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EVALUATION OF THE CHEMICAL COMPOSITION OF FLOURS AND BLENDS MADE FROM AFRICAN YAM BEAN (*Sphenostylis stenocarpa*) AND CORN (*Zea mays*) SEEDS

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ABSTRACT
Background: Diabetes mellitus is one of the diet-related non-communicable diseases that can be efficiently managed through diet therapy. The recent upsurge in the prevalence of diabetes has increased the number of patients facing the health challenge with limited choice of healthy foods, and the need to develop more indigenous foods to manage the disease condition.
Objective: This experimental study evaluated the chemical composition of flours and blends made from African yam bean (AYB) and corn seeds designed to supply one-third (12.7g) of the daily dietary fibre requirement of a reference man.
Methodology: Whole seeds of coffee brown AYB and white corn were respectively roasted at 191^{0}C for 40 mins and oven-dried at 50^{0}C for 24 h. These were processed into flours and blends in the ratios of 100:0, 70:30, 50:50, 30:70, 0:100, with 0:100 traditional corn flour serving as control. All flours were formulated to supply 12.7g dietary fibre. The flours and blends were evaluated for chemical composition using standard procedure. Results were presented as means, and standard deviations. T-test statistic was used to compare the means, and significance was accepted at $p < 0.05$.
Result: AYB had a higher content of energy (404.79, 395.60 kcal), protein (24.10, 6.05 mg), fat (5.31, 3.80 mg), ash (3.19, 1.50 mg), crude fiber (4.86, 2.77 mg), calcium (45.11, 3.10 mg), iron (4.86, 2.77 mg), thiamin (0.94, 0.86 mg), riboflavin (0.03, 0.01 mg) and vitamin C (11.40, 6.81 mg) but lower magnesium (40.50, 42.93 mg), sodium (2.35, 5.44 mg), potassium (166.78, 180.43 mg), beta-carotene (648.67, 813.67 µg) and niacin (2.27, 2.51 mg) than corn respectively. AYB had more phytochemicals, anti-nutrients, amylose, amylose/amylopectin ratio, and all dietary fibre variables but lower starch and amylopectin than corn. The protein content of the blends increased (6.82 to 12.74 mg) with an increased proportion of AYB, carbohydrate increased (34.42 to 95.08 mg) with greater proportions of corn. The flour blends had more fat, ash, crude fibre, minerals, vitamins, phytochemical, anti-nutrients, and amylose/amylopectin ratio but lower starch content than the traditional corn flour.
Conclusion: AYB and corn flour blends can provide more nutrients for the development of new foods required in diabetes management.

Keywords: *Chemical composition; African yam bean; corn; flours blends.*

INTRODUCTION

Diets in developing countries are originally based on cereals or root staples. In Nigeria for instance, these low nutrient density foods had constituted the main meals for the masses and has resulted in malnutrition states in both children and adults [1]. The malnutrition states are compounded by the change in global food consumption trends characterized by shifts in dietary pattern from the consumption of local staples to non-indigenous diets rich in highly processed foods and oils. The health consequences increased the number of patients with foods choices that lack variety due to slow development of new products from indigenous foods [2]. Many indigenous foods (African yam bean, pigeon pea, three-leaf yam, bambara groundnut and so on.) with desirable qualities abound. African Yam Bean (AYB) is a crop with seeds, tuber and leaves that are nutritionally rich for human consumption [3]. This economic crop is facing extinction due to poor consumption attributed to nutrition transition. Avenue of diversifying the utilization of AYB will not only halt the extinction of the crop but will add nutritional value and variety to family menu. Conversely, corn is a widely consumed cereal, and thus a good vehicle to reintroduce AYB into the consumption circle. Recently, the importance of dietary fibre in health has been emphasized [4]. Although these two crops are known to contain dietary fibre, there is dearth of data on their dietary fibre profile. There is need to develop flour blends of known chemical compositions to serve as a base for the development of new food products to help diet experts and consumers make informed food choices.

MATERIALS AND METHODS

Collection of samples

Coffee brown African yam bean (*Sphenostylis stenocarpa*) and white corn (*Zea mays*) seeds were purchased from Ndioro (a local) market in Abia State, Nigeria. The seeds were identified in the department of Crop Science, Michael Okpara University of Agriculture, Umudike in Abia State.

Preparation of samples

The seeds were sorted to obtain wholesome seeds, individually washed with tap water and drained on a colander. The AYB seeds were roasted in a sauce pan over a cooking burner at 191^0C (medium mark as indicated by the burner manufacturer) for 40 minutes and milled into flour using Saint Donkey Powder Crusher (Leshan Dongchuan Machinery Co Ltd, China) with 5mm sieve. The flour was packed into labeled air-tight polyethylene bags. The corn seeds were oven-dried to a constant weight at a temperature of 50ºC for 24 h using Uniscope Laboratory Oven (SM9023 Surgifriend Medigals, England), milled into fine flour using Saint Donkey Powder Crusher with in-built 5mm sieve and packed into labeled air-tight polyethylene bags.

Blending of flour

The flours were coded as $S_{100,}$ and Z_{100}, where S = Sphenostylis, and Z = Zea, and formulated into blends in the ratio of 100, 70:30, 50:50, 30:70, 100 to supply 1/3 of the daily dietary fibre requirement (38g/day) of a reference man weighing 70kg [5]. The blends $S_{100,}$ $S_{70}Z_{30,}$ S_{50} $Z_{50,}$ $S_{30}Z_{70,}$ Z_{100} (Z_{100} - whole-milled white corn) and Zc_{100} (Zc_{100} - white corn milled and sieved to remove all germs and brans as in traditional gruel making was used as control) were mixed thoroughly in a Kenwood food processor at full speed for 5mins and placed in air-tight Ziploc bags, packed in polyethylene bags and stored in a deep freezer (-10ºC) until use.

Analytical methods

Determination of chemical composition

The proximate composition, minerals (calcium, iron, magnesium, potassium and sodium), vitamins (beta-carotene, thiamin, riboflavin, niacin and vitamin C), and phytochemicals (phenol, flavonoids and saponins) of AYB and corn seed flours were determined using the standard procedures of AOAC [6], Total carbohydrate was obtained by difference as: 100 - %(moisture + ash + protein + fat + crude fiber) and energy value was calculated using the Atwater factors (multiplying protein, carbohydrate and fat contents by 4, 4, and 9 Kcals, respectively and taking the sum). Phytic acid was determined as already described [7], total tannins by ISO 964, Trypsin Inhibitor by AOCS Ba 12-75, fiber, dietary complete by AOAC 991.43, starch according to NEN-EN-ISO 15914 [8]; total dietary fiber by HPLC as described by AOAC 2009.01 and AOAC 2011.25; amylopectin and amylose / amylopectin ratio were determined in accordance with AOAC 2011.25. The chemical composition and the dietary fibre profile of the flour blends were obtained from the base flour (*Sphenostylis stenocarpa* and *Zea mays*) by material balancing. Results were presented as calculated.

Statistical analysis

Data generated were analyzed using IBM SPSS Statistics version 21. Results were presented as means, and standard deviations. T-test statistic was used to compare the means, and significance was accepted at $p < 0.05$.

RESULTS

Table 1 shows the energy, proximate, and mineral compositions of *Sphenostylis stenocarpa* and *Zea mays* seed flours. The flours contained energy(404.79, 395.60 Kcal), protein (24.10, 6.05%), fat (5.31, 3.80%), ash (3.19, 1.50%) , moisture (2.28, 4.35%) and crude fiber (4.86, 2.77%) respectively. *Sphenostylis stenocarpa* flour minerals values were significantly ($P < 0.05$) higher in calcium (45.11 mg), and iron (4.68 mg) but lower in magnesium (40.50 mg), sodium (2.35 mg) and potassium (166.78 mg) than *Zea mays* flour. The difference between the proximate contents of AYB and Corn flours was significant in moisture, protein, ash and carbohydrate at p= <0.05.

Table 1: Energy, proximate and mineral composition of African Yam bean and corn seed flours (mg/100g dry matter).

Variables	Sub-variables	Sample code	Mean	Mean Difference	Std. Deviation	t-test (p-values)	Decision	Remark
Energy Kcal	Energy Kcal	S_{100}	404.79	0.693	0.050	0.075	Not-Sig	-
		Z_{100}	395.60		16.043	(0.944)		
Proximate Composition	Mc (%)	S_{100}	2.28	-2.067	0.006	-438.406	Sig	Z_{100}
		Z_{100}	4.35		0.006	**(0.000)**		
	Prot (%)	S_{100}	24.10	18.047	0.087	117.446	Sig	S_{100}
		Z_{100}	6.05		0.252	**(0.000)**		
	Fat (%)	S_{100}	5.31	1.507	0.012	1.674	Not-Sig	-
		Z_{100}	3.80		1.558	(0.169)		
	Ash (%)	S_{100}	3.19	1.693	0.006	5.227	Sig	S_{100}
		Z_{100}	1.50		0.561	**(0.006)**		
	Crude Fiber (%)	S_{100}	4.86	2.083	0.006	2.308	Not-Sig	-
		Z_{100}	2.77		1.563	(0.082)		
	CHO (%)	S_{100}	65.15	-21.263	0.072	-47.430	Sig	S_{100}
		Z_{100}	84.30		0.773	**(0.000)**		
Mineral Composition	Ca (mg)	S_{100}	45.11	42.010	0.040	210.342	Sig	S_{100}
		Z_{100}	3.10		0.344	**(0.000)**		
	Fe (mg)	S_{100}	4.68	4.300	1.356	5.493	Sig	S_{100}
		Z_{100}	0.38		0.006	**(0.005)**		
	Mg (mg)	S_{100}	40.50	-2.427	0.006	-115.107	Sig	Z_{100}
		Z_{100}	42.93		0.036	**(0.000)**		
	Na (mg)	S_{100}	2.35	-3.084	0.172	-7.015	Sig	Z_{100}
		Z_{100}	5.44		0.742	**(0.002)**		
	K (mg)	S_{100}	166.78	-13.650	0.046	-178.381	Sig	Z_{100}
		Z_{100}	180.43		0.124	**(0.000)**		

Values are mean, mean difference,+/-SD, t-test of triplicate determinations; p-value is significantly (sig) different at $\alpha = 0.05$; 1 kcal equals 4.286 kJ. ***Sphenostylis stenocarpa*** = $S_{100;}$ ***Zea mays***= $Z_{100;}$ Mc- moisture content, prot- protein, CHO- carbohydrate, Ca- calcium, Fe- iron, Mg- magnesium, Na- sodium, K- potassium, Remarks - flours with content of the indicated variable

Table 2 presents the vitamin, anti-nutrient and phytochemical compositions of *Sphenostylis stenocarpa* and *Zea mays* seed flours. The vitamin composition of the flours were beta-carotene (648.67, 813.67 µg), thiamin (0.95, 0.86 mg), riboflavin (0.03, 0.01 mg), niacin (2.27, 2.51 mg), and vitamin C (11.40, 6.81 mg) respectively. The phytochemical composition were Phenol (0.26, 0.11 mg), flavonoids (0.47, 0.19 mg), saponins (0.62, 0.19 mg), and the anti-nutrient composition were phytates (0.66, 0.57 mg), tannins(6.25, <0.05 mg) and trypsin-inhibitor(1100.00, <1100.00 TIU/mg) respectively.

Table2: Vitamin, anti-nutrient and phytochemical compositions of African Yam bean (*Sphenostylis stenocarpa*) and corn (*Zea mays*) seeds (mg/100g dry matter).

Variables	Sub-variables	Sample code	Mean	Mean Difference	Std. Deviation	t-test (p-values)	Decision	Remark
Vitamin Compositions	B-Caro (µg)	S_{100}	648.67	-1.650	0.029	-57.543	Sig	Z_{100}
		Z_{100}	813.67		0.040	**(0.000)**		
	B1 (mg)	S_{100}	0.9470	0.085	0.009	15.059	Sig	S_{100}
		Z_{100}	0.8617		0.005	**(0.000)**		
	B2 (mg)	S_{100}	0.027	0.016	0.001	16.971	Sig	S_{100}
		Z_{100}	0.011		0.001	**(0.000)**		
	B3 (mg)	S_{100}	2.273	-0.237	0.040	-9.323	Sig	S_{100}
		Z_{100}	2.510		0.017	**(0.001)**		
	Vitamin C (mg)	S_{100}	11.403	4.590	0.041	139.098	Sig	S_{100}
		Z_{100}	6.813		0.041	**(0.000)**		
Anti-nutrient Composition	Phenol (mg)	S_{100}	0.260	0.153	0.020	11.500	Sig	S_{100}
		Z_{100}	0.107		0.011	**(0.000)**		
	Flavonoids (mg)	S_{100}	0.470	0.280	0.017	28.000	Sig	S_{100}
		Z_{100}	0.190		0.000	**(0.000)**		
	Saponin(mg)	S_{100}	0.620	0.430	0.017	37.239	Sig	S_{100}
		Z_{100}	0.190		0.010	**(0.000)**		
	Phytate(mg)	S_{100}	0.663	0.097	0.006	20.506	Sig	S_{100}
		Z_{100}	0.567		0.006	**(0.000)**		
	Tannin(mg)	S_{100}	6.2500	6.20	0.000			
		Z_{100}	<0.0500		0.000	NA		NA
	Trypsin inhibitor (TIU/mg)	S_{100}	1100.00	<0.00	0.000	NA		NA
		Z_{100}	<1100.00		0.000			

Values are mean, mean difference,+/-SD, t-test of triplicate determinations; p-value is significantly (sig) different at $\alpha = 0.05$; (NA= Not applicable; ***Sphenostylis stenocarpa*** **=** $S_{100;}$ ***Zea mays*= Z**$_{100,}$ B-caro-betacarotene, B1-thiamin, B2-niacin, B3-ribflavin, Remarks -flour blend with significantly higher variable value)

The starch, amylose, amylopectin and dietary fiber profile of AYB (*Sphenostylis stenocarpa*) and corn (*Zea mays*) flours is shown in Table 3. The flours had starch(44.00, 65.00 mg), amylose(31.80, 29.20 mg), amylopectin(68.00, 71.00 mg) insoluble dietary fibre(16.53, 9.53%), soluble dietary fibre (7.49, 1.73%), total dietary fibre (24.02, 11.26%), high molecular weight soluble dietary fibre (1.96, 0.58%) and low molecular weight dietary fibre (5.53, 1.15%) respectively.

Table 3: Starch, amylose, amylopectin and dietary fibre profile of African yam bean (*Sphenostylis stenocarpa*) and corn (*Zea mays*) flours

Variables	S_{100}	Z_{100}
Starch (mg/g)	44.00	65.00
Amylose (mg/100g)	31.80	29.20
Amylopectin (mg/100g)	68.00	71.00
Amylose/amylopectin	0.47	0.41
Fiber dietary total (%)	13.50	9.4
Fiber dietary insoluble (%)	12.10	9.2
Fiber dietary soluble (%)	1.40	0.2
Insoluble dietary fiber (%)	16.53	9.53
*High molecular weight SDF (%)	1.96	0.58
*Low molecular weight SDF (%)	5.53	1.15
**Soluble dietary fiber = (HMWSDF + LMWSDF) (%)	7.49	1.73
**Total dietary fiber = (IDF + HMWSDF + LMWSDF) (%)	24.02	11.26

***Sphenostylis stenocarpa* =** S_{100}; ***Zea mays*= Z_{100}**, SDF- soluble dietary fiber, HMWSDF- high molecular weight soluble dietary fiber, LMWSDF- low molecular weight soluble dietary fiber, TDF- total dietary fiber.

Table 4 shows the energy, proximate and mineral compositions of *Sphenostylis stenocarpa* and *Zea mays* flour blends. The moisture content ranges (1.21 to 4.91%) of the blends were below the traditional corn flour (control 8.33%). The control had the least crude protein content (5.71%). The fat content of the flour blends increased as the proportion of *Sphenostylis stenocarpa* decreased. The ash contents of the flour blends were approximately the same (1.69%) except the control which had a lower value (0.32%). The crude fibre and carbohydrate contents of the flour blends ranged from 2.57 in S_{100} to 3.13% in Z_{100} and 34.44 in S_{100} to 95.08% in Z_{100} respectively. The available carbohydrate (ACHO) increased as the proportion of S_{100} decreased. Sample $S_{30}Z_{70}$ had the highest calcium (Ca) content (96.20 mg), S_{100} though lower in weight (52.87g) than the other blends, had a high iron content (Fe 2.41mg) compared with Z_{100} (0.43 mg). Z_{100} had the highest magnesium (Mg, 48.42 mg) and the sodium (Na) content range of the flour blends (1.24 to 6.14 mg) were lower than the control Zc_{100} (13.62 mg). S_{100} had the least potassium value (61.74 mg) while Z_{100} had the highest content (203.51 mg).

Table 4: Energy, proximate and mineral compositions of African yam bean *(Sphenostylis stenocarpa)* and corn (*Zea mays*) flour blends

Variables	S_{100} (wt - 52.87 g)	$S_{70}Z_{30}$ (wt- 70.85 g)	$S_{50}Z_{50}$ (wt- 82.84 g)	$S_{30}Z_{70}$ (wt- 94.81 g)	Z_{100} (wt- 112.79 g)	Zc_{100} (wt- 104.18 g)
Energy (Kcal)	214.01	283.68	330.15	376.53	446.20	379.40
Mc (%)	1.21	2.31	3.05	3.80	4.91	8.33
Prot (%)	12.74	10.97	9.78	8.60	6.82	5.71
Fat (%)	2.81	3.26	3.54	3.84	4.29	2.80
Ash (%)	1.69	1.69	1.69	1.70	1.69	0.32
Crude Fiber (%)	2.57	2.74	2.85	2.96	3.13	2.75
CHO (%)	34.42	52.62	64.78	76.87	95.08	82.84
ACHO (%)	21.72	39.92	52.08	64.17	82.38	70.14*
Ca (mg)	23.85	54.87	75.54	96.20	3.51	54.81
Fe (mg)	2.47	2.16	1.45	0.51	0.43	2.57
Mg (mg)	21.42	29.52	34.92	40.31	48.42	97.94
Na (mg)	1.24	2.71	3.69	4.66	6.14	39.62
K (mg)	61.74	122.79	145.86	168.90	203.51	324.78

S_{100} = *Sphenostylis stenocarpa;* $S_{70}Z_{30}$= *Sphenostylis stenocarpa* $_{70}$/*Zea may*$_{30}$; $S_{50}Z_{50}$ = *Sphenostylis stenocarpa* $_{50}$/ *Zea mays*$_{50}$; $S_{30}Z_{70}$ = *Sphenostylis stenocarpa* $_{30}$/*Zea mays*$_{70}$; Z_{100} = *Zea mays*$_{100}$, Zc_{100} = *Zea mays* control; Mc- moisture content, Prot- protein, CHO- carbohydrate, ACHO- available carbohydrate, Ca- calcium, Fe- iron, Mg- magnesium, Na- sodium, K- potassium, wt- weight of flour blend required to contribute 1/3 of daily dietary fiber requirement[12.7g] of a reference adult man; *ACHO of Zc100 calculated from FAO, Dietary fiber value (12.19g) of refined white corn flour (1992).

Table 5 presents the vitamin, phytochemical and anti-nutrient compositions of *Sphenostylis stenocarpa* and *Zea mays* flour blends. The vitamin contents of S_{100}, $S_{70}Z_{30}$, S_{50} Z_{50}, $S_{30}Z_{70}$, Z_{100} and Zc_{100} were 342.95, 515.42, 630.42, 745.27, 917.74 µg for beta-carotene; 0.50, 0.64, 0.74, 0.83, 0.97 mg for thiamin; 0.014, 0.014, 0.013, 0.013, 0.012, 0.008 mg for riboflavin; 1.20, 1.69, 2.02, 2.34, 2.83, 0.30 mg for niacin and 6.03, 6.53, 6.86, 7.19, 7.68, 4.28 mg for vitamin C respectively. The phytochemical contents of S_{100}, $S_{70}Z_{30}$, S_{50} Z_{50}, $S_{30}Z_{70}$, Z_{100} and Zc_{100} were 0.14, 0.13, 0.13, 0.13, 0.12 mg for phenol; 0.25, 0.24, 0.23, 0.23, 0.21 mg for saponin; and 0.33, 0.29, 0.27, 0.25, 0.21 mg for flavonoids respectively; while the anti-nutrients contents of the blends were 0.35, 0.43, 0.50, 0.56, 0.64 mg for phytate; 3.30, 2.46, 1.90, 1.34, 0.50 mg for tannin; and 581.57, 745.51, 854.74, 963.96, 1127.90 TIU/mg for trypsin inhibitor respectively.

Table 5 Vitamin, phytochemical and anti-nutrient composition of African yam bean *(Sphenostylis stenocarpa)* and corn (*Zea mays*) flours bends

Variables	S_{100} (wt - 52.87 g)	$S_{70}Z_{30}$ (wt - 70.85 g)	S_{50} Z_{50} (wt - 82.84 g)	$S_{30}Z_{70}$ (w t- 94.81 g)	Z_{100} (wt - 112.79g)	Zc_{100} (wt - 104.18 g)
B-Caro (µg)	342.95	515.42	630.42	745.27	917.74	1.00
B_1(mg)	0.50	0.64	0.74	0.83	0.97	0.33
B_2 (mg)	0.014	0.014	0.013	0.013	0.012	0.008
B_3 (mg)	1.20	1.69	2.02	2.34	2.83	0.30
Vit C (mg)	6.03	6.53	6.86	7.19	7.68	4.28
Phenol (mg)	0.14	0.13	0.13	0.13	0.12	0.07
Flavonoid (mg)	0.25	0.24	0.23	0.23	0.21	0.18
Saponin (mg)	0.33	0.29	0.27	0.25	0.21	0.05
Phytate (mg)	0.35	0.43	0.50	0.56	0.64	0.01
Tannin (mg)	3.30	2.46	1.90	1.34	0.50	0.05
Trypsin inhibitor (TIU/mg)	581.57	745.51	854.74	963.96	1127.90	NA

B-caro = beta-carotene; S_{100} = *Sphenostylis stenocarpa;* $S_{70}Z_{30}$= *Sphenostylis stenocarpa* $_{70}$/*Zea may*$_{30}$; $S_{50}Z_{50}$ = *Sphenostylis stenocarpa* $_{50}$/ *Zea mays*$_{50}$; $S_{30}Z_{70}$ = *Sphenostylis stenocarpa* $_{30}$/*Zea mays*$_{70}$; Z_{100} = *Zea mays*$_{100}$, Zc_{100} = *Zea mays* control; NA = not available; B-caro- betacarotene, B1- thiamin, B2- niacin, B3- ribflavin, Vit C - vitamin C.; wt- weight of flour blend required to contribute 1/3 of daily dietary fiber requirement[12.7g] of a reference adult man.

Table 6 shows the starch, amylose, amylopectin and dietary fibre profile of *Sphenostylis stenocarpa* and *Zea mays* flour blends. The starch composition of the blends (S_{100}, $S_{70}Z_{30}$, S_{50} Z_{50}, $S_{30}Z_{70}$, and Z_{100}) were 23.95, 38.28, 48.29, 58.30, 73.31 mg; amylose were 16.81, 21.65, 24.88, 28.09, 32.94 mg; amylopectin were 35.95, 49.20, 58.02, 66.84, 80.88 mg; insoluble dietary fiber were 8.74, 9.35, 9.74, 10.14, 10.75% , soluble dietary fiber were 3.96, 3.37, 2.96, 2.56, 1.95 %, and total dietary fiber was 12.70% (for all blends) respectively. The flour blends also contained 1.04, 0.93, 0.85, 0.77, 0.65% high molecular weight soluble dietary fiber (HMWSDF) and 2.29, 2.44, 2.11, 1.80, 1.30% lower molecular weight soluble dietary fiber (LMWSDF) respectively.

Table 6: Starch, Amylose, Amylopectin and Dietary Fiber Profile of African Yam Bean *(Sphenostylis stenocarpa)* and Corn (*Zea mays*) Flour Blends

Variables	S_{100} (wt - 52.87 g)	$S_{70}Z_{30}$ (wt - 70.85 g)	S_{50} Z_{50} (wt - 82.84 g)	$S_{30}Z_{70}$ (wt - 94.81 g)	Z_{100} (wt - 112.79 g)	Zc_{100} (wt - 104.18 g)
Starch (mg/g)	23.95	38.28	48.29	58.30	73.31	87.60*
Amylose (mg/100g)	16.81	21.65	24.88	28.09	32.94	28.00*
Amylopectin (mg/100g)	35.95	49.20	58.02	66.84	80.08	72.00*
Amylose/amylopectin	0.47	0.44	0.43	0.42	0.41	0.39
FDT (%)	7.14	8.18	8.87	9.56	10.60	NA
FDI (%)	6.40	7.59	8.39	9.18	10.38	NA
FDS (%)	0.74	0.59	0.48	0.38	0.22	NA
IDF (%)	8.74	9.35	9.74	10.14	10.75	10.94*
SDF = (HMWSDF + LMWSDF) (%)	3.96	3.37	2.96	2.56	1.95	1.25*
TDF (%)	12.70	12.71	12.70	12.70	12.70	12.19*
HMWSDF (%)	1.04	0.93	0.85	0.77	0.65	NA
LMWSDF (%)	2.29	2.44	2.11	1.80	1.30	NA

S_{100} = *Sphenostylis stenocarpa;* $S_{70}Z_{30}$= *Sphenostylis stenocarpa* $_{70}$/*Zea may*$_{30}$; $S_{50}Z_{50}$ = *Sphenostylis stenocarpa* $_{50}$/ *Zea mays*$_{50}$; $S_{30}Z_{70}$ = *Sphenostylis stenocarpa* $_{30}$/*Zea mays*$_{70}$; Z_{100} = *Zea mays*$_{100,}$ Zc_{100} = *Zea mays* control. FDT - fiber dietary total, FDI - fiber dietary insoluble, FDS - fiber dietary soluble, IDF - insoluble dietary fiber, SDF - soluble dietary fiber, TDF - total dietary fiber, HMWSDF - high molecular weight soluble dietary fiber, LMWSDF - low molecular weight soluble dietary fiber* - source FAO (1992), NA = not available.

DISCUSSION

As expected, the proximate compositions of *Sphenostylis stenocarpa* (AYB) and *Zea mays* (Corn) flour varied considerably. AYB had slightly higher energy content than corn which is higher than the 365kcal reported by USDA [9]. This could be because of different processing methods - (roasting and drying respectively) used. The energy content of the base flours will contribute to daily requirement. Similarly, the lower moisture contents of AYB and corn flour compared to the 10.37% reported by USDA [9] could be due to the roasting and oven-drying. Griffith & Castell-Perez [10] reported that roasting can reduce moisture, concentrate larger solids by weight, and increase viscosity. The difference in the protein content of AYB flour from that reported by other authors could be attributed to genetic background, variety, environmental conditions, plant age, processing and geographic location [11]. Since legumes and cereal proteins were considered biologically less valuable due to insufficient composition of some amino acids, the combination of these flours will complement each other, and yield a good quality protein. The higher fat content of AYB flour was in line with USDA [9] report that legumes had high fat content and will require good storage condition. AYB flour had crude fibre content lower than the range (15 to 32%) reported by Tosh & Yada [12] for legumes. High carbohydrate content of Corn flour was similar to almost all cereal grains.

The mineral contents was significantly higher for AYB flour than corn flour in calcium, and iron but lower in magnesium, sodium, and potassium at $p < 0.05$. The lower content of magnesium, sodium and potassium of AYB flour could be attributed to high heat during roasting as underscored by Malik et al. [13]. AYB flour had more calcium and potassium but lower iron content than was reported (43.6%, 116.4%, 12.6%) by Kine, Eka & Aremu [14]. The low sodium content of AYB flour is a plus to reduced/low salt diets. High potassium and calcium with low sodium of AYB flour is beneficial to hypertensive patients as well as diabetics since these diseases are comorbidities. Diabetes and hypertension have similar risk factors, hypertension occur more in diabetics with majority of hypertensive patients presenting insulin resistance [15].

Beta-carotene content of corn flour was contrary to report that white corn is devoid of carotenoids [9]. AYB flour had a higher thiamin (B_1) and riboflavin content compared to corn. The niacin content of these flours although low will contribute to dietary intake. This study AYB and corn flour had lower phytochemicals and anti-nutrients contents compared to cowpea (phytic acid – 836mg; phenol 517mg) [16]. Low anti-nutrients value of corn flour was because white corn was used, which unlike coloured corn have little or no anti-nutritive factors [17]. The variations in the phytate contents of the base flours under study with that of other authors was attributed to growing conditions, type of fertilizers used, harvesting, processing and testing methods, and age of food [18]. Phytate is the storage form of phosphorous in all grains and oil seeds [9], so, the phytic acid contents reported in this study is an indication of the phosphorus content of the flours. The anti-nutrient effect of phytic acid on mineral absorption occurs only at 10 fold higher levels; lower levels are more beneficial [18]. AYB low content of trypsin inhibitor could be because of roasting as explained [13].

The starch content, type and quality of a food is a determining factor in the glycemic index (GI) of the food since it is completely digested into sugar [19]. The lower value of AYB starch thus indicates a lower glycemic index than corn. AYB had more amylose (the un-branched and insoluble component of starch) than corn indicating that it will have reduced tendencies to raise blood glucose since sugar units will be split slowly from its lone end as previously explained [20]. This high amylose content of AYB is in line with the work of McCrory et al. [21] that legumes starches have higher amylose compared with cereal starches, because of their high capacity for retrogradation, resulting in reduced digestion rate and lower GI. Since AYB had more resistant starches than corn, its effects on postprandial rise in blood glucose will be reduced. The implied lower glycemic response of AYB (not determined in this study), could also be attributed to roasting that formed amylose-lipid complexes that are thermally stable and highly resistant to enzymatic digestion as earlier explained [22].

Corn had higher amylopectin, the branched and soluble component of starch than AYB. This confirmed that corn will raise postprandial glucose level more than AYB as more sugar units will be split off simultaneously from amylopectin with its numerous ends. Higher amylose/amylopectin ratio implied low GI. Both flours carried a higher amylose/amylopectin ratio than cocoyam (0.12) and yam (0.10-0.14) [19]. This indicated that the flours had low GI which is desired in healthy meal. AYB had higher values than corn in all dietary fibre variables. AYB had higher soluble dietary fibre (SDF) than wheat bran (4.6%) [22], dried raw white beans (4.3%), oat fibre (1.5%) and barley bran (3.0%); but lower than rice bran (4.7%), apple fibre (13.9%) and tomato fibre (8.3%) [23]; corn had slightly higher SDF than oat fibre. AYB and corn flours had appreciable quantity of SDF in comparison with other desirable products. The viscosity and fermentability of SDF carry many health benefits [24]. The SDF components of the flours studied will be a plus to overweight and obese patients as they will have more meals with extended stomach emptying time, causing greater feelings of fullness and fewer cravings as well.

AYB had much lower IDF than wheat bran (49.6%) [25], oat fibre (73.6%), rice bran (46.7%), apple fibre (48.7%), tomato fibre (57.6) and barley bran (67%) but higher than dried white beans (13.4%) [24]. AYB TDF content although much lower than that of wheat bran (54.2%) [24], oat fibre (75.1%), rice bran (51.4%), apple fibre (62.6%), tomato fibre (65.9%) and barley bran (70%) was higher than dried white beans (17.7%) [24]. The TDF of the flours will contribute to weight loss. The HMWSDF and LMWSDF content of AYB was significantly more than that of corn. The molecular weight or chain length of fibre is directly related to its viscosity, higher weights implied increased viscosity [26]. Higher content of HMWSDF in AYB means increased ability to reduce both glucose and cholesterol levels in the blood as these functions had been linked to its high molecular weight [27]. The Low HMWSDF of corn than AYB implied that corn will not meet the criteria of bakery quality, so it can be used only as an additive to other flour for bread making.

The low moisture range of the flour blends was a plus to their storage stability as it was reported that moisture contents above 14% could affect the storage stability of products [28]. The decrease in moisture content resulted in increased protein concentration and is in consonance with Agrahar-Murugkar & Jha, [29] report that decrease in moisture leads to increase in protein concentration. The flour blends had more crude protein content than the traditional corn flour (control - 5.71%). This is similar to the report of Okoye et al. [30] since they contained both the germ and bran which had their shares of protein. These flour blends with considerable protein content compared to traditional flour will be appreciated as animal proteins are costly and inaccessible to most people in developing countries. A similar study reported decreased fat as the proportion of AYB increased [30]. The increase may be explained by the combined effect from corn and the different quantity of the flour blends required for the 1/3 of adult daily fibre recommendation. The flour blends had higher ash content than the traditional corn flour. Ash content provided a quantitative estimation of the minerals available in a food [31], the flour yield and milling functionality [32], and the color [33].

Lower crude fibre content of the flour blends could be due to the quantity required to obtain the desired dietary fibre content. The increased carbohydrate content of the flour blends in all levels of substitutions with corn was due to the replacement of AYB with corn flour which had more carbohydrate (addition effect). Flour blends with higher available carbohydrate (ACHO) will impact more on blood sugar level than those with lower ACHO. Although the flour blends had lower magnesium (Mg), sodium (Na) and potassium content (attributed to the low quantity of the flour blends required to obtain 1/3 of the IOM [5] RDI of dietary fibre for adults) than the control, they were superior to the control in all minerals especially calcium and iron.

The flour blends had more beta-carotene contents than the control as expected since white corn had little or no carotenoid content [9]. The vitamin B_1, B_2, B_3 and vitamin C contents of the flour blends were more than the traditional corn flour. The blends had higher phenol value than the traditional corn flour (control), as well as rice, oat, and wheat flour [34] because they were constituted from whole grains. The phenol value of the flour blends although very low will contribute to health. The lower anti-nutrient composition of these flour blends will be beneficial to health [14].

The control had more starch content than the flour blends because dehulling, milling, and size of mesh improved the starch content of grains and its digestibility. The control had more amylopectin than the blends and will thus raise post-prandial glucose level more than the blends. The blends had higher amylose/amylopectin ratio indicating lower glycemic index than the control (19). Although all blends have good combination of nutrients, and dietary fiber content (as designed by the study), $S_{70}Z_{30}$ could be preferred as it contained moderate combination of nutrients (available carbohydrate, sodium, potassium, amylose/amylopectin ratio and so on as indicated in the tables) that are of importance in diabetes management

CONCLUSION

The study shows that AYB and corn flour blends have appreciable dietary fibre profile, lower glycemic index as indicated by their high amylose/amyopectin ratio as well as the potential to produce nutrient dense foods needed for good health. A steady consumption of these nutrient-rich flour blends will also introduce meal variety and help to reduce hunger.

REFERENCES

1. Maziya-Dixon, B., Akinyele, I. O., Oguntona, E. B., Nokoe, S., Sanusi, R. A., & Harris, E. 2004. Nigerian Food Consumption and Nutrition Survey 2001–2003, Summary. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria.

2. Wagas, S., Tahir, A., Nadeem, S.B. & Mohd, R.A. (2017). Effect of diet on type 2 diabetes mellitus: A review. *International Journal of Health Sciences,* 11(2), 65 - 71.

3. Henry-Unaeze, H.N. (2018). Chemical composition, organoleptic and storage attributes of African yam bean and corn flour blends; nutritional status and glycemic response of diabetic adults fed the blends. *Ph.D Thesis of the Department of Nutrition and Dietetics, Univeristy of Nigeria,* Nigeria.

4. British Nutrition Foundation (BNF, 2018) Dietary Fibre. BNF London. https://www.nutrition.org.uk/healthyliving/basics/fibre.html

5. Institute of Medicine (IOM, 2002). *Dietary reference intakes for energy, carbohydrate, Fibre, fat, fatty acids, cholesterol, protein and amino Acids.* Food and Nutrition Board, Institute of Medicine (Chap.6 & 7). Washington DC: National Academy Press.

6. Association of Official Analytical Chemists (AOAC, 2009) Official methods of analysis (18^{th} ed. Revision 3), Washington DC: Association of Official Analytical Chemists International

7. Ellis, R., Morris, E.R. & Philpot, C. (1977). Quantitative determination of phytate in the presence of high inorganic phosphate. *Analytical Biochemistry,* 77, 536-539.

8. European Committee for Standardization ISO15914 (2004). Animal feeding stuffs – enzymatic determination of total starch content. *International Organization for Standard*, 1, 1-12

9. United States Department of Agriculture (USDA 2008) "*Nutrient Data Laboratory*" United States Department of Agriculture http://www.ndl.usda.gov/fnic/foodcomp.com 2009/08/Data/SR18/Sc/8.html.

10. Griffith, L.D. & Castel-Perez, M.E.(1998). The impact of blends versus processing method on the nutritive quality of weaning foods made from select cereals and legumes. *Cereals Chemistry*, 75 (1), 105- 112.

11. CIMMYY, IITA (2010). Maize-Gloal alliance for improving food security and the livelihoods of the resource-poor in the developing world. Draft proposal submitted by CIMMYT and IITA to the CGIAR Comortium Board. El Batan, Mexico, p 91.

12. Tosh, S.M., & Yada, S. (2010). Dietary fibres in pulse seeds and fractions: Characterization, functional attributes, and applications. *Food Research International*, 43, 450–460.

13. Malik, M., Singh, U. & Dahiya, S. (2002). Nutrient composition of pearl millet as influenced by genotypes and cooking methods. *Journal of Food Science and Technology*, 39, 463-468.

14. Kine, B.B., Eka, O.U., Aremu, C.Y., & Ifon, E.T. (1991). Chemical evaluation of the nutritive value of African yam bean (Sphenostylis stenocarpa). *Tropical Journal of Applied Science*, 1, 99-102.

15. Petrie, J.R., Gzik, T.J., & Touyz, R.M. (2018). Diabetes, hypertension and cardiovascular diseases: Clinical insight and vascular mechanisms. *The Canadian Journal of Cardiology,* 34 (5), 575 - 584.

16. Sinha, R. & Kawatra, A. (2003). Effect of processing on phytic acid and polyphenol contents of cowpea (*Vigna unguiculata* [L] Walp). *Plant Foods for Human Nutrition*, 58, 1-8.

17. Sheng, S., Li, T., & Liu, R. (2018). Corn phytochemicals and the benefits. *Food Science and Human Wellness,* 7 (3), 185 - 195.

18. Abdoulaye, C., Brou, K. & Jie, C. (2011). Phytic Acid in Cereal Grains: Structure, Healthy or Harmful ways to reduce phytic acid in cereal grains and their effects on nutritional quality. *American Journal of Plant Nutrition and Fertilization Technology,* 1(1), 1 – 22.

19. Oboh, G. (2015). Effect of processing on glycemic indicies, amylose and amylopectin contents of some tropical tubers in Nigeria. *Proceedings of the Nutrition Society of Nigeria, 45, 39 -48.*

20. Khattak, W.A., Maazhar, U.I., & Joong, K.P. (2012). Prospects of reuseable endogenous hydrolyzing enzmes in Bioethanol production by simultaneous saccharification and fermentation. *Korean Journal of Chemical Engineering*, 29, 1467-1482

21. McCrory, M.A., Hamaker, B. R., Lovejoy, J. C., & Eichelsdoerfer, P. E. (2010). Pulse Consumption, Satiety, and Weight Management. *Advances in Nutrition,* 1, 17-30.

22. Claye, S.S., Idouraine, A. & Weber, C.W. (1996). Extraction and fractionation of insoluble fiber from five fiber sources. *Food Chemistry*, 57, 305-310.

23. Cho, S.S., & Dreher, M.L. (2001). Handbook of dietary fiber. New York: Marcel Dekker, Inc.

24. Tabatabai, A, & Li, S. (2000). Dietary fiber and type 2 diabetes. *Clinical Excellence for Nurse Practitioners*, 4(5), 272–276.

25. Karlsson, M.E., Loeman, A.M.B., Orck, I.M. & Eliasson, A.C. (2007). Some physical and Nutritional characteristics of genetically modified potatoes, varying in amylose/amylopectin ratios, *Food Chemistry,* 100 (1), 136 - 146.

26. Gillespie, C. (2018). Does viscosity increase with the size of the molecule? *Sciencing*, https://sciencing.com/viscosity-increase-size-molecule-13388.html Accessed 28/05/2019

27. Arvill, A. & Bodin, L. (1995). Effect of short-term ingestion on konjac glucomannan on serum cholesterol in healthy men. *American Journal of Clinical Nutrition,* 61, 585– 589.

28. Okoye, J.I. & Mazi, E.A. (2011). Proximate Composition and functional properties of kidney bean/wheat flour blends. Abia State University. *Journal of Environmental Sciences and Technology,* 1: 113-118.

29. Agrahar-murugkar, D. & Jha, K. (2011). Influence of storage and packing conditions on the quality of soy flour from sprouted soybean. *Journal of Food Science and Technology, 48,* 325-328.

30. Okoye, J.I., & Obi, C.D. (2017). Chemical Composition and Sensory Properties of WheatAfrican Yam Bean Composite Flour Cookies. *Discourse Journal of Agriculture and Food Sciences,* 5 (2), 21-27.

31. Eleazu, C., Eleazu, K., Awa, E., & Chukwuma, S. (2012). Comparative study of the phytochemical composition of the leaves of five Nigerian medicinal plants *Journal of Biotechnology and pharmaceutical Research 3*: 42-46.

32. Park, J. & Henneberry, S.R. (2010). South Korean Millers' preferences for the quality characteristics of hard white wheat that is used in producing all-purpose flour *2010 Annual General Meeting of Agricultural Economics Association*, Orlando FL, Southern

33. Uchechukwu-Agua, A.D., Caleb, O.J., Maneley, I.M. & Opara, U.L. (2015) Effect of Storage conditions and duration on physicochemical & microbial quality of the flour of two cassava cultivars (TME 419, UMUCASS 36), *CYTA-Journal of Food*, *13*(4), 635-645.

34. Shaidi, F., & Nackz, M. (1995). Food Phenolic: Sources, chemistry, effects, application. Landcaster: Technomic Publishing Co., Inc., p 1-5

35. Food and Agriculture Organization (FAO, 1992). Maize in Human Nutrition Report Series 25, Rome Food and Agriculture Organization.