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Antihyperglycemic potential of a squarch based flour

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Abstract— Diabetes is a public health problem worldwide and in Africa in particular. An attempt was made to produce squash based anti-diabetic flour from squash, soybeans, cinnamon and neem leaves using mixture design. The nutritional content of the flour blends were then assessed. Water, ash, total digestible carbohydrates, crude proteins, lipids, fibers, calcium, zinc, iron, vitamin C, beta carotene and alpha tocopherol were determinate using standard methods. Result show that the squash based antihyperglycemic flour satisfies the recommended Acceptable Macronutrient Distribution Ranges (AMDR) according to reference diabetes organizations ensuring by this a balanced diet. It contains minerals and bioactive compounds with scientific based evidence of maintaining ideal blood glucose levels, achieving optimal blood lipid levels, reducing the risk for diabetic complications. Therefore, it can be used in diabetes management as nutraceutical.

Index Terms— Diabetes, anti-diabetic flour, balanced flour, blood glucose levels.

1 Introduction

Diabetes is a chronic disease characterized by persistent hyperglycemia requiring lifelong treatment. According to the International Diabetes Federation (IDF) Diabetes Atlas, 366 million people have diabetes in 2011 and this number is expected to increase to 552 million people by 2030 [1]. In Africa, diabetes like other non-communicable diseases paid little attention, despite its social, human and economic repercussions [2]. Diet is a leading contributor to morbidity and mortality worldwide according to the Global Burden of Disease Study carried out in 188 countries [3]. Medical Nutrition therapy (MNT) has been stated as the foundation of all diabetes management [4]. Diabetes management through diet and its effectiveness has been demonstrated; but difficulties remain concerning contextualization, accessibility, availability and comprehensibility of dietary guidelines by patients and healthcare professionals pointing out a barrier to counsel patients [3]. Non-compliance or discontinuation of medications and cultural issues surrounding the care of diabetes represents other difficulties of maintaining treatment successes over time [5]. Therefore, constructive actions such as the development of a ready to used balanced nutraceutical as a complement to drug therapy open a new alternative approach. Plant products like *Allium cepa* L (bulb), *Allium sativum* L, *Momordica charantia* L etc have been utilized as alternative treatments for diabetes [6],[7]. However, in recent years, neem (*azadirachta indica*) has received particular attention because of scientific evidence demonstrating its strong antihyperglycemic potential [8],[9],[10],[11]. Scientific research has shown that adding cinnamon to the diet can help reduce blood glucose levels [12],[13]. Components present in cinnamon are said to relieve and prevent signs and symptoms of metabolic syndrome in type 2 diabetes and cardiovascular and related diseases [14],[15]. The health benefits of foods are likely to result from the additive and synergistic effects of different kinds of phytochemicals rather than a single component. The combination of cinnamon and neem's leaves products will surely enhance the therapeutic effect but their poor taste remains a problem regarding consumption. A mixture of these ingredients with tasty foods such as squash (*curcubita* spp), soybeans would certainly enhance the taste. The choice of these foods is not random. Indeed, squash is one of those low GI foods recommended for overweight or obese people with type 2 diabetes [16]. Beyond controlling carbohydrate intake, diabetic patients are advised to control their lipid and protein intake, avoiding saturated fatty acids in favor of polyunsaturated fatty acids, and regulating protein intake [17]. Soy consumption is therefore of particular interest for diabetics because of its high content of polyunsaturated fatty acids [18]. The dietary importance of soybeans is also due to the presence isoflavones which improve the regulation of blood sugar [19] and alpha-galacto-oligosaccharides (α-GOS) which positively modify intestinal flora since alteration is often related the development of type 1 diabetes [20], [21],[22]. Mixing squash and soy flour, neem's leaves and cinnamon powder in formulating a ready to used anti-diabetic balanced food as nutraceutical have not been implement. If it is true that squash, soy, neem leaves and cinnamon in a dynamic formulation can help in producing a balanced diet able to control blood sugar levels and related complications, research questions emerge regarding the percent of each ingredient in the mixture for a better result. The present work aims at producing a balanced anti-hyperglycemic food based on soybeans and squash flour, neem leaves and cinnamon powder able in avoiding nutritional deficiencies and ensuring glycemic control and it related complications in diabetic patients. More specifically, it aims at formulating using mixture design, a balanced diet meeting standards goals in terms of macro and micronutrients.

Material and methods

Sample collection

Squash (*curcubita* spp), soy (G*lycine max*), cinnamon (*Arachis hypogaea*), neem leaves (*azadirachta indica*), were purchased from local market in Douala city. All the samples were kept at room temperature before processing

Processing technologies

Preliminary treatment of the raw materials

Cleaning and washing

Squash and neem leaves were wash using tape water. Soybeans were manually sorted to remove husks, stones, damaged and colored foreign grains. Noxious seeds, insects and any foreign material were also removed.

Dehulling

Soybeans were completely dehulled to reduce the fiber and antinutrients content to minimum levels. They were then roasted over low heat during 20 minutes. Sample were subsequently crushed and varnished to remove the fibrous film and other impurities. They were stored in plastic bags before grinding.

Drying

Squash were sized and cut into 0.5 cm thick slices before drying. Each sample (squash, neem leaves) were placed in simple and aerated layers on pre-weighed drying trays, and dried at 45 ± 5°C in a cross flow cabinet dryer (Binder, FDL 115), with an air flow rate of 24 m^3/h. Drying trays were periodically weighed all along the drying process. Samples were dried to a moisture content of 10%. For each sample, drying experiment was conducted in triplicate and from the three values of tray weight, average of sample moisture was determined as a function of time.

Milling

All dry samples (squash, neem leaves, soybean and cinnamon) were ground into fine flour using a hammer mill (Cullati) or a robot blender (Moulinex®) (neem leaves). Flour was then sieved through a sieve of 500µm, packaged in an air tight polyethylene bags and stored at -18 ° C until analyzed

Formulation of squash based flour

The methodology of mixture design as a mathematical approach was used to calculate the proportions of ingredients needed in order to have balanced composite flour. Optimal mixture of ingredients in formulating balanced anti-hyperglycemic flour is: 6:2:1.7:0.03 respectively for squash flour, soy flour, cinnamon powder and Neem leaves.

Chemical analysis

Proximate composition

Moisture and ash were determined by AOAC method [23]. Crude protein has been analyzed according to Kjeldahl method [24]. Total fat content was quantified according to Weibull–Stoldt method [25]. Total dietary fiber was analyzed according to the AOAC 985.29 method [**26**]. Carotenoids profile and alpha tocopherol were determined by HPLC [**27**]. Total available carbohydrate was calculated as 100% minus the sum of moisture, protein, fat, ash, and total dietary fiber obtained using proximate analysis.

Minerals analysis

Determination of calcium, zinc and iron concentrations in the samples was performed using flame atomic absorption spectroscopy in acid digested ash according to the AOAC, 999.11 methods [28]. Phosphorus ions analysis in acid digested ash was done by antimony-phosphomolybdate colorimetric method AOAC, 1990 [29].

Results and discussion

Results

Nutritional quality of the formulated composite flour

Macronutrients content, gross energy and Acceptable macronutrient Distribution Ranges of the formulated composite flour

Proximate composition of the formulated squash based anti-hyperglycemic flour compared to standards is shown in Table 1. Protein, lipids and carbohydrates content are 19.643, 7.452 and 38.78 % respectively. The value of ash content is 4.612% while fibers content is 21.536%. These values were calculated from the model equations. The gross energy of the formulated flour calculated is 300.748 Kcal/100g. Protein, lipids and carbohydrates contributes to about 26.126, 22.30 and 51.574% of the total energy respectively. Fiber's energy density is about 7.18g/100 kcal. This macronutrient contribution falls within all Acceptable macronutrient Distribution Ranges (AMDR) in term of carbohydrates. Lipid energy distribution fulfills all the AMDR except for ICMR reference. Protein energy contribution fulfills only the AMDR for Traditional guidelines for T2DM management and IOM reference standard. The fibers energy density is higher than the Traditional guidelines for T2DM management and American Diabetic Association (ADA).

Table 1: Macronutrients content, gross energy and macronutrient Distribution Ranges (AMDR) of the formulated composite

Composite flour			Acceptable Macronutriment Distribution Ranges (AMDR)						
Proximate analysis	Macronutrients content (g/100g)	Macronutriment Distribution Ranges	CDA Canadian diabetic association (1)	Indian Council of Medical Research (ICMR) (1)	National diet and nutrition survey (NDNS) of UK (1,2)	Traditional guidelines for T2DM management (1)	American Diabetic Association (3)	The European Association for the Study of Diabetes (4)*****	The Japan Diabetes Society on medical nutrition therapy JDS (2020) (5)
Moisture	4.98								
Ash	4.612								
Protein	19.643	26.126	15–20% %	10–15%	10–20%	15–25%	10 to 35	10-to-20 15-to-20 23-to-32	≤20%
Lipids	7.2	22.30	20- 35%	> 30%	<35%	20–35%	20 to 35		≤30%
Carbohydrates	38.777	51.574	45–60%	50–60%,	47–60%	45-60	45 to 65		50–60%
Fibers	21.54	7.18/100 kcal			>1.5/100kcal	1.4/100kcal	1.4/100kcal	4/1000KJ	≥20%
Gross energy (Kcal/100g)	300.748		2750	2155	2500		1800-2200		

(1) Prasathkumar et al., [1].
(2) Diabètes UK, [30]
(3) American Diabetes Association [31].
(4) Diabetes and Nutrition Study Group (DNSG) of the European Association for the Study of Diabetes (EASD), [32]
(5) Japanese Clinical Practice Guideline for Diabetes, [33]
*****10–20% and 15–20% of total energy intake is recommended, respectively. In the case of obesity and normal renal function, a short-term protein intake of 23–32% is acceptable; a total of 10–15% protein intake is recommended for stage 3 nephropathy.

Macronutrient value of the formulated composite flour when using total diet replacement (TDR) pattern

The daily portion intake of carbohydrates, protein, lipids and fibers as a function of the quantity of flour needed to satisfy estimated energy requirement when using total diet replacement (TDR) pattern is presented in Table 2. They were calculated according to the estimated energy requirement. Standard energy requirement and the Macronutrient Distribution Ranges (AMDR) were used to calculate the theoretical amount of proteins, carbohydrates and lipids provided by utilizing the following factor of conversion: 1g carbohydrates or protein = 4Kcal; 1g lipids = 9Kcal. These theoretical values were compared with experimental values. When using CDA reference, the quantity of flour needed to fulfill the daily requirement standard energy is 916.7g. This quantity fulfills the calculated RDA for carbohydrates (309.375-412.5g) and lipids (61.11-106.944). The protein and fibers level is slightly higher (1.3 and 1.37 respectively) than the upper limit of the range (137.5 and 50 respectively). The quantity of flour needed to fulfill the ICMR daily energy requirement is 718.33g. This quantity fulfills the calculated RDA for carbohydrates only. The quantity of protein provided by the composite flour was higher (1.75) than the upper recommended value and the amount of lipids was lower (1.34) than the lower recommended value. When using NDNS standard, the quantity of composite flour needed to fulfill the daily requirement energy is 833.33g. This quantity fulfills the calculated RDA for carbohydrates and lipids. The protein level provided by the composite flour is slightly higher (1.04) than the upper limit of the range. The ADA and Japan Diabetes Society on medical nutrition therapy individualize the protein requirement allowance as 0.8 and 0.8-1.5 g/kg BW/day respectively. Japan Diabetes Society and ADA preferred to give a lower RDA limit as 150 and 130g/d of carbohydrates respectively.recommended value and the amount of lipids was lower (1.34) than the lower recommended value. When using NDNS standard, the quantity of composite flour needed to fulfill the daily requirement energy is 833.33g. This quantity fulfills the calculated RDA for carbohydrates and lipids. The protein level provided by the composite flour is slightly higher (1.04) than the upper limit of the range. The ADA and Japan Diabetes Society on medical nutrition therapy individualize the protein requirement allowance as 0.8 and 0.8-1.5 g/kg BW/day respectively. Japan Diabetes Society and ADA preferred to give a lower RDA limit as 150 and 130g/d of carbohydrates respectively.

Alpha tocopherol, β Carotene and mineral composition of the formulated composite flour

The levels of β-carotene and alpha-tocopherol in the Squash based anti-hyperglycemic formula are presented in Table 3. The values were calculated from the model equations. Alpha tocopherol (the highest fraction of vitamin E) content of the formulated flour is 115.106 μg/100g. The anti-hyperglycemic flour contains beta carotene (445.815μg/100g) among provitamin A carotenoids and vitamin C (64.517). The calcium

Table 2: Estimated Energy Requirements and daily intake of carbohydrates, protein, lipids and fibers as a function of amount of flour needed when using a total diet replacement (TDR) pattern.

Standards	Energy (kcal/j)	Carbohydrate g or g/day	Proteins (g/day) or (g/kgbw/day)	Lipids (g/day)	Fiber (g/day) or g/100kcal /d	Quantity of flour needed (g)	Proteins (g/day)	fibers (g/day)	Lipids (g/day)	Carbohy-drates (g/day)
			Theoretical values			Quantity provided when using total diet replacement (TDR) pattern				
CDA Canadian diabetic association	2750	309.375-412.5	103.125-137.5	61.11-106.944	30-50g	916.67	180.061	197.45	68.31	355.455
Indian Council of Medical Research (ICMR)	2155	269.375-323.25	53.875-80.813	>71.833		718.33	141.102	154.73	53.530	278.548
National diet and nutrition survey (NDNS) of UK	2500	281.25-375	93.75-156.25	55.56-97.22		833.33	163.69	179.5	62.1	323.142
Japan Diabetes Society on medical nutrition therapy		>150g/d	0.8-1.5 g/kgbw/day		≥ 20 g					
The American Diabetes Association (ADA)		130 g/day	0.8g/kgbw/day		1.4g/100kcal					
The European Association for the Study of Diabetes (EASD)	1000–1200*	-	10-to-20 ** 15-to-20 23-to-32	-	≥35 g 1.67g/100kcal					

*(1000–1200 kcal/day) is commonly advocated with obesity.

Table 3: Recommended dietary allowance and daily portion intake of mineral and vitamin as a function of quantity of flour needed when using a total diet replacement (TDR) pattern.

	Standard Energy requirement (Kcal)	Quantity of flour	Beta carotene (µg/100g)	Vitamin A µg retinol equivalent (RE)	Vitamin E mg (α- Tocopherol) (µg/100g)	Vitamin C (mg/100g))	Zinc (mg/100g)[4]	Iron (mg/100g)[5]	Ca (mg/100g)
Macronutrient composition of the composite flour			445.815	37.15	115.106	64.5165	2.827	9.147	92.778
Standard references									
Reference Nutrient Intake (INL98) [**35**]				550	8.8 mg	45	3.6; 6.0, 11.9 (4)	14.3; 18.0; 21.6; 43.1 (5)	1000
Daily ration of the formulated complementary Food (at least 50% of INL98)				225	4.4	32,258	1.8; 3.00; 5.95	7.15; 9; 10.8, 21.55	500
ANSE [**36**]	2000-2500			650-750	9-10	100-110	7.5-11.76	42675	950-1000
IOM, 2014 [**37**]	1900-2900			700-900	15	75-90	45604	43313	1000-1200
EFSA [**38**]	1624-2340.5			650-750	11-13	110-95	45602	7.5-16.3	750-1000
Anti-diabetic formula									
CDA Canadian diabetic association	2750	916.67		340.542	1.055	295.701	25.914	83.8475	850.465
Indian Council of Medical Research (ICMR)	2155	718.33		266.861	0.827	231.722	20.307	65.706	666.455
National diet and nutrition survey (NDNS) of UK	2500	833.33		309.583	0.959	268.819	23.558	76.225	773.15
IOM, 2014	1900-2900	666.33-967.67		235.283-359.117	0.729-0.111	408.605-623.660	17.904-27.328	57.931-88.421	587.594-896.854
EFSA	1624-2340.5	541.28-780.08		67.029-96.600	207.2-299.306	116,405-167.760	5,101-7.351	16.504-23.785	167.396-241.248

[4] Zinc values are given for high, medium and low dietary zinc bioavailability [35];
[5] Iron values are given for 15, 12, 10 and 5% dietary iron bioavailability [35];

content of the formulated flour is 92.778g/100g. Zinc and iron content is 2.827 and 9.147 respectively.

Micronutrient value of the formulated composite flour when using total diet replacement (TDR)

Standard daily energy requirements were used to calculate the quantity of composite flour needed to satisfy these energy requirements when using total diet replacement (TDR) pattern in Medical Nutrition Therapy. In general, these quantities meet the calculated INL98 (at least 50%) for Vitamin A, Vitamin C, zinc, iron and calcium. When using CDA, ICMR, NDNS and IOM standards, the quantities of flour needed to satisfy the energy requirements fulfills 100 % of the RDA value for vitamin C, zinc and iron. The daily quantities of flour satisfy only 39.9-55.25% of vitamin A retinol equivalent derived from beta carotene. The daily quantities of composite flour satisfy only 0.74-11.722% of apha tocopherol. These results show that apha-tocopherol is the limiting micronutrients.

Discussion

Estimated Energy Requirements were given by most reference organization for people with diabetes on the basis of those of healthy adults. All these references insist on respecting Acceptable Macronutrients Distribution Range (AMDR) as a percent of energy intake for fat, carbohydrate, protein and fibers to ensure a nutritionally balanced adequate diet. They were written in percentages as a preferred middle solution for diets neither too enriched in carbohydrates (around 50% of the energy intake), nor too defatted (30% of the energy intake favoring mono lipid and polyunsaturated sources) and neither too enriched in protein to prevent cardiovascular and renal diseases associated with diabetes complications [1],[33],[31]. By consuming fat and carbohydrates within these ranges, the risk for obesity, as well as for coronary heart disease (CHD) and diabetes, can be kept at a minimum. Furthermore, these ranges allow for sufficient intakes of essential nutrients while keeping the intake of saturated fatty acids at moderate levels [38]. Based on Estimated recommended energy requirements by diabetes organizations, the daily quantities of composite flour to be eaten in order to satisfy the daily allowance in a total diet replacement (TDR) pattern were calculated. Result show that the AMDR for carbohydrates meets all reference standards distributions range at all daily quantities of composite flour needed. Therefore, the daily carbohydrate allowance is largely covered by consumption of daily quantities of composite flour in a total diet replacement (TDR) pattern whatever the references standards. While some organizations like CDA, ICMR or the NDNS continue to advise AMDRs for people with diabetes, the most recent nutritional guideline from the ADA or the Japan Diabetes Society (JDS) on medical nutrition therapy suggest that an ideal carbohydrate/fat/protein ratio does not exist for diabetic patients and should be set individually. In fact, the final objective of diabetes treatment is to reduce weight for obese patient and maintain body weight, blood sugar and lipid levels at an acceptable level in order to avoid additional complications and suppress the progress thereof by maintaining a good metabolic state throughout the body [31],[39]. This target leads some nutritional guides to personalize energy intake by taking into account the fact that the target weight will depend on age, physical activity, the state of metabolism (high blood glucose, dyslipidemia) etc. of patients [39]. In a consensual manner, the Japan Diabetes Society on medical nutrition therapy defines recommendation relating to energy intakes according to an ideal target weight by taking in account age and an energy factor determined according to the level of physical activity [39]. The amount of carbohydrates intake required for optimal health in humans is unknown. If some reference standards guide insist on the minimum RDA (19 years and older) value of 130g/d, it is because this quantity was determined based on the glucose requirements necessary for the proper functioning of the brain. However, this metabolic need can be provided by the body during metabolic processes such as glycogenolysis, gluconeogenesis (via metabolism of the glycerol component of fat or gluconeogenic amino acids in protein), and/or ketogenesis in the setting of very low dietary carbohydrate intake (minimum of 14 g of fiber per 1,000 kcal) [31]. For EASD, a wide range of carbohydrate intakes are acceptable, provided recommendations relating to dietary fiber, sugars (10% of total energy intake), saturated fats (<10% of total energy intake) and protein intakes are met [32]. The regular intake of sufficient quantities of dietary fiber is associated with lower all-cause mortality in people with diabetes [38]. Therefore, people with diabetes should consume at least the amount of fibers recommended by the DGA 2015–2020 (minimum of 14 g of fiber per 1,000 kcal). Regarding recommendations relating to dietary fiber, the consumption of an appropriate amount of composite flour calculated in a total diet replacement (TDR) pattern will largely cover the daily fiber energy density whatever the reference standards. AMDR for protein fulfills standards only for Traditional guidelines for T2DM management and The American Diabetes Association (ADA) guidelines. Proteins into adult body play a crucial role in maintaining and repairing damaged tissues. Insufficient protein intake can lead to malnutrition or sarcopenia or frailty, whereas too high protein intake can cause diet related kidney damage [40]. For this reason, the daily quantity of protein in diabetic's diet should be personalized based on age, weight, nutritional and metabolic status. The ADA and Japan Diabetes Society on medical nutrition therapy personalized the protein requirement allowance as 0.83 and 0.8-1.5 g/kgbw/day respectively. In all cases, the total energy intake should be no less than 0.8 g/kg BW/day and 30–35 kcal/kg BW/day to prevent risk of undernutrition and sarcopenia [4]. If some reference guidelines accept slightly higher values of protein, it is in relation to the general characteristics of the population. In the Jap-

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anese population where the proportion of elderly people is high, the prevalence of sarcopenia and frailty leads in tolerating consumption of slightly higher quantities, notably 1.3 (1.5) g/kg BW/day [39]. In Western and North American societies, the AMDR standard for proteins is low. Indeed, the prevalence of obesity in the diabetic population is very high and the objective of reducing weight is the priority of any Medical Nutrition Therapy. In this case, reduction in protein and carbohydrate intake is important to increase insulin sensitivity in obese and type 2 diabetes patients [32]. EASD advises an energy restriction (840kcal/day) for 12–20 weeks and a step-down approach starting with 4200 kJ/day or 5000 kJ/day (1000–1200 kcal/day) is commonly advocated with obesity. In Cameroon, the percentage of obese people among patients suffering from diet related non-communicable diseases is low (19.2% of adult (aged 18 years and over) women and 7.5% of adult men) [41] and malnutrition even among adults (5.8% of adult women and 6.8% of adult men) exist [42]. For this reason, the consumption of slightly higher quantities of protein should be tolerable but at a threshold where the risks of nephropathy (diabetic kidney disease), malnutrition/sarcopenia and frailty and cardiovascular diseases are reduced. The average daily level of protein intake for people with diabetes without kidney diseases is typically 1–1.5 g/kg body weight/day or 15–20% of total calories [38]. However, some research has found successful management of type 2 diabetes with meal plans including slightly higher levels of protein (20–30%), which may contrib ute to increased satiety [31]. This is a confirmation that AMDR for protein of the composite flour is in conformity with reference standards. AMDR for Lipid fulfills the standards except for ICMR which requires high percentage. In all cases, there are not an optimal percentage of calories from fat for people with or at risk for diabetes [31]. The type of fats consumed is more important than total amount when looking at metabolic goals and CVD risk. However, it is recommended that the percentage of total calories from saturated fats should be limited [31]. Standards guidelines state that dietary fats should come primarily from plant-based foods rich in mono and polyunsaturated fats [32]. Plant proteins are low in saturated fat and support planetary health [31]. Scientific evidences have shown that switching to a more soy-based protein source may improve risk factors for cardiovascular disease [31]. Large epidemiological studies have shown also that consumption of polyunsaturated fats or polyunsaturated fatty acid biomarkers is associated with a lower risk of type 2 diabetes [39]. Consumption of soy is therefore interesting due to its high content of polyunsaturated fatty acids [17]. Soybean stand as the main source of proteins and lipids in the composite flour and multiple benefits could arise after its consumption, thereby improving the nutri-therapeutic value of composite flour with respect to anti-diabetic potential. The use of the glycemic index (GI) and glycemic load (GL) to rank carbohydrate-rich foods based on their effects on blood sugar continues to be of interest to people with diabetes and those at risk for diabetes [38]. Squash stand as the main source of carbohydrates in composite flour and has been found to have a low GI [16]. Therefore, the presence of pumpkin flour in the composite flour enhances the anti-diabetic potential of the composite flour.Though there is no specific recommendation for nutrients and minerals at present, a nutrient deficiency in diabetic patients must be seriously addressed [1]. The composite food contains beta –carotene among pro-vitamin A carotenoids. The biological activity of carotenoids is estimated as retinol equivalent [43]. The retinol equivalent activity of the composite flour meets the requirement of **FAO/WHO** specification (at least 50%) (225RE). Daily quantities of composite flour in a total diet replacement (TDR) pattern satisfy 39.9-55.25% of vitamin A retinol equivalent derived from beta carotene only. A part from provitamin A activity, beta carotene is associated with antioxidant activity. The composite flour contents Vitamin C which exhibits also an antioxidant activity. The content in vitamin C meet the recommended values of at least 50% INL98 (32.258), CDA, ICMR, NDNS and IOM standards. Alpha tocopherol which displays an antioxidant activity is also present in the composite flour even in a low amount. This result shows that the anti-diabetic flour is enrich in antioxidant vitamin. Calcium, iron and zinc as minerals are present in the composite flour. The mineral content meets the INL98 (at least 50%) specifications values for calcium (500) and 49-100% of the other standards. Zinc and iron meet the FAO/WHO specification (at least 50%) for high, medium and low dietary bioavailability and also for others standards values evaluated. Preview study report a high content of polyphenols in cinnamon [14],[15]. Neem leaves contain glycosides, terpenoids and flavonoids as bioactives compounds responsible for anti-diabetic activity [11]. These findings suggest that squash based anti-diabetic formulation have a great potentiality as anti-hyperglycemic flour. The optimal formulation respects the recommended AMDR for macronutrients ensuring by this a nutritionally balanced adequate diet. It can offer several healths' beneficial do to the presence of bioactive compounds. The health benefits of the composite flour regarding antidiabetic activities are likely to result from the additive and synergistic effects of different kinds of phytochemicals able in maintaining ideal blood glucose levels, achieving optimal blood lipid levels, reducing the risk for diabetic complications, and maintaining healthy body weight through a balanced diet. Therefore, it can be used in managing diabetes by preparing adequate anti-hyperglycemic food with flours blended according to the percentage of ingredients stipulated in the optimal formula.

Conclusion

The study has shown that squash based composite flour produced from squash, soybean, cinnamon and neem leaves using optimal formula has a great potentiality as anti-diabetic flour as it can satisfies the recommended AMDR for macronutrients according to reference organizations ensuring a balanced diet. It contains bioactive compounds with scientific based evidence of maintaining ideal blood glucose levels, achieving optimal blood lipid levels, reducing the risk for diabetic complications. Therefore, it can be used in diabetes management as nutraceutical.

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Conflict of interest

No potential conflict of interest relevant to this article was reported.

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