Applied Tropical Agriculture
Volume 24, No 1, 200-207, 2019

PHYSICO-CHEMICAL AND FUNCTIONAL PROPERTIES OF CASSAVA AND AFRICAN YAM BEAN FLOUR BLENDS

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ABSTRACT

The purpose of this study was to investigate the physico-chemical and functional properties of Pro-vitamin A cassava (Manihot esculenta CRANTZ*) (07/593) and African yam bean (Sphenostylis stenocarpa) (TSs 94) flour blends. The crops were processed into flour and their desirable flour blends combinations were obtained using Response Surface Methodology (RSM) of central composite rotatable design. Pro-vitamin A cassava flour and African yam bean flour ranged from 40-90% and 10-40% respectively. The physico-chemical and functional properties were determined based on the standard methods. The physico-chemical properties were colour: l*(78.73 to 102.99): a*(-1.79 to 4.23) and b* (13.50 to 37.21):titratable acidity (0.17-0.25): pH (5.92 to 6.87): starch(49.93 to 60.34%): sugar (2.00 to 4.34%): amylose (18.56 to 24.05%) and amylopectin (75.95 to 81.18%).The functional properties- water absorption capacity, oil absorption capacity, packed bulk density, loose bulk density, dispersibility, swelling power, foam capacity and stability and least gelation capacity ranged from 1.5 to 2 g/g, 0.9-1.3 g/g, 0.60 to 0.97 g/ml, 0.38 to 0.75 g/ml, 60.00 to 73.33%, 1.62 to 5.5, 5.63 to 9.9% and 2% respectively. There were significant differences (p<0.05) in physico-chemical and functional properties of the flour blends except the least gelation capacity that were not significantly different from one another.*

Keywords: Cassava, Flour blends, Fortification, Nutritional quality, Under-utilised legume,

INTRODUCTION

Indigenous raw materials replacement for wheat flour is progressively essential due to the growing market for confectioneries (Noor Aziah and Komathi, 2009) and convenience foods in developing countries. Thus, many developing countries have encouraged the initiation of programmes to evaluate the alternative locally available flours as substitute for wheat flour (Abdelghafor et al., 2011). This development would reveal the potential of non-wheat flours in food formulation. Muoki et al. (2012) emphasised that cassava roots are rich in carbohydrates, deficient in proteins and many essential micronutrients. They have high starch content of about 60% thus, an inexpensive and outstanding source of dietary carbohydrate. Previous studies on cassava utilisation were frequently using cassava as a partial substitute for wheat flour especially in bread and biscuit production (Eggleston et al., 1992; Oluwamukomi et al., 2011). Presently, composite flours have been used extensively and successfully in the production of bakery products. This is economically advantageous to developing countries as it boosts the utilisation of local crops in flour production(Hugoetal., 2000). Cassava has been criticised for its low and poor quality protein content (Zvinavashe et al., 2011). Therefore, efforts to fortify cassava flour with legume are highly essential to enhance its nutritional quality, boost its utilisation in food formulation and thereby reducing the protein malnutrition problem of the consumers. African yam bean (AYB) seeds have protein content varied from 21 to 29% with about 50% carbohydrate commonly starch (Eromosele et al., 2008). It is one of the perfect sources for protein supplementation of starchy food sowing to its nutritional potential. Its utilisation in food formulation could help in creating more awareness about this lesser-known and under-utilised legume in the developing countries (Blessing et al., 2013).This would boost its demand and thus encourage the farmers to cultivate the crop. Therefore, the purpose of this investigation was to study the physico-chemical and functional properties of cassava-African yam bean flour blends.

MATERIALS AND METHODS

Sources of Raw Materials

Yellow-fleshed cassava roots (07/593) and African yam bean seeds (TSs 94) were obtained from Cassava Processing Unit and Genetic Resources Centre of International Institute of Tropical Agriculture (IITA), Ibadan.

Formulation of Flour Blends

Cassava and African yam bean flours were prepared as described by Aniedu and Omodamiro (2012)and Nwosu et al. (2011) respectively. Response surface methodology of central composite rotatable design was employed for the establishment of their desirable flour blends using Design Expert of version 6.0.6 (Stat-Ease Inc, Minneapolis).The ranges of 40-90% and 10-40% of cassava and African yam bean flours respectively were chosen based on preliminary work. These ingredients optimisation generated thirteen random combinations of five central points as shown in Table 1. These combinations were weighed and carefully mixed using Bajaj grinder mixer of model number GX 10 DLX for 1 min to attain a homogenous blend.

Physico-chemical Characteristics of the Blends

The colour of flour blends and the intermediate products were determined based on method described by Choy (2011) using Konica Minolta Chroma meter of model CR-410. Titratable acidity and pH were determined as described by Erickson et al. (2014). Sugar and starch contents were investigated based on the method described by AOAC (2005). The amylose content was determined as described by Mohana et al. (2007) while, amylopectin of the blend was calculated by subtracting the value of amylose from 100.

Table 1: Ingredients Optimisation of Flour Blends

Number of runs	Sample code CF:AYB	Cassava flour (%)	AYB flour (%)
1	29.64:25	54.25	45.75
2	40:10	80	20
3	40:40	50	50
4	65:46.21	58.45	41.55
5	65:25	72.22	27.78
6	65:25	72.22	27.78
7	65:25	72.22	27.78
8	65:25	72.22	27.78
9	90:40	69.23	30.77
10	90:10	90	10
11	65:3.79	94.49	5.51
12	65:25	72.22	27.78
13	100.36:65	80.06	19.94

CF: AYB, CF=cassava flour and AYB=African yam bean flour.

Determination of Functional Properties

Water and oil absorption capacities of the flour blends were determined as described by Isah *et al.* (2015) with slight modification. The packed and loose densities were determined as described by Appiah *et al*. (2011). The dispersibility of flour blends was determined as described by Kulkarni *et al.*(1991). The foaming capacity and least gelation concentration of the flour blends were determined based on the method described by Onwuka (2005) and Sathe *et al*. (1982) respectively.

Statistical Analysis

All analyses were done in triplicate and data obtained were statistically analysed and subjected to one-way analysis of variance (ANOVA) with the use of Statistical Package for Social Sciences (SPSS) (version 20, 2013). Means were compared and separated using Duncan's New Multiple Range Test (DNMRT) and LSD at ($p<0.05$).

RESULTS AND DISCUSSION

Physico-chemical Properties

The colour of the flour blends and other intermediate products was presented in Table 2. The colour ranged from 78.73 to 102.99 for l*, -1.79 to 4.23 for a* and 13.50 to 37.21 for b*.These were lower than those obtained from Choy (2011). The lightness of pulverised cassava mash and pressed cassava were not significantly ($p \geq 0.05$) different. The lightness intensity was reducing as the quantity of AYB was increasing in the flour blends. Yellow-fleshed cassava roots was the most yellowness (b*) while, sample AYB had the least. It was observed that as the quantity of AYB was increasing, yellowness intensity was reducing. This reduction in yellowness could be as result of dilution effect of colour pigments such as carotenoids presence in yellow-fleshed cassava flour. Significant ($p \leq 0.05$) differences were noted among the samples based on their yellowness except samples29.64CF:25AYB and 40CF:40AYB that were similar.

The results of titratable acidity, pH, sugar, starch, amylose and amylopectin of the flours and flour blends were presented in Table 3.The titratable acidity and the pH of the flour blends

Table 2:Colour of Cassava Roots, Flour Blends and Intermediate Products

Samples code CF:AYB (g)	Lightness (l*)	Reddish (a*)	Yellowness (b*)
29.64:25	$79.56\pm0.26_{de}$	$-1.79\pm0.11_{j}$	$28.88\pm0.26_{f}$
40:10	$79.94\pm0.16_{d}$	$-1.56\pm0.07_{ghij}$	$30.37\pm0.21_{de}$
40:40	$79.70\pm0.41_{de}$	$-1.65\pm0.12_{hij}$	$28.27\pm0.12_{f}$
65:46.21	$79.67\pm0.23_{de}$	$-1.68\pm0.08_{ij}$	$29.87\pm0.56_{e}$
65:25	$79.67\pm0.03_{de}$	$-1.50\pm0.01_{ghi}$	$30.12\pm0.11_{e}$
65:25	$79.54\pm0.15_{de}$	$-1.48\pm0.04_{ghi}$	$30.18\pm0.38_{e}$
65:25	$79.99\pm0.02_{d}$	$-1.45\pm0.10_{ghi}$	$30.17\pm0.03_{e}$
65:25	$79.78\pm0.05_{de}$	$-1.47\pm0.10_{ghi}$	$29.89\pm0.46_{e}$
90:40	$79.89\pm0.08_{d}$	$-1.37\pm0.11_{g}$	$29.71\pm0.16_{e}$
90:10	$80.35\pm0.08_{d}$	$-1.42\pm0.07_{gh}$	$31.29\pm0.13_{c}$
65:3.79	$80.45\pm0.18_{d}$	$-1.14\pm0.3_{f}$	$30.35\pm0.33_{de}$
65:25	$79.99\pm0.04_{d}$	$-1.62\pm0.08_{ghij}$	$30.03\pm0.04_{e}$
100.36:25	$80.23\pm0.12_{d}$	$-1.46\pm0.11_{ghi}$	$30.3\pm0.07_{de}$
Root	$78.73\pm0.64_{e}$	$4.23\pm0.08_{a}$	$37.21\pm0.05_{a}$
Grated	$86.88\pm1.46_{c}$	$1.57\pm0.36_{c}$	$35.67\pm1.16_{b}$
Pressed	$88.63\pm0.73_{b}$	$0.83\pm0.02_{d}$	$31.10\pm0.36_{c}$
Pulverised	$88.64\pm0.69_{b}$	$0.31\pm0.01_{e}$	$30.92\pm0.26_{cd}$
CF	$102.99\pm1.59_{a}$	$-0.96\pm0.05_{f}$	$21.26\pm0.33_{g}$
AYB	$85.23\pm0.69_{d}$	$3.27\pm0.13_{b}$	$13.50\pm0.12_{h}$

CF:AYB, CF means cassava flour, AYB meansAfricanyambeanflour. Mean triplicate determinations ± standard deviation. Mean values of different subscript along the column are significantly different (P<0.05).

Table 3: Physico-chemical Composition of Flour Blends

Samples CF:AYB	Sugar (%)	Starch (%)	Amylose (%)	Amylopectin (%)	Titratable acidity (%)	pH
29.64:25	2.04±0.11fg	51.39±0.74f	24.05±0.10a	75.95±0.10h	0.24±0.09ab	6.73±0.07b
40:10:00	2.15±0.12fg	49.93±0.54g	19.81±0.35d	80.19±0.35e	0.19±0.01e	6.41±0.01d
40:40:00	3.12±0.09e	53.31±0.17e	22.83±0.37b	77.17±0.37g	0.23±0.09b	6.87±0.18a
65:46.21	4.34±0.07b	59.37±0.82ab	19.05±0.10fg	80.95±0.10bc	0.25±0.01a	6.73±0.13b
65:25:00	2.01±0.1g	60.34±0.79a	19.07±0.17fg	80.93±0.17bc	0.20±0.01cd	6.6±0.02bc
65:25:00	2.07±0.06fg	59.74±0.35ab	19.28±0.16ef	80.72±0.16cd	0.19±0.01de	6.47±0.06cd
65:25:00	2.08±0.09fg	58.99±1.34b	19.49±0.16de	80.51±0.16de	0.19±0.01e	6.49±0.08cd
65:25:00	2.11±0.06fg	59.30±0.58ab	19.07±0.17h	80.93±0.17bc	0.18±0.01e	6.43±0.02d
90:40:00	5.75±0.05a	59.74±0.67ab	19.55±0.1de	80.45±0.10de	0.24±0.01ab	6.73±0.10b
90:10:00	3.33±0.11d	46.48±0.69h	21.35±0.13c	78.65±0.13f	0.18±0.01e	6.02±0.02e
65:3.79	3.96±0.06c	53.12±0.05e	21.05±0.10c	78.95±0.10f	0.17±0.01e	5.92±0.02e
65:25:00	2.03±0.11fg	57.56±0.28c	18.82±0.13gh	81.19±0.13ab	0.19±0.01de	6.54±0.05cd
100.36:25	2.19±0.13f	55.26±0.25d	18.56±0.06h	81.44±0.06a	0.21±0.01c	6.41±0.08d

CF: AYB, CF means cassava flour, AYB means African yam bean flour. Mean triplicate determinations ± standard deviation. Mean values of dissimilar subscript along the column are significantly different (P<0.05).

ranged from 0.17 to 0.25% and 5.92 to 6.87% respectively. Sample 65CF:46.21AYB had the highest titratable acidity while, 65CF:3.79AYB had the least. Likewise, sample 40CF:40AYB had thehighest pH while, 65CF:3.79AYB had the least. These values were within the tolerable range as reported by Dziedzoave *et al*. (2006) of (>5.8) and (<0.25).The pH values compared well with those reported by Apea-Bah *et al*. (2011) of values 5.07-6.65. Significant rise was observed in the pH of the flour blends as the level of AYB flour was increasing.

The starch and sugar contents ranged from 49.93 to 60.34% and 2.00 to 4.34% respectively. These values fell within the range reported by Chijioke *et al.* (2016) of values 37.74 to 94.96% and 1.76 to 10.83% respectively. The amylose and amylopectin contents ranged from 18.56 to 24.05% and 75.95 to 81.18% respectively. Sample 29.64CF:25AYB had the greatest amylose content while, 100.36CF:25AYB had the least. The range of these values matched well with those reported by Iwe *et al*. (2016) of values 17.13-28.07%.

Functional Properties

The results of functional properties of flour blends were presented in Table 4. The water absorption capacities of the flour blends fell within the range of 1.5 to 2 g/g. Sample AYB had the greatest value while, 40CF:10AYB had the least. These values were lower than those reported by Chijioke *et al.* (2016) of values 1.84-2.66%. The oil absorption capacities of the flour blends ranged from 0.9-1.3 g/g with sample CF had the highest value while, AYB had the lowest. These values fell within the range reported by Ohizua *et al.* (2017) of values 0.92 to 1.54 g/g. The packed density of the flours and the flour blends ranged from 0.60 to 0.97 g/ml. Sample AYB had the highest value while, 90CF:10AYB had the least. This compared well with those reported by Adeola *et al.* (2017) of values 0.58-1.05 g/ml. The loose density and dispersibility of the flour blends ranged from 0.38 to 0.75 g/ml and 60.00 to 73.33% respectively. Sample AYB had the peak loose density and dispersibility, while, sample 65CF:25AYB had the least loose density. Meanwhile, samples CF and 65CF:3.79AYB had the least dispersibility. The dispersibility values obtained in this study matched well with the range reported by Ohizua *et al.* (2017) of values 52 to 79%. It was observed that all the flour blends had reasonably higher dispersibility that suggests the ease of reconstitution to form well consistent dough during mixing (Adebowale *et al*., 2008). The foaming capacity and stability of the flours and their flour blends were represented in Table 5. The foaming capacity ranged from 5.63 to 9.9% with sample 65CF:3.79AYB had the highest while, 65CF:25AYB had the least. This matched well with the range reported by Ohizua *et al*. (2017) of values 2.01 to 12.88%. The foaming stability was evaluated over a period of 80 min at 20 min interval. It was observed that the foaming stability of the flour blends were reducing with time. The least gelation concentration (LGC) of the flour blends was 2%. There was no significant difference (P≥0.05) among the flour blends based on LGC. Adeola *et al*. (2017) stated that the higher the LGC, the more the quantity of flour required to form a gel and the lower the LGC the better the gelling ability of the flour.

Table 4: Functional Properties of the Flour Blends

Samples Code CF:AYB	Water Absorption Capacity (g/g)	Oil Absorption Capacity (g/g)	Bulk density (g/ml)	Loose density (g/ml)	Dispersibility (%)
29.64:25	$1.9±0.14_{ab}$	$1±0.14_{cde}$	$0.70±0.01_{d}$	$0.44±0.01_{cde}$	$63.33±1.26_{ef}$
40:10	$1.5±0.00_{d}$	$0.95±0.07_{de}$	$0.65±0.06_{def}$	$0.47±0.06_{c}$	$62.5±0.5_{efg}$
40:40	$1.65±0.35_{bc}$	$1±0.00_{cde}$	$0.81±0.04_{c}$	$0.54±0.03_{b}$	$67.67±0.58_{b}$
65:46.21	$1.65±0.07_{bc}$	$1±0.00_{cde}$	$0.68±0.05_{de}$	$0.45±0.01_{cd}$	$68.67±3.06_{b}$
65:25	$1.85±0.07_{ab}$	$1±0.14_{cde}$	$0.68±0.05_{de}$	$0.44±0.03_{cde}$	$64.33±1,16_{de}$
65:25	$1.85±0.07_{ab}$	$1±0.00_{cde}$	$0.67±0.00_{de}$	$0.41±0.00_{def}$	$63.67±0.58_{e}$
65:25	$1.85±0.00_{ab}$	$0.98±0.04_{cde}$	$0.63±0.00_{ef}$	$0.38±0.01_{f}$	$65.00±1.00_{cde}$
65:25	$1.9±0.00_{ab}$	$1.25±0.07_{ab}$	$0.65±0.02_{def}$	$0.40±0.01_{ef}$	$64.67±0.58_{de}$
90:40	$1.65±0.07_{bc}$	$0.95±0.07_{de}$	$0.68±0.03_{de}$	$0.44±0.01_{cde}$	$63.83±1.53_{e}$
90:10	$1.6±0.00_{bc}$	$1.1±0.00_{bcd}$	$0.60±0.04_{f}$	$0.41±0.03_{def}$	$67.33±0.76_{bc}$
65:3.79	$1.8±0.14_{abc}$	$1.15±0.07_{abc}$	$0.66±0.01_{def}$	$0.40±0.01_{ef}$	$60.00±2.65_{g}$
65:25	$1.88±0.04_{ab}$	$1.05±0.07_{cde}$	$0.67±0.02_{de}$	$0.40±0.03_{ef}$	$66.83±0.76_{bcd}$
100.36:25	$1.85±0.0_{7ab}$	$1±0.00_{cde}$	$0.64±0.0_{2def}$	$0.43±0.02_{cde}$	$64.17±1.89_{de}$
100:0	$1.75±0.07_{abc}$	$1.3±0.00_{a}$	$0.88±0.02_{b}$	$0.42±0.03_{cdef}$	$61.00±1.00_{fg}$
0:100	$2±0.28_{a}$	$0.9±0.14_{e}$	$0.97±0.03_{a}$	$0.75±0.03_{a}$	$73.33±1.53_{a}$

CF:AYB, CF means cassava flour, AYB means African yam bean flour. Mean triplicate determinations ± standard deviation, Mean values of different subscript along the column are significantly different (P<0.05).

Table 5: Foaming Capacity and Stability of Flour Blends

Samples CF:AYB (g)	Foaming capacity (%)	Foaming stability (20 min)	Foaming stability (40 min)	Foaming stability (60 min)	Foaming stability (80 min)
29.64:25	$8.25\pm1.19_{ab}$	$5.51\pm0.07_{ab}$	$3.67\pm0.04_{abc}$	$2.75\pm1.27_{a}$	ND
40:10	$8.25\pm1.19_{ab}$	$5.51\pm0.07_{ab}$	$2.75\pm1.26_{bc}$	$1.82\pm2.57_{ab}$	$0.91\pm1.29_{a}$
40:40	$6.54\pm1.24_{ab}$	$3.74\pm0.05_{b}$	$1.87\pm0.02_{c}$	ND	ND
65:46.21	$6.535\pm1.24_{ab}$	$4.67\pm1.27_{ab}$	$3.74\pm0.05_{abc}$	$1.87\pm0.03_{ab}$	$0.93\pm1.31_{a}$
65:25	$5.63\pm2.52_{b}$	$4.76\pm1.28_{ab}$	$2.81\pm1.26_{bc}$	$1.85\pm2.62_{ab}$	$0.93\pm1.31_{a}$
65:25	$6.54\pm1.24_{ab}$	$4.67\pm1.27_{ab}$	$4.63\pm1.31_{ab}$	$2.80\pm1.28_{a}$	$0.87\pm0.03_{a}$
65:25	$6.54\pm1.24_{ab}$	$4.71\pm1.21_{ab}$	$2.82\pm1.25_{bc}$	ND	ND
65:25	$6.54\pm1.24_{ab}$	$4.72\pm1.34_{ab}$	$3.74\pm0.05_{abc}$	$1.86\pm0.01_{ab}$	$0.86\pm0.01_{a}$
90:40	$5.66\pm0.00_{b}$	$3.77\pm0.00_{b}$	$2.83\pm1.33_{bc}$	ND	ND
90:10	$6.54\pm1.24_{ab}$	$4.67\pm1.27_{ab}$	$4.67\pm1.27_{ab}$	$1.87\pm0.03_{ab}$	$1.85\pm0.00_{a}$
65:3.79	$9.9\pm1.24_{a}$	$6.3\pm1.19_{a}$	$5.41\pm0.07_{a}$	$3.61\pm0.05_{a}$	$1.81\pm0.02_{a}$
65:25	$5.63\pm2.52_{b}$	$4.67\pm1.27_{ab}$	$4.63\pm1.32_{ab}$	$2.79\pm1.29_{a}$	$0.94\pm1.32_{a}$
65:3.79	$6.54\pm1.24_{ab}$	$4.68\pm1.39_{ab}$	$2.81\pm1.36_{bc}$	$1.87\pm0.03_{ab}$	ND
100:0	$7.41\pm0.00_{ab}$	$5.56\pm0.00_{ab}$	$4.63\pm1.32_{ab}$	$2.78\pm1.31_{a}$	$0.93\pm1.31_{a}$
0:100	$8.25\pm1.19_{ab}$	$5.51\pm0.07_{ab}$	$3.67\pm0.04_{abc}$	$1.84\pm0.02_{ab}$	$0.93\pm1.31_{a}$

CF:AYB, CF means cassava flour, AYB means African yam bean flour. Mean triplicate determinations ± standard deviation, Mean values of different subscript along the column are significantly different ($P<0.05$). (ND = Not detected)

CONCLUSION

The study showed there were significant differences in the physico-chemical and functional properties of cassava-African yam bean flour blends. The results indicated that the flour blends obtained were of good quality based on the recommended standards. The information obtained will help the researcher to know the desirable quality attributes of the flour blends require in cassava-African yam bean formulation.

REFERENCES

Abdelghafor, R. F., Mustafa, A. I., Ibrahim, A. M. H. and Krishnan, P. G. (2011). Quality of bread from composite flour of sorghum and hard white winter wheat. Advance Journal of Food Science and Technology, 3: 9-15.

Adebowale, A. R. A., Sanni, S. A. and Oladapo, F. O. 2008. Chemical, functional and sensory properties of instant yam-breadfruit flour. Nigerian Food Journal, 26: 2-12.

Adeola, A. A., Idowu, M. A., Adepoju, Y. D., Adesina, O. T., Oyewade, S., Olunlade, B. A. and Ohizua, E. I. R. 2017. Chemical, functional and sensory properties of water yam, pigeon pea and carrot pomace flour blends. Annals, Food Science and Technology, 18(1): 57-64.

Aniedu,C.andOmodamiro,R.M.2012.UseofNewlyBredβ-CaroteneCassavain Production of Value-Added Products: Implication for Food Security in Nigeria. Global Journal of Science Frontier

Research Agriculture and Veterinary Science,12(10):1.

AOAC,(2005). Official MethodsofAnalysis,18thEd. Association of Official Analytical Chemists. Washington D.C., USA.

Apea- Bah, F. B., Oduro, I., Ellis, W. O. and Safo- Katanka, O. (2011). Factor analysis and age at harvest effect on the quality of flour from four cassava varieties. World Journal of Dairy and Food Sciences, 6(1): 43-54.

Appiah, F., Asibuo, J.Y. and Kumah, P. (2011). Physical and functional properties of bean flours of three cowpea (Vigna unguiculata L. walp) varieties in Ghana. African Journal of Food Science, 5(2): 100-104.

Blessing, N., Ishola, A. and Chikwendu, O. (2013). Effect of blending on the Proximate, Pasting and Sensory Attributes of Cassava-AfricanyamBean Fufu Flour. International Journal of Scientific and Research Publication, 3(8): 1-7.

Chijioke, U., Ojimelukwe, P. C. and Akachukwu, D. (2016). Determination of physicochemical properties of cassava mosaic disease (Cmd) resistant varieties and their potentials for the manufacture of noodles. International Journal of Biological Sciences and Applications,3(1): 22-28.

Choy, A. L. (2011). Enhancing the quality of instant noodles. The impact of low protein wheat flour, ingredients and processing conditions. A PhD thesis submitted to School of Applied Sciences, Science, Engineering and Health Portfolio RMIT University, Malaysia. xx+184pp.

Dziedzoave, N. T., Abass, A. B., Amoa-Awua, W.K.A and Sablah, M. (2006). Quality management manual for production of high quality cassava flour. G.O. Adegoke and L. Brimer, Eds. International Institute of Tropical Agriculture (IITA): 12: 68.

Eggleston, G., Omoaka, P. E., and Ihedioha, D. O. (1992). Development andevaluation of products from cassava flour as new alternatives to wheatbreads. Journal of the Science of Food and Agriculture,59(3): 377-385.

Eriksson, E., Koch, K., Tortoe, C., Akonor, P.T. and Baidoo, E. (2014). Physicochemical, functional and pasting characteristics of three varieties of cassava in wheat composite flours. British Journal of Applied Science and Technology, 4(11): 1609-1621.

Eromosele, C. O., Arogundade, L.A., Eromosele, I. C. and Ademuyiwa,O. (2008). Extractibility of African yam bean (Sphenostylisstenocarpa) protein in acid, salt and alkaline aqueous media. Food Hydrocolloids,22: 1622-1628.

Hugo, L.F., Rooney, L. W. and Taylor, J. R. N. (2000). Malted sorghum as a functional ingredient in composite bread. Cereal Science,79(4):428-432.

Isah, S., Oshodi, A. A. and Atasie, V. N. (2015). Oxidation of acha (Digitaria exilis) starch using 3.5% active chlorine sodium hypochlorite. African Journal of Pure and Applied Chemistry. 9(4): 65-70.

Iwe, M. O., Agiriga,O. and Yildiz. (2016). Proximate, functional and pasting properties of FARO 44 rice, African yam bean and brown cowpea seeds composite flour. Cogent Food and Agriculture, 2(1): 1-10.

Kulkarni, K. D., Kulkarni, D. N. and Ingle, U. M. (1991). Sorghum malt-based weaning formulations preparations, functional properties and nutritive value. Food and Nutrition Bulletin,13(4): 322-327.

Mohana, K., Asna, U. and Prasad, N.N. (2007). Effect of storage on resistant starch and amylose content of cereal-pulse based ready-to-eat commercial products. Food Chemistry, 102: 1425-1430.

Muoki, P. N., Kock, L. H. and Emmambux, M. N. (2012). Effect of soy flour addition and heat-processing method on nutritional quality and consumer acceptability of cassava complementary porridges. Journal of Food Agriculture Science, 92: 1771-1779.

Nwosu, J. N., Ahaotu, I., Ayazie, C., Udeoozor, L. O. and Ahaotu, N. N., 2011. The proximate and functional properties of African yam bean (Sphenostylis stenocarpa) seeds as affected by processing. Nigerian Food Journal 29.2: 39-48.

Ohizua, E. R., Adeola, A. A., Idowu, M. A., Sobukola, O. P., Afolabi, T. A., Ishola, R. O., Ayansina, S. O., Oyekale, T. O. and Falomo, A. (2017). Nutrient composition, functional, and pasting properties of unripe cooking banana, pigeon pea, and sweetpotato flour blends. Food Science and Nutrition,5: 750-762.

Oluwamukomi, M. O., Oluwalana, I. B. and Akinbowale, O. F. (2011).Physicochemical and sensory properties of wheat-cassavacompositebiscuit enriched with soy flour. African Journal of Food Science,5(2):50-56.

Onwuka, G. I. (2005). Food analysis and Instrumentation; Theory and Practice. Lagos: Naphthali prints. Nigeria.

Sathe, S. K., Desphande, S. S. and Salunkhe, D. K. (1982). Functional properties of lupin seed (lupinus mutabilis) protein and protein concentrates. Journal of Food Science,47: 491-497.

Zvinavashe, E., Elbersen,H. W., Slingerland, M.,Kolijn, S. and Sanders, J. P. M. (2011). Cassava for food and energy: exploring potential benefits of processing of cassava into cassava flour and bioenergy at farmstead and community levels in rural Mozambique. Biofuels, Bioproducts and Biorefining,5(2): 151-164.