Akwa-Ibom (66.09±0.02%) (Table 2). Generally, the moisture content of foods indicates how stable and vulnerable it is to microbial infestation (Frazier & Westhoff, 2005). Hence, the high percentage moisture observed reveals the high susceptibility of breadfruit to microbial infestation and spoilage. The percentage ash content of the bread fruit obtained in this study concurs with the findings of Bennett & Isaiah (2022) who reported similar values for the ash content of *Treculia africana* in South-South Nigeria. The protein content of the bread fruit seeds obtained from Ebony and Akwa-Ibom where significantly high compared to the samples obtained from Rivers State. The results of the protein content of breadfruit from Ebonyi and Akwa-Ibom states concurs with the findings of Osabor et al. (2009) who reported a percentage protein content of 12.47% for breadfruit. The difference in the nutrient composition of the breadfruit obtained from the three different states could be because of the difference in species. Moreover, the seeds of the breadfruit obtained from Ebonyi had a different morphology (smaller) compared to that obtained from Rivers and Akwa-Ibom states. This may be a useful hint into the difference in species.

The differences observed in the proximate compositions of the bush mango seeds across the different states could be due to the differences in species, considering that the proximate results of previous findings on the different species of bush mango have been equivocal (Adeoye et al. 2023; Abdulbaki et al. 2023; Ogunsina et al. 2012). The percentage ash content of the two species of bush mango obtained in this study concurs with the findings of Ekundayo et al. (2003) & Adeyeye et al. (2013) who reported percentage ash contents of 2.43-3.30%, and 2.40-2.50% respectively. However, Adeoye et al. (2023) reported higher values of 6.8%. Significant difference was also noted in previously reported crude fat content, considering that Adeoye et al. (2023) reported a percentage crude fat content of 7.9% while Ogunsina et al. (2012) reported a percentage crude fat content of 68.4%. Meanwhile, in this study the crude fat content was observed to be within the range of 37.43-41.45%.

Differences in soil textures, pre-harvest, and post-harvest practices may have also influenced this. Farmers noted that the wild species of Bush-mango have bitter taste and better viscoelastic behaviour compared to the domesticated specie. The significant (P<0.05) difference in the fat composition between these two species may explain the difference in viscoelasticity (Table 3). Improvement on the post-harvest handling and processing technology would make for more products which can be incorporated as part of a healthy meal.

The percentage moisture content of cocoyam obtained in this study concurs with previous reports that the moisture content of cocoyam ranges between 65-78% (Amah et al. 2018; Matikiti et al. 2017). The differences in proximate composition of cocoyam across the three states could be due to differences in soil texture, and climate/geographical location, considering that Mato reported a percentage moisture content within the ranges of 15.3-21.2% in Bauchi, Plateau, Gombe, and Kaduna states in Nigeria (Mato, 2025). These states are in the Northern part of Nigeria and are characterized by a Sahelian hot and semi-arid climate. Obviously, the short wet season (June to September) and the long dry season (October to May) experienced in this region may account for the significantly low moisture content obtained from cocoyam grown in this region. The percentage ash content obtained in this study concurs with previous findings on the percentage ash content of cocoyam (Amah et al. 2018; Mato, 2025; Matikiti et al. 2017). Meanwhile, the protein content of the cocoyam species was very low (0.44-

0.70%) compared to the findings of Amah et al. (2018) and Mato (2025) who reported higher values of 3.50-4.72% and 2.7-3.4% respectively. The carbohydrate contents were significantly higher than other nutrients, revealing that carbohydrate is the main nutrient supplied by cocoyam as with other root and tuber crops (Amah et al. 2018).

The percentage moisture (60.55-69.84%) content obtained in this study for cream fleshed sweet potatoes concurs with previous findings by Rose & Vasanthakaalam (2011) who reported a moisture content range of 62.58-64.34% in two varieties of white fleshed sweet potato (Rutambira 4-160 and Mugande, respectively) in Rwanda. Ukom et al. (2009) and Zulkifli et al. (2021) also reported a moisture range of 61-70% and 61.07-89.82% respectively for sweet potatoes, revealing that sweet potatoes generally have a high moisture content. The high moisture content of sweet potato as observed in this study accounts for the short shelf life of cream-fleshed sweet potato after harvest especially when stored in a humid area. Sweet potato is also a good source of carbohydrate as the carbohydrate content ranged from (23.64±0.23 – 33.07±0.15%), being significantly higher than other nutrients. This concurs with the findings of Zulkifli et al. (2021) who reported that sweet potatoes can be a good source of energy. Furthermore, these carbohydrates are essential because they serve as substrates for the Shikimic pathway, which produces phenolic and aromatic chemicals (Eleazu & Ironual, 2013).The protein content was very low suggesting that sweet potatoes have a negligible amount of proteins. These values are within the ranges of previous reports on the percentage protein content of sweet potatoes (Rose & Vasanthakaalam, 2011; Zulkifli et al. 2021; Krochmal-Marczak et al. 2014).

Traditional post-harvest practices and challenges of the neglected crops

Sun drying in an open field was the prevalent practice among the farmers of Bambara nut (Table 6) and this concurs with the findings of Ouili et al. (2022) who reported that the majority of bambara nut farmers in Burkina Faso use sunlight to dry their harvested bambara nut pods. However, this drying method has some setbacks such as animal and bird attack during drying as well as interruption of the drying process by rain (Table 7). The use of modernized forms of drying such as the NSPRI parabolic solar dryer would mitigate these challenges and ensure the non-seasonal drying of bambara nuts by these farmers. Meanwhile, the local storage system used by farmers to preserve bambara nut after sun drying were bags and airtight containers (Table 8). However, the adopted storage facilities face some setbacks including insect infestation of the nuts during storage (Table 9). Insects such as *Callosobruchus subinnotatus* and *Callosobruchus maculatus* have been reported to cause serious damage to Bambara groundnut during storage (Agboka et al., 2018; Kabir et al., 2017). Sealed bags reduces the risk of aflatoxin contamination and insect damage (Maina et al., 2016; Njoroge et al., 2019; Williams et al., 2014). Some modern storage system developed by Nigerian Stored Products Research Institute (NSPRI) which can effectively mitigate these challenges include the zero fly bags, Purdue Improved Crop Storage bags (PICS), hermetic storage (steel drums), and inert atmosphere system (silos) (NSPRI, 2018). Moreover, better storage keeps insects, rodents, and fungi from attacking seeds (Adetunji, 2007). Inadequate information on the nutrient composition of Bambara nut by the farmers was also observed and this might be one of the many reasons for the underutilization of this crop especially by rural dwellers. An improvement in the post-harvest handling of this crop would enhance the shelf life and improve the commercialization.

Most of the bread fruit farmers did not have any storage method, while a few stored in bags and airtight containers after sun-drying (Table 8). Moreover, the breadfruit obtained from the three states were affected by mould, especially when not properly dried before storage (Table 9). The high moisture content (Table 2) of the breadfruit seeds and the storage conditions may be responsible for this (Frazier & Westhoff, 2005). There is also little knowledge on the processing methods for breadfruit, therefore not too many products are obtained from this crop by the local farmers. Improvement on the post-harvest handling and processing technology of breadfruit would extend the shelf life and lead to more processed products from this food crop.

The most common post-harvest technologies adopted by Bush-mango farmers in this region were sun-drying, bagging, and the use of airtight containers for storage (Table 6, 9). Bush-mango seeds were prone to Insect infestation during storage (Table 9), and they were majorly harvested in this region for soup making purposes and at the time of this report, there were no other end products obtained from this crop by the farmers. This could be because of inadequate knowledge on the nutrient composition of bush mango by the local farmers as well as a gross deficiency in processing technologies. Abdulbaki et al. (2023) reported that modernized post-harvest technologies viz; multi-crop dryer and solar tent dryer were effective in retaining major nutrients such as fat in dried bush mango seeds. Multi-crop dryer was also reported to significantly reduce microbial infestation post-drying (Abdulbaki et al. 2023). These technologies can be adopted by farmers to ensure effective post-harvest handling and shelf-life extension.

Cocoyam farmers in Rivers and Akwa-Ibom states complained more on the short shelf life of cocoyam compared with farmers in Ebonyi state who could store their cocoyam a bit longer. Generally, the short shelf life of cocoyam was a problem for the farmers in the three states, and this could be attributed to the high moisture content of cocoyam (FAOSTAT, 2021). Traditionally, the most common storage method for cocoyam among the farmers were storage in bans, spreading of the corms on the floor and storage in trenches (although practiced by few) (Table 8). This concurs with the findings of Opata and Ogbonna who reported that most cocoyam farmers in South-east Nigeria stored cocoyam in bans and by heaping on the flour (Opata & Ogbonna, 2015). The average shelf life of cocoyam as indicated by the farmers ranged from 1 week to about 4 months, with farmers in Akwa-Ibom and Rivers States recording the shortest shelf life. This is a major problem hindering the commercialization of this crop. The carbohydrate content of cocoyam in Rivers and Akwa-Ibom states were significantly ($P<0.05$) low (22.45±0.01% and 14.24±0.06% respectively) compared to that obtained from Ebonyi which was 32.58±0.03% (Table 4). The low carbohydrate content of cocoyam in the two states (Rivers and Akwa-Ibom) may be because of the leaf rot disease affecting cocoyam in the two states. This also concurs with the findings of Shutt et al. (2022) who reported that Taro leaf blights affected the yield of cocoyam.

Majority of the sweet potato farmers stored sweet potato by spreading on the floor in an open & airy environment (Table 8). Some sundried the sweet potato before storage to extend the shelf life (Table 6). However, the disadvantage of the open sun drying method is the interruption of the drying process by rain and sometimes domestic animals which eat up the crop, thereby degrading the crops (Azeke et al. 2020; Braihma & Yola). The farmers were unable to store sweet potato for more than 2 months while some cannot store for more than 3 weeks. Generally, the short shelf life of sweet potato was a major problem in the three states, hence, a major constraint in the commercialization.

An improvement on the post-harvest handling practices and processing of sweet potato, would meet the daily energy need of consumers especially rural dwellers who consider it as a staple food. It will increase the number of products that can be processed from the crop and extend the shelf life of the crop. Meanwhile, the use of modernized drying techniques viz., dehytray, parabolic shaped and solar tent dryers is suggested (Azeke et al. 2020) to enhance the drying efficiency, nutrient retention, improved shelf-life and facilitate the emergence of many end products from processing potatoes. Potato chips seem to be the most common processed product among rural dwellers because it does not require a complex processing technology. Moreover, some of the farmers were already processing sweet potato into flour but on a small scale.

CONCLUSION

This study revealed the different post-harvest technologies adopted by farmers of the five crops studied, with some of these technologies specific to some crops. These post-harvest technologies currently being practiced by rural farmers suffer several setbacks such as spoilage, mould growth, germination during storage and degradation of nutrient composition which affect the maximum utilization and commercialization of these crops. Results from this study would foster research on improving the already existing post-harvest technologies of these food crops as well as the innovation of new processing methods and products from the crops.

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