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Influence of Genotype and Environment on Quality Attributes of *Fufu* Processed from Cassava Planted in Two Agro-Ecologies of Nigeria

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Abstract
Fufu is a fermented pasty food product commonly consumed in West Africa. A study aimed at determining the influence of genotypes and environment on material loss during processing, product yield and physicochemical properties of the intermediate *fufu*-product was conducted. Intermediate *fufu* products were processed from seventeen cassava genotypes in their advanced breeding stage planted in Otobi and Umudike locations within Nigeria. Fresh roots of the genotypes were processed into *fufu* following the standard operating protocol (SOP) of RTBfoods. Chaff loss, peel loss, *fufu* yield, crude fiber, dry matter, total titratable acidity (TTA), amylose, swelling power, solubility, starch and sugar of intermediate *fufu* product for each genotype was determined using standard analytical methods. Result obtained showed that genotype TMS13F1160P0004 had the highest *fufu* yield and chaff loss. Peel loss did not differ among the genotypes. Genotype and environment played significant roles in the processing and physicochemical properties of the fermented *fufu* wet paste. Swelling power, solubility, starch and sugar of the intermediate *fufu* product differed significantly ($P<0.001$) among the genotypes. NR174-1 had the highest amylopectin and swelling power while TMS13F1160P0004 had the lowest total titratable acidity and sugar content. Chaff loss, *fufu* yield, swelling power and starch were significantly influenced by environment ($P<0.001$). Genotype was found to have a major influence on chaff loss, starch and sugar. Genotype -by -environment interaction influenced only starch and sugar values. The result obtained will assist breeders develop cassava varieties that possess food qualities acceptable to *fufu* end-users.

Keywords: Fufu, Genotypes, environment, processing parameters, physicochemical properties, starch, swelling power

Introduction

Cassava *(Manihot esculenta)* is a known root crop in West Africa (Oyewole and Odunfa, 1992). It is simple to cultivate and has the ability to grow on arid land, which is usually difficult for other crops (Olanrewaju, 2016). It is common ingredients used in preparation of major cassava- based food products consumed in Nigeria such as *fufu*, gari and *lafun*. Most of these products are made and consumed locally by farming households themselves (IITA, 2012). Among these fermented cassava products, "*fufu*" is unique because in the traditional processing, the product is not subjected to any other processing after fermentation before cooking. *Fufu* is a traditional fermented food product in southern, western and eastern Nigeria and some other parts of West Africa (Rosalessoto *et al*., 2016). *Fufu* is usually described as a wet paste food product and ranks second after gari as food product from cassava (http://www.cassavabiz.org/postharvest/*fufu*). The quality of *fufu* can be affected by many factors such as the genotypes, agronomic practices, farm location and methods of preparations specific to cultural context in which it is consumed. According to Oluwafemi and Udeh, (2016), different cassava genotypes can have significant impact on *fufu* quality as those processed from different varieties of cassava may have varying levels of starch and other characteristics that can impact the texture and taste of the *fufu*. Adebayo *et al*. (2013) found out that genotypes also affects the nutrient composition of *fufu* as high starch varieties of cassava gave *fufu* with higher levels of protein and ash content compared with genotypes with low-starch varieties. Location where cassava is grown can also play a role in determining the quality of *fufu* as Oluwafemi and Udeh (2016) found out that cassava grown in different locations had varying levels of starch and other characteristics which led to differences in textural properties and taste of *fufu*. The study stated that cassava grown in the southern region of Nigeria had higher level of pasting viscosity compared to cassava grown in the northern region. Recently, breeders have been working to develop varieties with high food qualities that are acceptable by consumers. Differences exist in the quality of the products as regards to the cassava varieties (Tokula and Ekwe, 2006) and also planting location (Sanoussi *et al*., 2015, Laya *et al*., 2018). Hence, there is need to assess these varieties and their locational effects on the food quality attributes of *fufu* processed from some NextGen cassava varieties planted in two locations in Nigeria.

Materials and Methods

Source of Material and Wet Fufu Preparation

17 NextGen cassava genotypes established using randomized complete block design at its Advanced Yield Trial stage in two locations in Nigeria (Otobi and Umudike) were used for the study. Five kilogram of freshly harvested matured cassava roots from each genotype were manually peeled, washed and processed into *fufu* using the method described by Omodamiro *et al*. (2012). Processing parameters such as chaff loss, peel loss and *fufu* yield of each genotype were evaluated during processing as described by Ugo Chijioke *et al*. (2020). Physico-chemical parameters, sugar and starch content were determined using standard AOAC (2002), while method described by Onwuka and Ogbogu (2007) were used to determine the Total titratable acidity (TTA). Swelling power was determined by the method described by Li and Yeh (2001), while solubility was determined using a method modified by Onwuka (2005). Amylose and amylopectin content of the samples were determined according to the methods as described by Ronoubigouwa *et al*. (2009). Statistical analysis was carried out using GenSTAT software and means were separated using Duncan multiple range test (DMRT) as described by Duncan (1955) and significance accepted at 5% probability level ($p = 0.05$)

Results and Discussion

Table 1 shows the mean estimate of the processing parameters of *fufu* sample. The result indicated that there were significant differences ($P<0.05$) in chaff loss and *fufu* yield but not in the peel loss, where the peel loss of the samples ranged from 18.50-30.00% with NR14B-218 having the lowest value and TMS13F1122P0005 having the highest value. In the same vain, Chaff loss ranged from 35.47-57.96% with the *fufu* sample processed from NR292-D having the lowest chaff loss while that from TMS13F1160P0004 had the highest chaff loss. The result also show that there is significant difference ($P<0.05$) across the locations, which indicates that location has effect on the percentage peel loss, chaff loss and *fufu* yield. The knowledge of the processing parameters of *fufu* is an important economic factor in screening cassava genotypes suitable for products (Shittu *et al*., 2007). Hence, some of the genotypes with high *fufu* yield, low chaff loss and peel loss could be produced in larger quantities for farmers, processors and investors interested in cassava products. Losses in peel and chaff could also be attributed to increasing difficulty in processing procedures such as in peeling and sieving as cassava genotypes with too thick/thin outer covering as well as high fiber content may have be difficult to peel and sieve after grating (Akingbala *et al*., 2005).

Table 2 showed there was also a significant interaction effect on percentage chaff loss which means that different location react differently on the percentage chaff loss**.** The result obtained in this work is in line with report by Sobowale *et al*. (2016) as well as Agunbiade and Ighodaro (2010) as they discovered that apart from dry matter content and genotypes, location may also affect product yield.

The result in Table 3 shows the mean estimate of the physiochemical properties of *fufu* samples. The result show that there is significant difference ($P<0.05$) for swelling power, sugar content and starch content but there is no significance for TTA, crude fibre, DM, amylose, amylopectin and solubility. The swelling power content of the samples ranged from 8.30 - 9.88, with NR174-1 having the highest and TMS13F1122P0005 had the least swelling power. The crude fibre value ranged from (0.37-0.72), dry matter (42.20-44.54), amylose (0.57-2.62) and amylopectin (97.38-99.43). The solubility value shows that sample TMS13F1153P0001 had the highest value (4.75) while TMS13F1343P0022 had the lowest value (1.63). The sugar content values ranged from 3.43 - 6.07 and they differed significantly except TMS13F1343P0022, TMS13F2110P0008, IITA-TMS-IBA000070 and NR14B-218. The starch content ranged from 41.69 - 60.87. The amylose content is lower than the amylose content from cassava flour. *Fufu* sample from TMS13F1160P0004 (0.14) had the lowest value and NR095-F (0.51) had the highest. There were differences between the values obtained from NR174-1, TMS13F1307P0016, NR292-D, IITA-TMS-IBA30572, TMS13F2110P0008, TMS13F1160P0004 and the other samples. The swelling power content of the samples ranged from 8.30 - 9.88, with NR174-1 having the highest and TMS13F1122P0005 the lowest swelling power.

Result of the solubility of the *fufu* sample showed that TMS13F1153P0001 had the highest value (4.75) while TMS13F1343P0022 had the lowest solubility value (1.63). The result also show that there is significant difference ($P<0.05$) across the locations, which indicates that location has effect on the amylose, amylopectin, swelling power, solubility, sugar and starch content and there is a significant interaction effect only for sugar and starch content which means that different location react differently on the sugar and starch content of the genotypes (Table 4). This is in line with the report by Nilusha *et al*. (2021). Adeboye and Adebiyi (2017) discovered that genotype used in *fufu* production can affect the total titratable acidity, crude fiber and dry matter content of the final product. TTA values obtained in this study were lower compared to 0.45-1.85% reported by Akharaiyi and Gabriel, (2007) while the crude fiber contents were higher than the values reported by Oyeyinka *et al*. (2019). Differences in the amylose and amylopectin content of the *fufu* samples are due to varietal differences as reported by M.R *et al*. (2014) The relationship observed between swelling power and amylose content of the *fufu* samples were in agreement with the reports of Leach *et al*. (1959) as he opined that amylose acts as a diluent as well as inhibitors of swelling hence, samples with lower swelling power recorded higher Amylose content. Swelling index and solubility of granules are used to reflect the extent of associative forces existing within the granules as reported by Sanni *et al*., (2005) hence higher associative forces results in lower swelling power (Singh *et al*., 2004). The values of starch obtained in this study is within the range of 56.1- 61.7g/100g reported by Ogbe *et al*. (2015)

Conclusion

The study showed that variety and location played significant roles in the processing and physicochemical properties of the *fufu* genotypes evaluated. This means the processing and physiochemical properties of *fufu* genotypes react differently across locations. It is therefore recommended that *fufu* processes should be location specific because genotypes behave differently across environmental seasons.

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Table 1: Mean estimate of processing parameters of *Fufu* samples

Clone	Peel loss (%)	Chaff loss (%)	*Fufu* yield (%)
TMS13F1122P0005	30.00^{a}	41.14^{de}	58.00^{abcd}
TMS13F1153P0001	28.50^{ab}	47.29^{abcd}	51.00^{abcde}
NR130022	27.00^{ab}	40.91^{de}	49.25^{bcde}
TMEB419	26.50^{ab}	48.37^{abcd}	51.50^{abcde}
NR174-1	26.00^{ab}	41.23^{de}	47.50^{de}
TMS13F1343P0022	24.50^{ab}	57.43^{ab}	58.25^{abc}
TMS13F1307P0016	24.50^{ab}	54.80^{abc}	56.00^{abcde}
NR292-D	24.00^{ab}	35.47^{e}	46.50^{e}
IITA-TMS-IBA30572	23.50^{ab}	45.09^{cde}	49.00^{bcde}
NR095-F	23.25^{ab}	49.67^{abcd}	54.00^{abcde}
NR130124	23.00^{ab}	51.00^{abcd}	56.00^{abcde}
TMS13F2110P0008	21.75^{ab}	44.34^{cde}	48.00^{cde}
TMS13F1343P0044	21.50^{ab}	57.26^{ab}	59.00^{ab}
Local	21.50^{ab}	40.28^{de}	48.50^{bcde}
TMS13F1160P0004	20.50^{ab}	57.96^{a}	60.00^{a}
IITA-TMS-IBA000070	19.36^{ab}	46.88^{bcd}	51.00^{abcde}
NR14B-218	18.50^{b}	53.27^{abc}	59.00^{ab}

Table 2: P-value of the processing parameters of *Fufu* samples

Parameter	Peel loss (%)	Chaff loss (%)	*Fufu* yield (%)
Mean	23.75	47.79	53.09
Location	X	Xxx	Xxx
Location x genotype	Ns	X	Ns
Range	18.50-30.00	35.47-57.96	46.50-60.00
Genotype	Ns	Xxx	Xxx

Table 3: Mean estimate of the physicochemical properties of processed *Fufu* samples

Clone	TTA	Crude fibre	DM(%)	Amylose	Amylopectin	Swelling power	Solubility	Sugar	Starch(%)
TMS13F1122P0005	0.27^{ab}	0.62^{a}	43.47^{a}	2.03^{a}	97.97^{a}	8.30^{d}	3.50^{ab}	4.19^{efg}	52.95^{defg}
TMS13F1153P0001	0.27^{ab}	0.51^{a}	42.77^{a}	1.49^{a}	98.51^{a}	8.89^{abcd}	4.75^{a}	4.00^{fg}	52.54^{defg}
NR130022	0.28^{ab}	0.37^{a}	43.59^{a}	2.49^{a}	97.51^{a}	8.86^{abcd}	3.25^{ab}	3.94^{fgh}	49.19^{fgh}
TMEB419	0.25^{ab}	0.54^{a}	42.20^{a}	2.26^{a}	98.40^{a}	9.24^{abcd}	2.75^{ab}	5.17^{bc}	60.87^{a}
NR174-1	0.18^{b}	0.61^{a}	43.94^{a}	0.57^{a}	99.43^{a}	9.88^{a}	3.50^{ab}	4.69^{cde}	52.79^{defg}
TMS13F1343P0022	0.31^{ab}	0.53^{a}	44.54^{a}	2.03^{a}	97.97^{a}	8.97^{abcd}	1.63^{b}	4.44^{def}	52.39^{defg}
TMS13F1307P0016	0.20^{b}	0.59^{a}	42.51^{a}	0.68^{a}	99.32^{a}	8.60^{cd}	3.25^{ab}	5.16^{bc}	41.69^{j}
NR292-D	0.19^{b}	0.50^{a}	43.33^{a}	2.43^{a}	97.70^{a}	9.59^{abc}	4.00^{a}	5.15^{bc}	45.59^{hij}
IITA-TMS-IBA30572	0.19^{b}	0.63^{a}	43.87^{a}	1.62^{a}	98.38^{a}	8.99^{abcd}	3.50^{ab}	5.34^{b}	57.78^{abc}
NR095-F	0.51^{a}	0.52^{a}	42.95^{a}	0.99^{a}	99.15^{a}	8.74^{bcd}	3.75^{ab}	4.99^{bcd}	53.66^{cdef}
NR130124	0.29^{ab}	0.55^{a}	42.28^{a}	0.79^{a}	99.21^{a}	9.10^{abcd}	2.75^{ab}	3.78^{gh}	54.41^{bcde}
TMS13F2110P0008	0.20^{b}	0.57^{a}	43.89^{a}	0.78^{a}	99.32^{a}	8.71^{bcd}	3.88^{ab}	4.48^{def}	51.07^{efg}
TMS13F1343P0044	0.32^{ab}	0.56^{a}	43.26^{a}	1.71^{a}	98.29^{a}	9.71^{ab}	4.00^{a}	6.07^{a}	48.90^{ghi}
Local	0.28^{ab}	0.72^{a}	43.11^{a}	1.15^{a}	98.85^{a}	8.33^{d}	3.88^{ab}	4.66^{cde}	44.55^{ij}
TMS13F1160P0004	0.14^{b}	0.57^{a}	44.18^{a}	1.78^{a}	98.23^{a}	8.56^{d}	3.00^{ab}	3.43^{h}	55.63^{bcd}
IITA-TMS-IBA000070	0.28^{ab}	0.66^{a}	43.89^{a}	2.26^{a}	97.74^{a}	9.04^{abcd}	4.50^{a}	4.43^{def}	53.30^{defg}
NR14B-218	0.23^{ab}	0.66^{a}	42.29^{a}	2.62^{a}	97.38^{a}	8.53^{d}	2.88^{ab}	4.47^{def}	58.48^{ab}

Table 4: P-value of the physicochemical properties of processed *Fufu* samples

	TTA	Crude fibre	DM(%)	Amylose	Amylopectin	Swelling power	Solubility	Sugar	Starch(%)
Mean	0.26	0.57	43.30	1.63	98.43	8.94	3.46	4.61	52.11
Location	Ns	ns	Ns	*	*	**	*	*	***
Location x genotype	Ns	ns	Ns	Ns	Ns	Ns	Ns	***	***
Range	0.14-0.51	0.37-0.72	42.20-44.54	0.57-2.62	97.38-99.43	8.30-9.88	1.63-4.75	3.43-6.07	41.69-60.87
Genotype	Ns	ns	Ns	Ns	Ns	***	Ns	***	***