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ORIGINAL PAPER

Blood glucose lowering, glycaemic index, carbohydrate-hydrolysing enzyme inhibitory activities of potential functional food from plantain, soy-cake, rice-bran and oat-bran flour blends

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Abstract

The samples, PLT (100% Plantain), PSC (Plantain 70%, Soycake 30%), PSR (Plantain 65%, Soycake 30%, Rice bran 5%), PSO (Plantain 65%, Soycake 30%, Oat bran 5%) and PSRO (Plantain 60%, Soycake 30%, Rice bran 5%, Oat bran 5%), and CNL (Cerolina—a wheat and soybean blend) were evaluated for glycaemic index (GI)/load (GL), and in vivo antidiabetic potentials. The GI (30.48–35.33) and GL (18.79–21.98) of PSR, PSO and PSRO were lower than PLT, CNL and recommended values for low GI (= < 55%) and GL (= 20%). The PSRO sample (82.72%) had the highest blood glucose reducing activity compared to other blends, PLT and Cerolina. This study established that PSRO (60% plantain, 30% soycake, 5% rice bran, 5% oat bran) exhibited low glycaemic index, glycaemic load, and high blood glucose lowering potential. Hence, PSRO may be suitable as a functional food for the prevention and treatment of Type-2 diabetes.

Keywords Functional foods · Carbohydrate-hydrolyzing enzymes · Blood glucose lowering

Introduction

Diabetes mellitus is a chronic degenerative disease characterized by high blood glucose concentration due to low insulin secretion, insensitivity of the body cell to insulin or both [1]. Epidemiological study has indicated that, the prevalence of diabetes among individual within the age of 20–79 years is increasing, and it is projected that by year 2040, over 600 million people would have been affected [2]. Recent finding has established that Type-2 diabetes is the most common of all the cases of diabetes mellitus in both developed and developing countries, including Nigeria [3]. Lifestyle adjustment such as dietary modification, moderate daily physical activity and regular intake of antidiabetic medication are important to treat diabetes [4]. However, in recent times, synthetic antidiabetic medications have been implicated with several health challenges [5, 6]. This has led to a shift towards the development of non-toxic plant-based functional food as a therapeutical agent for diabetes patients [7]. For instance, researchers have focused on the formulation of functional foods with locally available food materials like plantain, soy-cake, rice-bran, etc. to manage Type-2 diabetes [8–11].

Plantain (Musa ABB) is a staple food and widely cultivated in many parts of the world, including Nigeria. Nutritionally, unripe plantain is a good source of energy, dietary fiber and vital minerals (Fe & K) [12, 13]. In Nigeria, plantain flour is consumed in form of dough meal by the diabetic patients [14]. Medicinally, plantain is consumed to control weight loss and to manage Type-2 diabetes, due to its high resistant starch content and low glycemic index property [15].

Oat-bran is a good source of β-glucan (a soluble viscous polysaccharide), with the property to inhibit glucose absorption and metabolism in the gastrointestinal tract. Hence, decreasing blood glucose concentration by enhancing insulin activities [16]. Rice-bran is a by-product of rice milling industry with many applications in the food industry. Rice-bran has ability to lower blood cholesterol and glucose, which makes it of interest in the formulation of healthy diets [17, 18]. Soy-cake is a by-product of oil extraction and

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usually used in the food formulations. Soy-cake is a good source of protein with a good number of advantages ranging from low cost, ready availability and health benefits. The application of soycake in food formulation particularly with unripe plantain flour has recently been reported [11, 19].

In recent times, several efforts have been shifted towards development of functional foods from locally available food materials [8–11]. Despite all these efforts, there is a scanty information on the development of functional foods from the combination of plantain, oat-bran, rice-bran and soy-cake flour to manage Type-2 diabetes. Likewise, previous studies make used of raw flours developed from raw materials for test on glucose reduction potential, However, the present study used the heat treated or prepared dietary swallow meal for the test in order to ascertain the effectiveness of the developed dietary swallow meal. Therefore, the present study aimed to develop and evaluate nutritional and therapeutic potential of meals from plantain, oat bran, rice bran and soycake for the management of Type-2 diabetics.

Materials and methods

Sources of food sample

Unripe plantain (*Musa ABB*); soy-cake (*Glycine max*); rice-bran (*Oryza sativa*) and oat-bran (*Avena sativa*) were obtained from the Teaching and Research farm of Federal University of Technology, Akure, Nigeria; Rom oil mill factory, Ibadan, Nigeria; Igbimo rice processing company, Aisegba-Ekiti, Nigeria and Richardson Milling Limited, Portage La Prairie, Manitoba (MB), Canada, respectively. Acarbose (a synthetic antidiabetic agent) was purchased from a reputable Pharmaceutical Ltd in Akure, Ondo State, Nigeria. The Albino Wistar rats were obtained from Central Animal House, University of Ibadan, Ibadan, Nigeria.

Processing of flour samples and food formulation

Processing of flour samples

The plantain, soy-cake, oat-bran and rice-bran samples were processed into flour using standard methods. Plantain was manually peeled, sliced into pieces (1 cm thick), blanched in 1.25% $NaHSO_3$ solution to prevent browning at 80 °C for 15 min. and drained [20]. Also, soy-cake, rice-bran and oat-bran were thoroughly cleaned. The food samples were dried in hot-air oven (Plus11 Sanyo Gallenkamp PLC, Loughborough, Leicestershire, UK) at 55 °C for 12 h, milled (Laboratory blender (Model KM 901D; Kenwood Electronic, Hertfordshire, UK) and sieved through no 200 mesh sieve (British Standard). The flour samples were then stored at room temperature (~ 27 °C) until analysis.

Formulation of flour samples

The plantain, soy-cake, rice-bran and oat-bran flour samples were blended using mixture response surface methodology (RSM), Design-Expert® version 10.0.0 (Stat-Ease, Inc., USA) with reference to protein (14 g) and fiber (5 g). After blending, 16 runs were generated from which four blends were selected for further study based on the outcome of preliminary sensory evaluation and ability of the samples to provide 25% of daily requirement of protein (14 g/day) and fibre (5 g/day) for adults. The selected runs were as follows: PSC (Plantain 70%, Soycake 30%), PSR (Plantain 65%, Soycake 30%, Rice bran 5%), PSO (Plantain 65%, Soycake 30%, Oat bran 5%), PSRO (Plantain 60%, Soycake 30%, Rice bran 5%, Oat bran 5%). Cerolina – a wheat and soybean blend (CNL), a commercial dough meal flour produced by More Foods Lagos, Nigeria and 100% Plantain (PLT) were used as control samples.

Preparation of formulated food sample aqueous extracts

The food sample flour (500 g) was extracted exhaustively via marceration for 48 h. with 2.5 L of distilled water. After marceration, the mixture was filtered (Muslin cloth & Whatman No.1 filter paper, Qualitative Circles 150 mm Cat No. 1001 150); and the filtrate was concentrated (Rotary evaporator; Model 349/2, Corning Limited) at 35 °C for 24 h. and thereafter, the filtrate was freeze-dried and the dried extract was stored (~ 27 °C) until required for use.

Determination of macronutrient composition and energy value of developed dietary swallow meals

Proximate compositions (moisture content, total ash, crude fiber, crude fat and crude protein content) of the food samples were determined [21]. Carbohydrate (CHO) content was obtained by difference as follow:

$$CHO(\%) = 100 - (\%Moisture + \%Crude\ fat + \%Total\ ash + Crude\ fibre + Crude\ protein)$$

The calorific value of the food samples was calculated by using Atwater factor values, i.e., carbohydrate content was multiplied by 4, lipid by 9 and protein by 4, and the values were added to obtain the energy value (kcal/100 g) of the food samples.

Determination of α-amylase activity of developed dietary swallow meals

To the experimental food extract solution (500 µL), 0.02 M sodium phosphate buffer (pH 6.9 with 0.006 M NaCl) (500 µL) and hog pancreatic α-amylase (0.5 mg/mL) were added and the mixture was incubated (25 °C, 10 min.). After incubation, 500 µL of 1% starch in buffer solution was added and the mixture was re-incubated (25 °C, 10 min.). The reaction was terminated with addition of 1.0 mL of dinitrosalicylic acid (DNSA), and the mixture was re-incubated in water bath (100 °C, 5 min.), cooled to room temperature and then 10 mL of distilled water was added. The absorbance was measured at 540 nm. (UV–Vis spectrophotometer; Model 6305; Jenway, Barloworld Scientific, Dunmow, United Kingdom). The α-amylase inhibitory activity (%) was calculated [22].

$$Percentage\ inhibition = \left[\frac{\left(Abs_{control} - Abs_{samples}\right)}{Abs_{control}}\right] x100$$

Determination of α-glucosidase activity

$$GI = \frac{Incremental\ area\ under\ 2\ h\ blood\ glucose\ curve\ for\ food\ sample\ (2.0\ g)}{Incremental\ area\ under\ 2\ h\ blood\ glucose\ curve\ for\ glucose\ (2.0\ g)} \times 100$$

of developed dietary swallow meals

To the sample aqueous extracts (50 µL) was added 100 µL of α-glucosidase solution (EC.3.2.1.20) and then incubated at 25 °C for 10 min. Thereafter, 50 µL of 5 mM p-nitrophenyl-α-D-glucopyranoside solution in 0.1 M phosphate buffer (pH 6.9) was added. The mixture was re-incubated (25 °C, 5 min), and the absorbance reading was measured at 405 nm using spectrophotometer. The inhibitory activity of α-glucosidase (%) was calculated [23].

$$Inhibition\ (\%) = \left[\frac{\left(Abs_{control} - Abs_{samples}\right)}{Abs_{control}}\right] \times 100$$

Glycemic index, glycemic load of developed dietary swallow meals

Statement of animal rights

The experiment on the animals were conducted in accordance with the laws and regulations as regards animal use and care reported in the Canadian Council on Animal Care Guidelines and Protocol Review [24].

Determination of glycemic index and glycemic load of developed dietary swallow meals

Experimental animals

Twenty-one Wistar Albino rats (male & female, body weights = 120–150 g) were grouped (3 rats/group), and housed individually in metabolic cages with free access to feed and water. The rats were acclimatized under standard laboratory conditions (22 °C ± 3 °C; 12 h light and dark periods, respectively & humidity- 40–45%) [25]. After 7 d acclimatization, the food samples and glucose (control) in a portion that was calculated to contain 2.0 g of available carbohydrate were dissolved in warm distilled water (40 °C, 5 mL) and administered to the rats through oral gavage. Immediately after the oral feeding, the initial blood glucose concentration of the rat was measured via the tip tail, while the subsequent readings were taken at the interval of 30 min for 120 min. using an automatic glucose analyzer ('Accu-Chek Active' Diabetes monitoring kit; Roche Diagnostic, Indianapolis, USA). The glycaemic Index (GI) (%) for each food sample was calculated by described by Wolever et al. [26].

Calculation of glycaemic load (GL)

The Glycemic Load (GL) for each of the food samples was determined as described by Salmerón et al. [27] using the formula below:

$$GL = \frac{Net\ Carbohydrate\ (g) \times GI}{100}$$

Classification:

Low-GI = < 55%, Medium-GI = 56–69%, and High-GI = > 70% [28].

Low-GL = < 10, Medium-GL = 11–19 and High-GL = > 20 [28].

Evaluation of antidiabetic potential of developed dietary swallow meals in streptozocin-induced diabetic rats

The blood glucose lowering activity of the developed food samples and control (Cerolina & 100% Plantain flour) was evaluated as described by Abu et al. [29]. Male and female Wistar albino rats (40) were fasted overnight and induced with freshly prepared streptozocin (STZ) (150 mg/kg body

weight) in saline solution as described by Abu et al. [29]. After intraperitoneal STZ injection, the rats were allowed to have access to 5% glucose solution to avoid hypoglycemic effects of the drug. The blood glucose concentration of the rats was measured before and after 72 h of STZ administration through tail tipping using glucometer (Accu-Chek, Active, Roche Diagnostic's, Indianapolis, IN, Lot No 115764). The rats with serum glucose concentration of ≥ 250 mg/dL were selected for the study [30, 31]. The diabetes induced rats were grouped into 8 groups per 5 rats each. The rats in six groups were fed on experimental food samples, while the remaining two groups were treated with animal Chow with and without Acarbose (a synthetic antidiabetic agent) for 14 days. The blood glucose concentration of the rats was measured at regular 3-day intervals via tail tipping using Accu chek® Glucometer kit [11].

Data analysis

Triplicate data were analysed using statistical package for social sciences (SPSS version 21) and results were presented as means (± SEM), while differences between means were determined using Analysis of Variance (ANOVA) and Duncan's Multiple Range Test (DMRT), and values were considered as statistically significant at $p < 0.05$ [32].

Results

Nutrient composition of the developed swallow meals

The macronutrient compositions of the developed swallow meals enriched with soycake, rice-bran and oat-bran and control samples are presented in Table 1. The moisture and crude protein content of the food samples varied from 4.20 g/100 g in PLT to 5.43 g/100 g in PSRO and 4.97 g/100 g in PLT and 19.43 g/100 g in PSRO, respectively. The crude fibre content ranged from 1.23 g/100 g in PLT to 5.43 g/100 g in PSR, while energy value ranged from 373.53 kcal/100 g in PSR to 399.99 kcal/100 g in CNL. The moisture contents of the food samples were lower than 10.00 g/100 g recommended for flour sample. The moisture, crude protein and fibre contents of the developed food samples were significantly ($p < 0.05$) higher than control samples (PLT = 4.20, 4.97, 1.23 and CNL = 5.32, 17.91 & 3.34 g/100 g, respectively).

The moisture content of the formulated food samples in this study was close to the value obtained for the control sample and lower than the recommended value for flour samples (< 10 g/100 g) [33]. This implies that the developed products could be stored for a longer time without being spoiled or deteriorated in nutritional quality [34]. It is well established that a non-fatty food product with low moisture content has the ability to be stored for longer period than those with higher moisture content that is > 10 g/100 g [34]. Reports have shown that foods with high moisture content could facilitate the growth and activities of microorganisms, hence, speedy spoilage [33, 34]. The moisture content that was observed in this study was comparable to the values reported by Odebode et al. [10] for plantain-based swallow meal enriched with soybean and rice bran, but lower than the value reported by Famakin et al. [9], Oluwajuyitan and Ijarotimi [11]. The variation between moisture content in this study and other similar studies could be attributed to processing techniques and type of food materials used.

The crude protein content of experimental food samples was significantly ($p \geq 0.05$) higher than that of traditional plantain-based sample (i.e., PLT = 100% plantain), but comparable to that of the control sample (CNL, a commercial dough meal flour for diabetic patients). This finding implies that the developed food products in this study were

Table 1 Proximate composition (g/100 g) and energy value (Kcal/100 g) of plantain, soycake, rice bran and oat bran dough meal and control sample

Samples	PLT	PSC	PSR	PSO	PSRO	CNL	*RDA
Moisture	4.20 ± 0.04^{f}	4.28 ± 0.02^{e}	4.50 ± 0.04^{d}	5.14 ± 0.02^{c}	5.43 ± 0.03^{a}	5.32 ± 0.04^{b}	< 10.00
Total Ash	1.90 ± 0.02^{f}	3.25 ± 0.01^{c}	4.10 ± 0.03^{a}	2.93 ± 0.04^{d}	3.81 ± 0.03^{b}	1.98 ± 0.04^{e}	< 3.00
Crude Fat	1.97 ± 0.02^{e}	4.50 ± 0.01^{d}	5.93 ± 0.05^{d}	5.92 ± 0.05^{c}	6.53 ± 0.03^{b}	8.51 ± 0.04^{a}	10–25
Crude Protein	4.97 ± 0.09^{e}	16.21 ± 0.04^{d}	16.23 ± 0.05^{d}	19.11 ± 0.07^{b}	19.43 ± 0.04^{a}	17.91 ± 0.05^{c}	> 16.00
Crude Fibre	1.23 ± 0.02^{f}	2.11 ± 0.04^{e}	5.43 ± 0.03^{a}	2.91 ± 0.04^{d}	4.58 ± 0.09^{b}	3.34 ± 0.06^{c}	< 5.00
Carbohydrates	85.73 ± 0.05^{a}	69.65 ± 0.04^{b}	63.83 ± 0.05^{d}	63.99 ± 0.07^{c}	60.22 ± 0.03^{f}	62.94 ± 0.08^{e}	64.00
Energy	380.53 ± 0.17^{d}	383.94 ± 0.21^{c}	373.53 ± 0.15^{f}	385.68 ± 0.23^{b}	377.37 ± 0.10^{e}	399.99 ± 0.24^{a}	400–425

Means (± SEM) with different alphabetical superscripts in the same column are significantly different at $p < 0.05$

Key: PLT: 100% Plantain; PSC: Plantain: Soycake (70:30%); PSR: Plantain: Soycake: Rice bran (65:30:5%); PSO: Plantain: Soycake: Oat bran (65:30:5%); PSRO: Plantain: Soycake: Rice bran: Oat bran (60:30:5:5); CNL: 100% Commercial dough meal flour

*RDA: recommended daily allowance[33]

nutritionally better than that of local plantain-based dough meal in terms of protein content. This finding agreed with the report of Odenigbo et al. [35] who reported that plantain is a good source of calories, but deficient in protein. Hence, this justified the complementation of plantain flour with the soy-cake flour (a protein source) to improve nutritional quality of the final food products. This observation agreed with the report of other similar studies [9–11]. It is evident that regular intake of diets high in quality protein is essential in diabetic management [36, 37].

The fibre content of the developed food products was higher than sole plantain flour, and this could be attributed to the inclusion of soycake, oat-bran and rice-bran to the flour blends. The PSR flour sample, i.e., a diet containing plantain and rice bran flour, had higher fibre content compared to other food products; and this indicates that rice-bran is a good source of dietary fibres. The high value of crude fiber that was observed in this present study formulations was in line with the report of Famakin et al. [9], who developed food product from plantain, soy-cake and rice-bran. Scientific studies have revealed that regular dietary fiber intakes delay digestion and absorption of carbohydrates in gastrointestinal tract; and thereby reducing postprandial blood glucose and risks of diabetes [38–40].

α-amylase and α-glucosidase inhibitory activity of the developed dietary swallow meals

The α-amylase and α-glucosidase inhibitory activity of the developed swallow meals and control samples are presented in Fig. 1a, b and IC_{50} values in Fig. 1c, respectively. The α-amylase and α-glucosidase enzyme inhibitory activities of the formulated food samples were increased with increasing concentration (i.e., from 50 to 100 mg/mL) with PLT having the lowest inhibitory activities, while PSRO had the highest inhibitory activity. For the IC_{50}, α-amylase and α-glucosidase enzyme inhibitory activities ranged from 19.11 to 32.82 mg/mL and 20.66 to 36.97 mg/mL in PSRO and PLT, respectively.

The percentage α-amylase and α-glucosidase enzymes inhibitory potential of the developed food samples (Fig. 1a and b) are concentration dependent, that is, as the amount of food samples consumed increased the enzyme inhibitory activities also increased. The PRSO, PSO and PRS samples had higher percentage of enzyme inhibitory activities when compared to that of PSC and PLT sample, respectively (Fig. 1c). This variation could be due to the inclusion of rice-bran and oat-bran into the formulated food samples. Studies have revealed that rice-bran and oat-bran contain bioactive compounds like protein, dietary fibre and β-glucan with the property to inhibit glucose absorption and cholesterol [16]. The α-amylase and α-glucosidase enzyme inhibitory activities of the present study experimental food samples were in line with other scientific studies [9–11]. It is worth noting that PSRO sample (a combination of plantain, soy-cake, rice-bran and oat-bran) had higher α-amylase and α-glucosidase enzyme inhibitory activities when compared with PLT (a traditional plantain based dough meal for diabetic patients) and formulated food samples. This observation could be due to synergetic effects of bioactive compounds in oat-bran and rice-bran, which formed part of the diet components. Scientific studies have established that inhibitor of α-amylase enzyme (hydrolyzes polysaccharides to oligosaccharides) and α-glucosidase enzyme (hydrolyzes oligosaccharides to monosaccharides) are the critical strategy in the treatment of Type-2 diabetes [41, 42].

Glycemic index and load of the developed dietary swallow meals

The in-vivo glycemic index (GI) and glycemic load (GL) of the experimental food samples, and glucose are presented in Fig. 2a–c. The GI of the developed food samples varied from 30.48% in PSO to 40.77% in PSC, while that of CNL was 40.05% and PLT was 42.23% (Fig. 2b). For the GL, the values ranged from 18.79% in PSRO to 27.58% in PSC, while that of CNL and PLT were 24.89% and 35.42, respectively (Fig. 2c).

Dietary glycemic index (GI) (an index use to measure rate at which ingested carbohydrate increase blood glucose within 2 h of intake) and glycemic load (an index of carbohydrate quality and quantity) [24, 28] of the food samples, particularly PSR, PSO and PSRO, were lower than PLT, CNL and recommended values for low GI (= < 55%) and GL (= 20%). This implies that the formulated food samples could only increase the blood glucose slowly; hence they may be classified as low glycaemic index and load foods. Quite a number of studies have shown that consumption of low-GI and GL foods reduce diabetes by increasing insulin sensitivity [27, 43] and weight gain [44, 45]. In contrary, consumption of foods with high GI and GL increase the risk of higher blood glucose concentration [46], hence, development of Type-2 diabetes. The low GI and GL values observed in the present study formulations were in line with other scientific studies that reported on plantain-based food products [9–11, 47].

Antidiabetic activity of developed dietary swallow meals in diabetic-induced rats

The trend and percentage of blood glucose reduction in rats that were fed on developed food samples and control samples were presented in Fig. 3a and b show. The trend in blood glucose concentration of diabetic-induced rats that were fed on developed food samples reduced progressively as the experimental periods and quantity of the food consumed by the

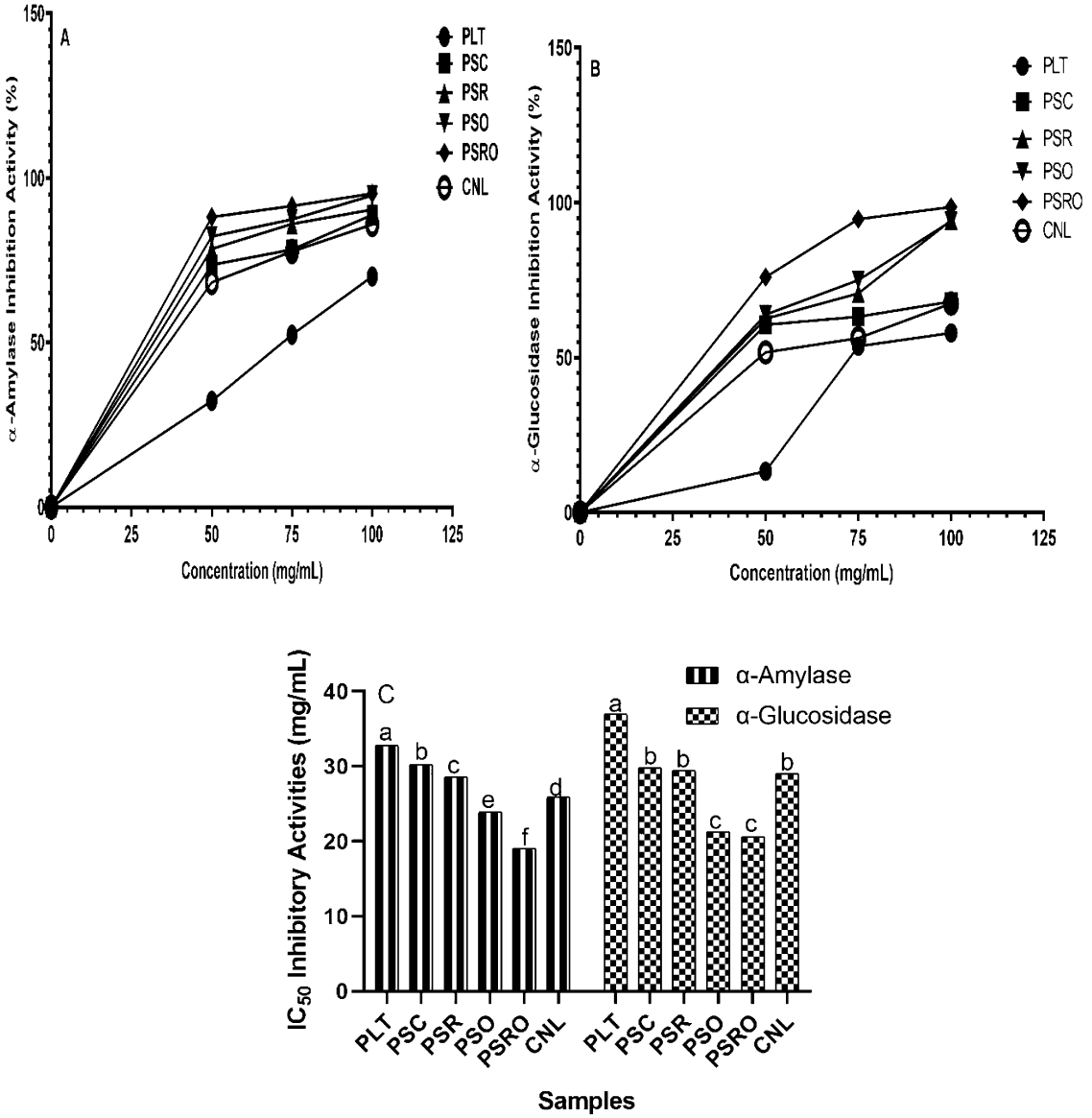

Fig. 1 In vitro α-amylase (%)[A], *α*-glucosidase (%)[B] and IC_{50} inhibitory activities (%)[C] of Plantain, Soycake, Rice Bran and Oat Bran Dough Meal. Key: PLT: 100% Plantain; PSC: Plantain: Soycake (70:30%); PSR: Plantain: Soycake: Rice bran (65:30:5%); PSO: Plantain: Soycake: Oat bran (65:30:5%); PSRO: Plantain: Soycake: Rice bran: Oat bran (60:30:5:5); CNL: 100% Commercial dough meal flour

rats increased (Fig. 3a). For the blood glucose concentration reduction, rats fed on PSRO sample (82.72%) had highest blood glucose reduction; while that of PSC (74.47%) had the lowest blood glucose reduction activity. The blood glucose reduction activities of the developed food samples decreased in this order PSRO > PSO > PSR > PSC. These activities were significantly ($p < 0.05$) higher than in PLT (71.08%) and CNL (67.65%), but were comparable to those rats treated with synthetic anti-diabetic drug (ACA = 73.31%; an Acarbose, synthetic anti-diabetic agent).

The antidiabetic potential of the formulated swallow meals in diabetic-induced rats showed that PSRO sample (Plantain 60%, Soy-cake 30%, Rice-bran 5%, Oat-bran 5%) had higher blood glucose lowering activity compared with other experimental food samples including PLT (100% plantain flour), CNL (Cerolina, a commercial dough meal) and ACA

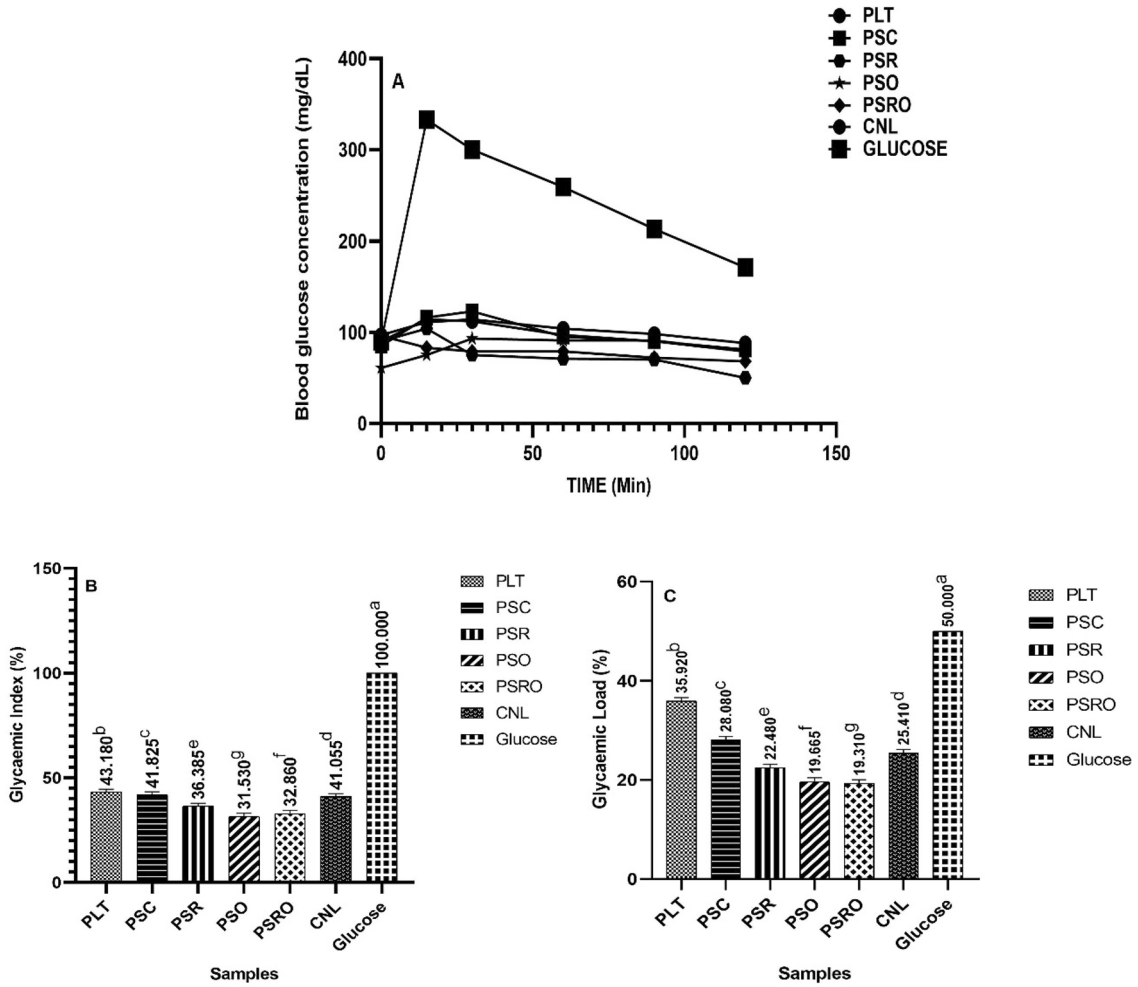

Fig. 2 Glycaemic index (%)[B], Glycaemic Load (%)[C] and Trend in blood glucose concentration (mg/dL)[A], of rat fed on formulated dough meals. Key: PLT: 100% Plantain; PSC: Plantain: Soycake (70:30%); PSR: Plantain: Soycake: Rice bran (65:30:5%); PSO: Plantain: Soycake: Oat bran (65:30:5%); PSRO: Plantain: Soycake: Rice bran: Oat bran (60:30:5:5); CNL: 100% Commercial dough meal

(Acarbose—a synthetic antidiabetic agent). The high percentage of blood glucose lowering activity of PSRO could be attributed to the synergistic effect of bioactive components of the food samples, that is, plantain, soy-cake, oat-bran and rice-bran. It is well known and described that phytochemicals may act preventing diabetes trough inhibition of carbohydrate-related enzymes but also enhancing insulin secretion at beta-cells level [48, 49]. The antidiabetic property of these formulated food samples was in line with other studies that reported on antidiabetic potentials of plantain-based food products [50–52].

Conclusion

The study developed and evaluated nutrient composition and antidiabetic potential of food products from plantain-based enriched with soy-cake, oat-bran and rice-bran. The finding established that the formulated food samples, particularly PSRO (Plantain 60%, Soy-cake 30%, Rice bran 5%, Oat bran 5%) exhibited low glycaemic index/load and higher percentage of blood glucose lowering activities in diabetic-induced rats. Hence, this formulation (PSRO) may be suitable as functional food for the treatment and prevention of Type-2

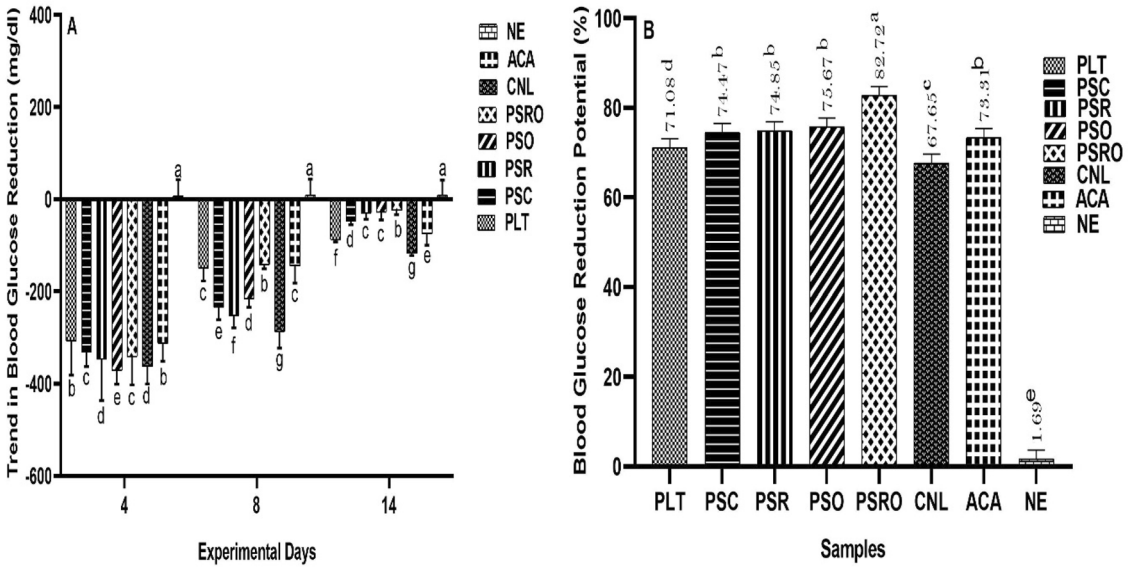

Fig. 3 Trend in blood glucose reduction (mg/dL) [A] and percentage of Blood glucose reduction potential (%)[B] of rat fed on formulated dough meals for 14 days. Key: NE: Streptozotocin (STZ) induced diabetic rat fed with chow; ACA: STZ + Animal Chow + Acarbose; PLT: STZ + 100% Plantain; PSC: STZ + Plantain: Soycake (70:30%); PSR: STZ + Plantain: Soycake: Rice bran (65:30:5%); PSO: STZ + Plantain: Soycake: Oat bran (65:30:5%); PSRO: STZ + Plantain: Soycake: Rice bran: Oat bran (60:30:5:5); CNL: STZ + 100% Commercial dough meal + STZ

diabetes. However, there is a need for clinical trials study to further substantiate antibiotics activity of the product.

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Author contributions OSI & TNF designed the research; while implementation of the research, OSI and TDO did data analyses and manuscript preparation.

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Data availability Data are available on request from authors'.

Declarations

Conflict of interest The authors declared that there were no conflicts of interest for the study.

Consent for publication All authors consent to the publication of this research.

Ethical approval The experiment on the animals were conducted in accordance with the laws and regulations as regards animal use and was approved by the Ethical Committee of School of Agriculture and Agricultural Technology, Federal University of Technology Akure, Nigeria (approval number FUTA/SAAT/2018/021).

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