Formulation and Nutritional Characterization of a Multipurpose Food Flour Blend for People Living with Diabetes

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Abstract: *This study sort to formulate and characterize a multipurpose food flour blend for people living with diabetes (PLWD) using the most recommended low glycemic index foods by physicians and determined to be the most preferred by PLWD. Six potential multipurpose food flour blends labelled ''D, E, F, G, H, and I'' were formulated from soybean, finger millet, unripe plantain, carrot and pumpkin leaves using material mass balance method. These food flours were characterized by proximate analysis, vitamin, mineral and antinutrient determinations. Blend ''D'' was found to be the most suited for PLWD as it was the most compliant in critical nutrient components for PLWD and superior to a popular proprietary equivalent currently sold in the market. Although, the multipurpose food flour labelled ''D'' completely complies with the International Diabetic Atlas' recommendations for protein (15-20 %), carbohydrate (45-60 %) and fat (7%) in the foods of PLWD, it fell short of the American Diabetic Association's recommendation for fat (25-35%) in the diet of PLWD by 15 % even though it met her recommendations for protein and carbohydrate. This suggests the need for supplementation with fatty food sources such as cooking oil or butter during final meal preparation. However, the desirable reduction in carbohydrate content achieved in blend ''D'' (60%), coupled with its elevated fat content when compared with its proprietary equivalent, makes ''D'' better poised to favour a lower glycemic impact, improved insulin sensitivity, and sustained energy release via a state of ketosis. These positive indicators suggest that when incorporated into the diets of PLWD, the formulated multipurpose flour ''D'' could potentially be a safer and nutritionally more adequate dietary alternative in the management of diabetes.*

Keywords: diabetes, low glycemic index foods, multipurpose food flour, soybean, finger millet, unripe plantain, carrot, pumpkin leaves.

INTRODUCTION

Reports have shown that diabetes is a very popular ailment among human populations around the world [1-3]. Due to the pathology of this ailment, many studies [4-6] still exempt foods with a high glycemic index (GI) from the dietary options available to people living with diabetes (PLWD). As a result, safe and nutritionally adequate dietary options available to PLWD appear to be fewer, even as most of the common staple foods including many finger foods are ruled out of the safe dietary options. In sub-Saharan Africa, where poverty is endemic in many countries [7-9], the situation is even more dire as safe and nutritionally adequate dietary options with low glycemic index are expensive and almost unaffordable to the larger demographic of PLWD in this region [10-12]. This is perhaps because the demographic of PLWD still comprises a substantial population of the aged, unemployed or retired and hence dependent, although some studies are beginning to show an emerging new trend in the demographics [13, 14]. The result of the aforementioned scenario is malnutrition among PLWD [14, 15] which stems from loss of appetite for the few dietary options available and very high cost of nutritional management of diabetes [11, 12]. All of these may not be unconnected with the rising cases of morbidities and mortalities of PLWD stemming from unhealthy diet [14,16]. As a result, there is need to intensify research efforts towards formulating nutritionally adequate food flours from the healthiest, indigenous food materials which in themselves, can allow for a diverse range of other food products including finger foods and other ready-to-eat meals to be made from them. The goal being to provide a wider variety of safe dietary food options for PLWD. As with attempts at functional food formulation for other special needs conditions [17-19], several studies have also been carried out to cater to the special dietary needs of PLWD [20-23] A number of such studies [24-28] have recommended soybean (*Glycine max*), finger millet (*Eleusine coracana*), unripe plantain (*Musa acuminata*), carrot (*Daucus carota*) and pumpkin leaves (*Cucurbita pepo*) as ideal food materials required to produce such a multipurpose diabetic food flour. The reason is that, these are among the most recommended low glycemic index foods (RLGIFs) by physicians and are among the most preferred by PLWD [12, 29-32].

In order to ensure a balanced diet intake by PLWD whilst managing the ailment nutritionally, the American Diabetes Association (ADA) recommends that the food of PLWD should contain 15-20% protein, 25-35% fat and 45-60% carbohydrate [33]. The International Diabetes Atlas (IDA) specifies a range of 45-60 % for Carbohydrate, 15-20 % for protein and 7 % for fat [34]. However, the problem is that most food materials are not sufficiently nutrient-dense to meet these requirements and this is further worsened by the nutrient loses associated with the various food processing methods employed to convert many food materials into edible forms. It is why this study seeks to advance the frontiers of literature by attempting to formulate a multipurpose food flour from the aforementioned RLGIFs, suited for the needs of PLWD and which meets the both the dietary recommendations of the ADA and IDA.

METHODOLOGY

Sample collection and processing

The RLGIFs used for this study were Finger millet, Unripe plantain, soybean fresh carrots and pumpkin leaves. Seven kilograms each of finger millet, unripe plantain and soybean were procured from the Wurukum food market in Makurdi- Benue State Nigeria. Also, 3 Kg each of fresh carrots and pumpkin leaves were procured. The food materials were made into two kinds of flour samples; unrefined flours and refined flours. Whereas the unrefined flour samples were obtained by merely crushing each dry food material into fine flour, the refined flour samples were produced as described in the flowcharts depicted in Figures 1 to Figure 5.

Unripe Plantain
↓
Debunching
↓
Washing with dist. H_2O
↓
Airdrying for 72 hours
↓
Milling and Sieving (80 µm mesh)
↓
Unripe Plantain Flour

Figure 1: Preparation of Unripe Plantain Flour

Carrot
↓
Washing with dist. H_2O
↓
Peeling
↓
Grating
↓
Airdrying for 72 hours
↓
Milling
↓
Sieving (80 µm mesh)
↓
Carrot Flour

Figure 2: Preparation of Carrot Flour

Pumpkin Leaves
↓
Washing with dist. H_2O
↓
Slicing
↓
Airdrying for 72 hours
↓
Milling
↓
Sieving (80 µm mesh)
↓
Pumpkin Leaf Flour

Figure 3: Preparation of Pumpkin Leaf Flour

Soybean Grains
↓
Winnowing
↓
Washing and soaking in dist. Water (14 hours)
↓
Straining and Blanching
↓
Dehulling and rinsing with water until clear
↓
Boiling for 15 mins and Airdrying for 48 hours
↓
Toasting and Milling
↓
Sieving (80 µm mesh)
↓
Soybean Flour

Figure 4: Preparation of Soybean Flour

Finger Millet Grains
↓
Soaking in excess water to remove debris and sand
↓
Fermenting (48 hours)
↓
Rinsing with dist. water
↓
Airdrying for 48 hours
↓
Milling
↓
Sieving (80 µm mesh)
↓
Finger Millet Flour

Figure 5: Preparation of Finger Millet Flour

Proximate analysis

Both refined and unrefined RLGIFs flours, the multipurpose food flour formulations made as well as the proprietary food flour sample were characterized by proximate analysis using standard methods prescribed by Association of Official Analytical Chemists-AOAC [35] to determine their moisture, ash, crude fiber, crude fat and crude protein contents. Total carbohydrate was determined by difference.

Mineral Analysis

Na, K, Ca, Mg, Fe, Se, Cu, and Zn in the samples were determined using an Atomic Absorption Spectrophotometer (SOLAR 929 Unicam A.A. Spectrophotometer, UK) in the process described by [36]. Where a muffle furnace set at 600 ^{O}C was used to ash 2.1 grams of the sample to be analysed and the ash digested in 10 mL of 5M HCl before washing with deionised water and transferring quantitatively into a 50 mL flask. The concentrations of Na, K, Ca, Mg, Fe, Se, Cu, and Zn in the solution was then analysed using the AAS at the following wavelengths; 589.0, 766.5, 422.7, 285.2, 248.3, 196.0, 324.7, and 213.9 nm respectively.

Vitamin Analysis

Vitamins A, D, E, K, C and B-complexes were determined following the instrumental methods reported by [36] Whereas the fat-soluble vitamins were determined using non-aqueous reversed-phase HPLC (NARP-HPLC), water-soluble vitamins were determined using reversed-phase HPLC (RPHPLC). The instrumental conditions were as follows;

Parameter	**Condition**
Temperature of Column:	25°C
Column for fat-soluble vitamins:	Acclaim C18, 3 µm, 3.0 × 150 mm
Column for water-soluble vitamins:	Acclaim PA, 3 µm, 3.0 × 150 mm
stationary & Mobile Phases:	(i) 25 mM phosphate buffer (pH 3.6)
	(ii) CH_3CN-mobile phase A (7:3, v/v)
Rate of flow:	0.5 mL/min
wavelength of UV Detection:	each vitamin's absorption maximum of
Injection volume:	5 µL
Mobile and stationary phases:	(i) Methanol-methylcyanate (8 : 2 v/v)
	(ii) Methyl tert-butyl ether (MTBE)

Determination of Oxalate

Oxalate was determined using the permanganate titration method described by [36] in which 2g of the sample was dissolved in 100 mL distilled water before 5 mL 6 M HCl was added to the solution. It was then digested by boiling at 100°C for 1 hour, after which it was cooled and filtered. The pH of the mixture was adjusted to 4.5 via drop-wise addition of concentrated aqueous ammonia before heating to 90°C in a water bath.

The solution was then cooled and filtered (to remove ferrous ion precipitates). The filtrate was then heated to 90°C before adding 10 mL of 5% $CaCl_2$ solution while constantly stirring it. It was then cooled and stored at 5°C for 8 hours in a refrigerator. The mixture was then removed and centrifuged at 3000×g for 5 min. The supernatant was decanted and the residue reconstituted in 10 mL 20 % H_2SO_4. The solution was made up to the mark in a 100 mL volumetric flask using distilled water and titrated against 0.05 M $KMnO_4$ to a faint pink colour that persisted for30 seconds. The oxalate content was obtained from the relationship that 1 mL of 0.05M $KMnO_4$ solution equals 0.00225 g oxalate. Equation 1 below was then used to calculate the oxalate content of the sample where W is the weight of sample analyzed.

$$\%\ Oxalate\ = \frac{100 \times Titre \times 0.00225}{W} \qquad (1)$$

Determination of Phytate

The spectrophotometric method reported by Oche et al, [36] was employed for the determination of Phytate in 2g of sample. The sample was subjected to acid hydrolysis, cold maceration and filtration using Whatman filter paper. A 0.5 mL portion of the sample extract with 1 mL of 0.05 M phytate solution were pipette into separate test tubes and 1 mL ferric ammonium sulphate added, before boiling in a water bath for 30 min and cooling to 25 ºC in ice. Thereafter, 2 mL of 2, 2-bipyrimidine was added to each tube, and agitated before measuring their respective absorbances using a UV-spectrophotometer at 519 nm. The sample's phytate content was then obtained by evaluating equation 2. Where; W, Au, As, C, Vt and Va are the weight of sample, absorbance of sample, absorbance of standard phytate solution, concentration of standard phytate (mg/mL), total extract volume and volume of extract used respectively.

$$\%\ Phytate = \frac{100 \times Au \times C \times Vt}{W \times As \times \times 1000 \times Va} \qquad (2)$$

Formulation of potential multipurpose food flours

Following an appraisal of the proximate analysis of refined flours of the RLGIFs, visa vis the recommendations of ADA and IDA for protein, fat and carbohydrate in the foods of PLWD, potential multipurpose food flours for PLWD were formulated by material mass balance alone [37]. This was done by blending refined flours of soybean, finger millet, unripe plantain, carrot, and pumpkin leaves to attain as close as possible, the aforementioned recommendations of ADA and IDA for protein, fat and carbohydrate in the foods of PLWD. The blend formulations are as shown in Table 1. This approach is adopted when proximate analysis reveals that the component RLGIF flours are not sufficiently nutrient-dense to meet the target macronutrient recommendations. Each formulation was chemically profiled and the formulation showing the closest conformity in nutrient composition with the American Diabetes Association's and or the International Diabetes Atlas' recommendations was elected the best and most suited multipurpose food flour for PLWD.

Table 1: Refined flours blend proportions for formulating multipurpose food flour for diabetics

SN	Formulation ID	Soybean	Finger millet	Unripe plantain	Carrot	Pumpkin leave
1	A	100	-	-	-	-
2	B	-	100	-	-	-
3	C	-	-	100	-	-
4	D	94	2	2	1	1
5	E	90	4	4	1	1
6	F	86	6	6	1	1
7	G	82	8	8	1	1
8	H	78	10	10	1	1
9	I	74	12	12	1	1

RESULTS AND DISCUSSION

Table 2 shows the proximate composition of refined and unrefined flours of finger millet, soybean and unripe plantain. Table 3 shows the micronutrient composition of the refined low glycemic index foods used for the formulation. Table 4 shows the proximate composition of potential multipurpose food flour blends for PLWD. Table 5 shows the Comparative nutrient and anti-nutrient compositions of the multipurpose food flour ‘’D’’, a Proprietary food flour and ADA recommended levels.

Table 2: Proximate composition of refined and unrefined flours of finger millet, soybean and unripe plantain

S/N		Finger millet		Soybean		Unripe Plantain	
		Unrefined	Refined	Unrefined	refined	Unrefined	Refined
1	Moisture (%)	$6.05{\pm}0.13^{a}$	$11.64{\pm}0.05^{b}$	$6.35{\pm}0.08^{a}$	6.04 ± 0.02^{a}	$5.92{\pm}0.06^{a}$	8.00 ± 0.23^{b}
2	Ash (%)	$4.67{\pm}0.06^{a}$	1.69 ± 0.03^{b}	$3.29{\pm}0.15^{a}$	3.52 ± 0.00^{a}	$4.12{\pm}0.06^{a}$	3.89 ± 0.05^{a}
3	Crude Fat (%)	$5.01{\pm}0.18^{d}$	0.39 ± 0.04^{a}	$2.54{\pm}0.05^{b}$	12.01 ± 0.35^{c}	$4.12{\pm}0.04^{d}$	0.13 ± 0.01^{a}
4	Crude Protein (%)	$3.38{\pm}0.04^{f}$	2.06 ± 0.05^{f}	$9.39{\pm}0.04^{a}$	34.71 ± 0.12^{e}	$8.15{\pm}0.06^{a}$	7.58 ± 0.04^{a}
5	Crude Fibre (%)	$8.57{\pm}0.17^{c}$	1.27 ± 0.01^{a}	$7.19{\pm}0.06^{c}$	1.01 ± 0.00^{a}	$16.63{\pm}0.34^{d}$	1.54 ± 0.01^{a}
6	Carbohydrate (%)	$72.32{\pm}0.12^{a}$	82.93 ± 0.09^{d}	$71.23{\pm}0.04^{a}$	42.70 ± 0.42^{b}	$61.06{\pm}0.13^{c}$	$78.86{\pm}0.29^{a}$

Results are Mean ± SD of triplicate determinations
Means with unidentical superscript within a row are significantly different at P>0.05

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The results in Table 2 shows that, although finger millet, soybean and unripe plantain are RLGIFs, in their unrefined forms, they are all deficient in the critical macro nutrients to consider when formulating foods for PLWD; fat and protein. For PLWD, fat is more preferred to carbohydrate because of its slower rate of energy release than with conventional carbohydrate energy sources. Protein on the other hand plays a crucial role in anabolic processes. The implication is that simultaneous equation and material mass balance method reported by Ikese et al [37] cannot be used jointly to derive with precision, the blend proportions needed to yield the recommended target percent of fat and protein in foods for PLWD using the aforementioned RLGIFs. This, forms the basis for the use of the progressive mass balance method depicted in Table 1 in an attempt to achieve these recommended nutrient targets to the best possible degree allowed by the inherent proximate composition of the raw food materials. However, it must be stated that this method is cumbersome and consumes more food materials and reagents in pre- and post-food characterization steps.

The results in Table 2 show that whereas the combination of food processing methods employed in transforming unrefined RLGIFs into refined flours have resulted in the appreciation of some proximate parameters by concentrating them in the refined food matrix, it also resulted in the depletion of other proximate parameters in the refined food matrix. In Table 2, it can be seen that for the most part, the combination of food refining methods employed have increased moisture in the refined flour samples, thus suggesting that the moisture used during refining was not completely lost in the drying process and as a result, the refined samples have a higher moisture content than the unrefined sample and this could eventually have implications for the shelf life of the formulated multipurpose food flour. This is because elevated moisture content has been associated with elevated microbial activity, hence a shorter shelf life [38]. With ash content, Table 2 shows that the refined flours contain lower ash content than the unrefined sample. This implies that the food processing methods employed in refining resulted in loss of minerals and this is consistent with reports by Khan et al, [39] and Adebowale et al, [40]. This observation is plausible because, unlike in finger millet and unripe plantain, with soybean, protein and fat are concentrated in the seed's fine cotyledon and most of this is retained by the sieving process. Whereas in unripe plantain, crude fat and protein are most concentrated within the sparse seedlike structures within its core and all of these are lost in the sieving step during processing. The implication is that the resulting refined soybean flour now contains a significantly higher protein content than the unrefined form and this is consistent with literature [41, 42].

The result in Table 2 also shows there is a significant decline in the fibre contents of all food materials following processing into refined flour, a trend that is consistent with literature [43]. This loss in fibre is most intense during the sieving stage, where coarse fibre-bearing aggregates are isolated and discarded and might negatively impact the movement of the resulting food formulation through the bowel of PLWD [44]. Table 2 shows that in finger millet and unripe plantain, the processing methods employed had increased the amount of total carbohydrate in the retained food matrix of the refined flour. However, in Soybean it resulted in a depletion of total carbohydrate and this is likely due to the dehulling step which removed the cellulose-rich seed coat; the part of the soybean seed where the bulk of the carbohydrate is concentrated as cellulose. The case is different with finger millet, and unripe plantain, where carbohydrate is abundant in all parts of the food material. This may have implications for PLWD as it is preferable that more of their energy needs are available from fats rather than carbohydrate as the former releases it more slowly via ketosis unlike the latter which releases it much faster via glucose.

Table 3: Micronutrient composition of recommended low glycaemic index food flours for the Formulation

S/N	Micro nutrient (mg/100g)	Finger millet	Soybean	Unripe Plantain	Carrot	pumpkin
1	Vit. A	1.05±0.04^{a}	2.50±0.03^{a}	1.71±0.04^{a}	1.92±0.04^{a}	1.99±0.03^{a}
2.	Vit. D	0.12±0.01^{a}	0.08±0.01^{c}	0.21±0.01^{a}	0.12±0.01^{a}	1.00±0.03^{b}
3.	Vit. E	0.48±0.04^{a}	0.40±0.01a	1.63±0.05^{b}	0.97±0.02^{c}	3.09±0.03^{b}
3.	Vit. K	0.08±0.01^{b}	0.47±0.02^{c}	0.15±0.01^{b}	0.10±0.01^{b}	2.47±0.03^{a}
4.	Vit. C	1.84±0.06^{a}	9.06±0.12^{b}	12.75±0.52^{c}	10.27±0.18^{c}	1.85±0.06^{a}
5.	B- Complex	14.88±0.27^{a}	12.58±0.20^{a}	11.01±0.09^{b}	13.76±0.41^{a}	9.81±0.06^{b}
6.	Na	1994.50±27.58 ^{e}	5926.00±41.01 ^{b}	2574.50±7.78 ^{d}	3048.00±4.24 ^{c}	7702.50±20.51 ^{a}
7.	K	787.70±6.22 ^{c}	1823.00±29.70 ^{a}	1380.00±19.80^{b}	1340.50±4.95 ^{b}	1381.00^{b}±36.77
8.	Ca	4923.50±38.89 ^{b}	2045.50±54.45 ^{d}	1505.00±18.38^{e}	6510.50±12.02^{a}	4322.50±38.89 ^{c}
9.	Mg	1760.00±21.21 ^{b}	792.15±4.17 ^{d}	612.15±18.74 ^{e}	2002.00±8.49 ^{a}	903.95±4.74 ^{c}
10	Fe	349.65 ± 3.46 ^{b}	105.40±1.27 ^{d}	16.15±0.49 ^{e}	583.50±2.69 ^{a}	177.00±1.56 ^{c}
11.	Zn	20.90±0.85 ^{d}	53.40±1.56 ^{a}	16.90±0.28 ^{e}	24.30±0.85 ^{c}	46.00±1.13 ^{b}
12.	Se	0.01 ± 0.00	ND	ND	ND	ND
13.	Cu	ND	0.01±0.00	ND	ND	ND

Results are Mean ± SD of triplicate determinations
Means with unidentical superscript within a row are significantly different at P>0.05

When considering the implication of the results in Table 3, it is important to note that, vegetables have proven to be generally richer in micronutrients compared with other food classes [45], hence the inclusion of carrot and pumpkin leaves in the intended formulation as potential micronutrient fortificants and the results in Table 3 largely support this. Table 3 shows that Carrot contains the most surplus amount of Fe, Mg, and Ca and second to finger millet, carrot contained the highest amount of B-complexes. Furthermore, with exception of unripe plantain, carrot also contained the highest amount of Vit. C. Similarly, Pumpkin leaves contained the highest amounts of Na, Vit. D, Vit. E and Vit. K, and except for soybean, pumpkin leaves contained the highest amount of Zn, and K. The implication of these comparative micro nutrient composition of the RLGIFs in Table 3 is that it affirms the suitability of carrot and pumpkin leaf flours as the most suited among the RLGIFs in the study for use as micronutrient nutrient premix in a multipurpose flour for PLWD. However, the availability of these micronutrients in the selected RLGIFs and hence the final formulated flour has health implications for PLWD. While Fe plays an essential role in various physiologic processes [46] including haemoglobin formation it is important to add that excessive levels can lead to oxidative stress, which has been linked to insulin resistance and other complications in diabetes [47]. But it must be added that for water-soluble micronutrients which are prone to loss by leaching during food processing, it is important that the starting food material contains a surplus amount of such nutrients as seen in carrot and pumpkin leaves so as to accommodate such losses. This way, the final food product can still contain an appreciable amount of lost nutrients that ensures the formulation still provides such nutrients in the required amount for PLWD. Mg is crucial for glucose metabolism and insulin sensitivity as it aids the activation of enzymes involved in glucose utilization and insulin action [48] but higher dietary intake of Mg has been inversely associated with the risk of type 2 diabetes [49]. Ca plays multiple crucial roles the dietary management of diabetes, for instance, it is essential for pancreatic beta-cell function, which is vital for insulin secretion. Also, evidence suggests that it can influence insulin sensitivity and glucose metabolism [50]. While there are mixed results available, some epidemiological studies have associated higher calcium intake with lower risk of diabetes [51]. Studies have shown that a deficiency in B-complex vitamins can lead to complications associated with diabetes as they play crucial roles in carbohydrate

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metabolism [52] and several studies show potential benefits of B-complex vitamins in the management of diabetes. For instance, B12 deficiency is common in PLWD, particularly those on metformin and replenishing B_{12} may improve metabolic control [53] There is considerable evidence that Zn plays supportive role in glucose metabolism and may help improve glycemic control in individuals with diabetes as it is involved in insulin synthesis and secretion [54]. Also, Zn supplementation has been shown to enhance insulin secretion and reduce oxidative stress. Selenium and copper were not detected in Carrot, pumpkin and unripe plantain, but are present in almost negligible amounts in finger millet and soybean. While these are known to promote general wellbeing of individuals, much study is needed to ascertain their actual impact in diabetes. The same is true for Vitamins A, and K as there are few studies which weakly suggest that they play some role in supporting immune function and regulating insulin sensitivity respectively.

Table 4: Proximate Composition of potential Multipurpose Food Flour blends for PLWD

S/N	Blend formulation code	Moisture (%)	Ash (%)	Crude Fat (%)	Crude Fibre (%)	Protein (%)	Carbohydrate (%)
1	**D**	7.60±0.08 ^{a}	3.17±0.03 ^{b}	9.14±0.26 ^{a}	1.39±0.02 ^{d}	18.38±0.04 ^{a}	60.33±0.27 ^{e}
2	**E**	6.98±0.15 ^{a}	3.28±0.01 ^{b}	7.58±0.10 ^{b}	1.40±0.04 ^{d}	18.13±0.01 ^{a}	62.63±0.25 ^{e}
3	**F**	7.72±0.23 ^{a}	3.05±0.11 ^{b}	4.95±0.07 ^{c}	1.38±0.02 ^{d}	16.73±0.10 ^{b}	66.17±0.31 ^{b}
4	**G**	8.46±0.07 ^{a}	3.10±0.06 ^{b}	6.66±0.21 ^{b}	1.23±0.03 ^{d}	16.34±0.08 ^{b}	64.20±0.22 ^{b}
5	**H**	7.36±0.03 ^{a}	2.96±0.15 ^{b}	3.90±0.23 ^{c}	1.44±0.04 ^{d}	16.04±0.03 ^{b}	68.30±0.16 ^{c}
6	**I**	8.20±0.28 ^{a}	2.83±0.04 ^{b}	6.52±0.12 ^{b}	1.41±0.01 ^{d}	16.24±0.12 ^{b}	64.81±0.13 ^{b}

Results are Mean ± SD of triplicate determinations
Means with unidentical superscript within column are significantly different at P>0.05

Having seen from the result in Table 3 that the unrefined forms of the RLGIFs; the raw materials for the food formulation ab initio, were not nutrient-dense enough to supply the recommended percent fat and protein in foods of PLWD, it is plausible to expect that even though they are RLGIFs, these food materials cannot give in any of the final food products in Table 4, a nutrient level that they already lack in themselves, except as the combination of food processing methods that were employed in refining them into flours had allowed to be concentrated in their refined flours. Consequently, the results in Table 4 shows that among the 6 formulated flour blends labelled "D, E, F, G, H and I", the blend labelled ''D" comes closest to meeting the critical fat, protein and carbohydrate requirements by the American Diabetes Association and the International Diabetes Atlas for foods of PLWD. However, it must be stated that statistically, there are no significant differences between the proximate compositions of blends D, E, F, G, H and I as the differences in their proximate composition parameters are only marginal but are nonetheless the yardsticks for determining which formulation best complies with ADA and IDA recommendations. Whereas for generally healthy non-diabetic adults, the Dietary Guidelines for Americans [55] recommends the following macronutrient ranges; carbohydrates: 45-65 %, protein: 10-35 % and fat: 20-35 %, to ensure a balanced healthy diet that supports overall health and prevents chronic diseases. However, for PLWD the American Diabetes Association's recommendation of; carbohydrates: 45-60 %, protein: 15-20 % and fat: 25-35 % [34, 56] is suggestive that for PLWD, the higher the fat and protein content of their diet, the better and the lower the carbohydrate content the better and this is without prejudice to the food's quality. In this regard, blend ''D" which contains the highest percent of fat, protein and the lowest of percent of carbohydrates while ranking amongst the top 2 richest in fibre and ash (hence mineral), easily becomes the most ADA-compliant formulation. Consequently, blend ''D" is the most suited multipurpose food flour blend for PLWD. However, it must be stated that while blend ''D" Completely meets the recommendations of the IDA for the foods of people living with diabetes and the formulation can be said to be a success, it falls short of the ADA's recommendation for fat in the diet of PLWD by 15 %. The implication is that PLWD will need to supplement formulation" D" with other dietary fat sources during their meal preparation in order to meet the recommendations of ADA for fat.

Table 5: Comparative nutrient and anti-nutrient compositions of the multipurpose food flour ''D", the Proprietary food flour and ADA recommended levels

S/N	composition	Multipurpose food flour –''D"	Proprietary flour	ADA Recommended level [56]
1	**Moisture (%)**	7.60 ± 0.08^a	6.71 ± 0.02^a	-
2	**Crude Fat (%)**	9.14 ± 0.26^a	5.04 ± 0.07^b	25-35
3	**Crude Fibre (%)**	1.39 ± 0.02^a	4.19 ± 0.04^b	-
4	**Crude Protein (%)**	18.38 ± 0.04^b	7.37 ± 0.15^a	15-20
5	**Total Carbohydrate (%)**	60.33 ± 0.27^a	71.35 ± 0.13^b	45-60
6	**Vit. A (mg/100g)**	3.52 ± 0.01^a	1.11 ± 0.03^b	-
7	**Vit. D (mg/100g)**	2.99 ± 0.04^a	1.17 ± 0.02^a	-
8	**Vit. E (mg/100g)**	3.18 ± 0.04^a	1.89 ± 0.02^b	-
9	**Vit. K (mg/100g)**	0.47 ± 0.03^a	0.12 ± 0.01^a	-
10	**Vit. C (mg/100g)**	7.21 ± 0.06^a	4.59 ± 0.04^b	-
11	**B complex (mg/100g)**	19.05 ± 0.13^a	11.42 ± 0.35^b	-
12	**Na (mg/ kg)**	670.70 ± 1.10^a	368.00 ± 6.98^b	-
13	**K (mg/100g)**	2403.00 ± 8.25^a	834.45 ± 6.75^b	-
14	**Ca (mg/100g)**	1494.50 ± 9.13^a	154.00 ± 1.67^b	-
15	**Mg (mg/100g)**	981.90 ± 1.70^a	347.60 ± 2.80^b	-

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16	**Fe (mg/100g)**	208.60 ± 1.70 [a]	53.05 ± 1.35 [b]	-
17	**Zn (mg/100g)**	53.70 ± 1.13 [a]	77.70 ± 1.40 [b]	-
18	**Se (µg/ kg)**	1.20 ± 0.14 [a]	0.04 ± 0.00[b]	-
19	**Cu (mg/100g)**	4.05 ± 0.15[a]	2.60 ± 0.10 [b]	-
20	**Oxalate (%)**	0.20 ± 0.01 [a]	0.23 ± 0.01 [a]	-
21	**Phytate (%)**	1.39 ± 0.02 [a]	1.18 ± 0.02 [a]	-

Results are Mean ± SD of triplicate determinations
Means with unidentical superscript within a row are significantly different at P>0.05

The result in Table 5 shows that with respect to crude fat, protein and all the micro-nutrients assayed, the formulated multipurpose flour ‘’D’’ is richer compared with its proprietary equivalent sold in the market. The implication is that ‘’D’’ is not just a safer dietary option for PLWD, as it is solely formulated from RLGIFs, it is also better poised to provide adequate nutrients for PLWD than its proprietary counterpart. This is even more so as the antinutrient levels in them are comparable even though minimal. Also, the result in Table 5 shows that the multipurpose food flour ‘’D’’ complies more with the ADA recommendation for protein, fat and carbohydrate in the diet of PLWD than the proprietary flour. It is particularly important to note that ‘’D’’ achieved a lower total carbohydrate content with an elevated crude fat content compared to the proprietary flour, thus implying that the former is better suited to favour a lower glycemic impact [57] improved insulin sensitivity [58] a state of ketosis [59] and sustained energy release [60] in PLWD than the proprietary equivalent, consequently reducing reliance on glucose and minimizing insulin surges.

CONCLUSION

This study sort to formulate a multipurpose food flour for PLWD using the most recommended low glycemic index foods by physicians and which were among the most preferred by PLWD. This is intended to broaden the dietary options available to them by introducing healthy, yet nutritious multipurpose food flours, which can be made into a variety of meals including ready-to-eat meals thus boosting the appetite of PLWD. This is intended to mitigate both the morbidities and mortalities often associated with the management of diabetes. Among the 6 potential food flours formulated, the multipurpose food flour coded as ‘’D’’ was found to be the most suited for PLWD. For the most part, ‘’D’’ was found to comply with the American Diabetic Association’s recommendation for protein and carbohydrate in the food of PLWD. This was not so for fat, as the fat content was lower than desired but found to be appreciably higher than that in a randomly selected proprietary food flour sold in the market. The multipurpose flour ‘’D’’ was found to be denser in nutrients than its proprietary equivalent, thus suggesting its potential to be a safer and nutritionally adequate dietary alternative for the management of diabetes. Its reduced carbohydrate content coupled with an elevated crude fat content makes ‘’D’’ better poised to favour a lower glycemic impact, improved insulin sensitivity and sustained energy release via a state of ketosis.

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Conflict of Interest
The authors declare no conflict of interest.

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