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Suitability of barnyard millet (*Echinochloa frumentacea*) for development of low glycemic index and hypolipidemic pizza base

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The present study was conducted to formulate low glycemic index pizza base using barnyard millet flour (BMF), analyze its nutrient composition and to evaluate its effect on the lipid profile of rats induced with hyperlipidemia. BMF pizza base was prepared by substituting refined wheat flour (RWF) with 40% of BMF. Incorporation of BMF resulted in significantly ($p<0.05$) higher crude fibre, protein, total ash, total dietary fiber (TDF), antioxidant activity, zinc and iron content in the pizza base in comparison to RWF pizza base. BMF incorporated pizza base with 8.89% of TDF was found to be rich in fiber. To determine the glycemic response and GI, ten non-diabetic adult female participants were administered with of BMF pizza base and pizza on alternate days. BMF pizza base and pizza with GI values of 36.67 and 43.43, respectively were observed as low GI products (<55). In order to analyze the effect of BMF pizza base on the lipid profile, albino rats (induced with hyperlipidemia) were supplemented with BMF pizza base diet for 28 days. Administration of BMF pizza base diet significantly ($p<0.05$) reduced triglyceride level, total cholesterol, very-low-density lipoprotein (VLDL), low-density lipoprotein (LDL) and increased high-density lipoprotein (HDL) level among hyperlipidemic rats. These results validate that the replacement of RWF with 40% of BMF is feasible for the formulation of low GI pizza base which also confers hypolipidemic property.

Keywords: Barnyard millet, Glycemic index, Lipid profile, Nutrient composition, Pizza base

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Diabetes mellitus (DM) is a progressive degenerative disease with several causal factors and characterized by persistent hyperglycemia accompanied with disturbances in the metabolism of macronutrients *viz.,* carbohydrates, fat and protein owing to disturbances in either insulin action or secretion[1]. India has second highest number of cases (69.2 million) of DM in the world after China and the cases are expected to rise to 123.5 million by 2040[2]. Diabetes is a primary risk factor responsible for stroke, heart failure and cardiovascular diseases. Guidelines for the management and prevention of diabetes primarily focus on maintaining the normal blood levels of glycated haemoglobin (HbA_1c), low density lipoprotein and cholesterol[3]. A meta-analysis of about 102 prospective studies revealed that the diagnosis of diabetes in the patients is often associated with the additional risk for CVDs[4].

In India, an enormous shift in the socio-economic growth in the last few decades has escalated the problem of diabetes. Intake of low fibre, high GI (glycemic index) food and sedentary life style are the major modifiable risk factors responsible for type-2 DM. Therefore, dietary modification is very crucial for the management of diabetes and in this context, inclusion of low GI foods has become a concept of prime importance since it helps in reducing fasting blood glucose level, total cholesterol, LDL level and the risk of CVDs[5].

With the massive rapid industrialization in India, fast foods, baked goods and ready to eat foods consumption has escalated among consumers. Breads, buns, muffins, cookies and pizza are some of the most relished baked goods available at market. According to market trends, pizza is one of the most relished ready meals among large number of populations all over the world[6]. It is prepared with refined wheat flour (RWF) and contains

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high amount of calories, fat and sodium and that is why not suitable for patients with diabetes and CVDs[7]. However, incorporation of other nutritious cereal grains may be of great significance in increasing the nutritive value of such food items.

Barnyard millet is one such oldest multi-purpose millet grain which is nutritionally superior to most commonly consumed cereal grains *viz,*; wheat, maize and rice[8]. Barnyard millet is considered a healthy protein source with sulphur containing amino acids, micronutrients, phytochemicals like dietary fibre and antioxidants. Therefore, barnyard millet flour (BMF) as a partial replacement of refined wheat flour may be considered as an effective strategy for the formulation of dietary fibre rich and low GI pizza base. Information available on nutritious pizza base and pizza formulations is scanty. Earlier, soy protein isolate and wheat fibre, soy paste, agathi leaves and peanut flour were used with emphasis on nutritious pizza base formulation[9-11]. Some of the latest researches include optimization of "multi-fabaceae pizza base (Kumar *et al*.[12]), pearl millet and chia seed pizza base (Gulia and Kawatra[13]) and grape skin and seed flour added pizza base (Difonzo *et al.*[14])". Although, few recent studies are based on utilization of millets for pizza base optimization however, all of the aforementioned researches have focused only on nutritional composition, sensory, texture evaluation and SEM analysis. None of these studies have included any clinical trial on the glycemic index and hypolipidemic effect of pizza bases.

Therefore the aim of the current study was (1) formulation of barnyard millet flour (BMF) incorporated pizza base, pizza and its nutritional evaluation (2) assessment of glycemic index (GI) of RWF pizza base, pizza and BMF pizza base, pizza among non-diabetic adult females, and (3) evaluation of effect of RWF pizza base and BMF pizza base diet among rats induced with hyperlipidemia.

Materials and Methods

Procurement of raw materials for study

The barnyard millet (*Echinochloa frumentacea*) variety PRJ-1 was acquired from Pauri Garhwal, Uttarakhand. Guar gum powder was purchased from Ganpati Global Pvt. Ltd., Jaipur, India. Yeast and GMS were acquired from Rich Cream Pvt. Ltd. Kashipur, India. Other raw ingredients namely refined wheat flour, sugar and oil were procured from local shops in Pantnagar market, Uttarakhand, India.

Formulation of barnyard millet flour (BMF)

Barnyard millet grains were made clean of chaff and grit followed by pearling with the help of Vivek Mandua Thresher/Pearler-1, Punjab Agricultural Implements Pvt. Ltd. Pearled grains were then milled into flour using Atta Master by Navdeep Pvt. Ltd. followed by sieving.

Pizza base and pizza formulation

Refined wheat flour (RWF) pizza base was prepared with 100% of RWF. BMF incorporated pizza base was prepared by replacing 40% refined RWF with BMF using the method of Chauhan *et al*.[15] with slight variations. In the present study pizza base with 40% BMF was selected based on the results of sensory analysis[16] (score card and Hedonic scale method) for its nutritional quality evaluation and to study the effect on glycemic index and lipid profile of rats with hyperlipidemia.

Method

Yeast (3 g) was dissolved in lukewarm water (38°C) followed by addition of sugar (5 g). Flour (100 g) was sieved and then fermented yeast, guar gum (1 g) and glycerol mono stearate (3 g) were added into it. Thereafter, all the ingredients were kneaded well with sufficient amount of water. Oil (5 mL) was then added and kneaded again till soft and smooth dough was made. Dough was covered and kept in a dry place at approximately 35°C for 1 h to allow it to double its size. After 1 h, dough was kneaded again gently with 5 mL of oil and divided into portions. Dough was then rolled into thin rounds on a lightly floured surface (4 mm thickness). Thin rounds were covered and kept in a dry, warm place (32°C temperature) to rise again approximately for half an hour. Pizza base was poked with the help of fork (to stop the rising during baking) and baked in a preheated oven at 150°C temperature for 10 min.

Further, RWF pizza and BMF pizza were prepared by adding 50 g of onion and capsicum each, 25 g of tomato, 1 tbsp pizza sauce and 20 g of mozzarella cheese as toppings followed by baking in preheated oven at 200°C for 15 min.

Nutrient composition of RWF pizza base and BMF pizza base

For the nutrient analysis, RWF pizza base and BMF pizza base were crushed and dried in hot air oven at 50°C temperature for 60 min. It was grinded afterwards into fine powder and subjected to analysis. Proximate composition (moisture, crude fat, fiber, protein, total ash) and calcium content were analyzed using AOAC[17] standard methods. Carbohydrate and

physiological energy value were determined as per the following given equations:

% Carbohydrate = 100 – [moisture (%) + ash (%) + crude fat (%) + crude protein (%) + total dietary fiber (%)];

Physiological energy value (Kcal/100g) = [Carbohydrate (%) × 4 + Protein (%) × 4 + Fat (%) × 9 + total dietary fiber (%) × 2]. Minerals namely iron, copper and zinc were determined as per the standard method of Raghuramulu *et al*[18]. Total Dietary Fibre (TDF) was analyzed according to standard procedure given by Asp and Johansson[19]. Total antioxidant activity was estimated by DPPH method as illustrated by Brand-William *et al*.[20].

Evaluation of glycemic index of RWF pizza base and BMF pizza base, RWF pizza and BMF pizza

Subjects and study design

To evaluate the glycemic response of products, a signed informed consent form was taken from ten healthy adult females between 23-29 years of age who were residing in Golden Jubilee Hostel, GBPUAT, Pantnagar, Uttarakhand. Food intake of subjects was assessed by three day estimated food record method given by Gibson[21] followed by nutrient calculation[22]. Height, body weight, blood pressure and body mass index (BMI) were also measured. Inclusion criteria for the study included no previous history of any chronic and acute disease, no pregnancy and no intake of any kind of medication. On the first day, overnight fasted participants were subjected to glucose tolerance test (GTT). The subjects were given glucose solution (50 g glucose dissolved in 200 mL water) and were briefed to ingest it within 15 min and to refrain from any kind of physical activity throughout the experiment. Thereafter, blood glucose level was measured at 30 min interval up to 150 min (0, 30, 60, 90, 120 and 150 min) using glucometer (Accu-Chek Active by Roche Diagnostics). On every alternate day, 10 overnight fasted participants were served with one type of pizza base and pizza containing 50 g carbohydrate with 200 mL of water. For 50 g equicarbohydrate portion, 78.91 g of RWF pizza base, 103.01 g of BMF pizza base and 121.73 g of RWF pizza, 145.67 g of BMF pizza was served. The blood glucose level was checked initially (0 min) and at 30, 60, 90, 120 and 150 min after ingesting the food product. The study design was approved by the University Ethics Committee for Human research (Approval No. UECHR/2016/05/8) of GBPUAT, Pantnagar, Uttarakhand, India.

Estimation of glycemic response and glycemic index (GI) of food products

For estimating glycemic response and GI of RWF pizza base and BMF pizza base the incremental area under the blood glucose response curve was determined as per method described by Wolever[23].

Evaluation of the hypolipidemic effect of RWF pizza base and BMF pizza base

Design of animal study

Thirty five healthy young albino rats of both genders weighing 200-250 g each were procured from Indian Veterinary Research Institute (IVRI), Bareilly, India. The groups of rats were kept separately in cages at controlled laboratory conditions (RH 60-70% and temperature 26-30°C) and were allowed to acclimatize for one week in controlled laboratory conditions before administration of experimental diets. Rats were divided into five groups at random, each with seven rats as follows: Group C1: (negative control) was fed standard basal diet, Group C2: (positive control) received high fat diet, Group M: given standard hypolipidemic drug "atorvastatin" with high fat diet[24], Group P1: fed on RWF pizza base at the rate of 30% of the total diet with high fat diet, Group P2: received BMF pizza base with high fat diet at the same rate. Hyperlipidemia in the rats was induced by supplementing basal diet with high fat *i.e.,* 2 g/kg body weight butter (Amul) every day. High fat food was given to all experimental animals except group C_1 throughout the study. All the rat groups were given experimental diet for a period of 28 days. On the 29th day, blood sample was taken from the tail vein of overnight fasted rats. Further, serum was prepared from the blood samples[25] and then analyzed for triglyceride level, total cholesterol, very-low-density lipoprotein, low-density lipoprotein and high-density lipoprotein using commercial diagnostic kits of Erba. Approval for the study protocol was taken from Institutional Animal Ethics Committee (Approval no. IAEC/2016/12/276) of GBPUAT, Pantnagar, Uttarakhand, India.

Statistical analysis

All the results were presented in terms of mean ± standard deviation. One-way ANOVA was applied to analyze the significant difference in the nutrient composition of BMF pizza base and RWF pizza base. To measure the significance of hypolipidemic effect and glycemic response of control RWF pizza base, pizza and BMF pizza base, pizza, one-way ANOVA was used at $p<0.05$ level of significance.

Table 1 — Nutrient composition of control RWF pizza base and BMF incorporated pizza base on dry weight basis

Nutrient	Refined wheat flour pizza base RWF:BMF::100:0	Barnyard millet incorporated pizza base RWF:BMF::60:40
Moisture (%)	24.27±0.15^b	30.40±0.21^a
Total ash (%)	0.55±0.023^b	2.23±0.027^a
Crude protein (%)	10.78±0.29^b	14.04±0.19^a
Crude fat (%)	4.18±0.034^b	8.86±0.034^a
Crude fibre (%)	0.82±0.017^b	5.14±0.101^a
Carbohydrate (by difference)	54.74±0.23^a	35.58±0.20^b
Energy value (Kcal/100 g)	310±0.10^a	296±0.32^b
Calcium (mg/100 g)	22.66±0.31^a	18.04±0.14^b
Iron (mg/100 g)	4.10±0.02^b	6.82±0.02^a
Copper (mg/100 g)	0.51±0.01^a	0.36±0.01^b
Zinc (mg/100 g)	0.93±0.27^b	5.33±0.32^a
Insoluble dietary fibre (%)	3.22±0.13^b	5.61±0.10^a
Soluble dietary fiber (%)	2.26±0.11^b	3.28±0.14^a
Total dietary fiber (%)	5.48±0.24^b	8.89±0.19^a
Total Antioxidant activity (%)	10.77±0.23^b	41.89±0.37^a

* Values expressed are mean ± standard deviation of triplicate observations
* Means in each row having different superscripts differ significantly ($p<0.05$)

Results

Nutrient composition of RWF pizza base and BMF incorporated pizza base

The nutrient composition of RWF pizza base and BMF incorporated pizza base has been summarized in Table 1. BMF pizza base prepared with 40% BMF and 60% RWF exhibited significantly ($p<0.05$) higher values of moisture, total ash, crude fat, protein, fibre and minerals (iron and zinc) when compared with RWF pizza base. Incorporation of 40% of BMF resulted in 30% increase in crude protein content, five-fold increase in crude fibre and zinc content and 66% increase in iron content when compared with RWF pizza base. Total dietary fibre content including insoluble and soluble dietary fibre was also significantly high ($p<0.05$) in BMF incorporated pizza base (up to 62% increase). TDF content in BMF pizza base was recorded as 8.89% therefore it can be categorized as a dietary fibre rich product[26]. Four-fold increase in the total antioxidant activity was also observed in BMF pizza base as compared to RWF pizza base.

Glycemic index of RWF pizza base and BMF pizza base, RWF pizza and BMF pizza

The glycemic index of RWF pizza and BMF pizza base was analyzed on 10 healthy female subjects of 23-29 years of age. Various parameters namely height, weight, blood pressure and BMI of the volunteers were recorded. Height and weight of the subjects ranged from 152.4 to 162 cm and 46.5 to 64 kg, respectively. BMI values were calculated using weight and height and observed in the range of 18.16 to 26.56 kg/m^2. All the subjects were found to have normal blood pressure and were free from diseases and not taking any kind of medication. The subjects were also analyzed for average daily dietary intake using 24 h recall method. The average daily protein, fat carbohydrate, and energy intake of the subjects was recorded as 39.19 g, 41.14 g, 259.06 g and 1736 Kcal/100 g, respectively.

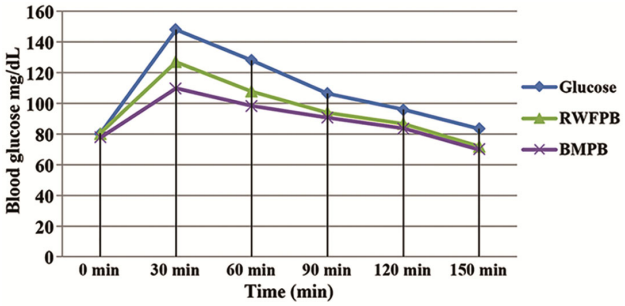

Fig. 1 — Blood glucose response curve for RWF pizza base (RWFPB) and BMF pizza base (BMFPB) against glucose

Data illustrated in Figure 1 & 2 shows elevation in the blood glucose concentrations at different time intervals (0 to 150 min) after the intake of RWF pizza base and BMF pizza base, RWF pizza and BMF pizza against glucose intake. A significant rise in the postprandial glucose levels was seen at 30 min, accounting the maximum glucose elevation for glucose (148.2±4.29 mg/dL) followed by RWF pizza base and BMF pizza base; RWF pizza and BMF pizza respectively (Fig. 1 & 2). However, highest peaks of blood glucose levels for RWF pizza and BMF pizza were observed at around 90 min followed by a

Table 2 — Incremental area under curve (IAUC) and glycemic index (GI) for glucose, RWF pizza base and BMF incorporated pizza base; RWF pizza and BMF pizza

Food Product	Available CHO (g/100 g) (portion size in g)	IAUC (mg min/100 mL) (mean ± SD)	Glycemic index (mean ± SD)
Glucose	50 (50 g)	4898±383.91[a]	100[a]
Pizza base			
RWF pizza base	50 (78.91 g)	2846.5±422.04[b]	58.06±5.97[b]
BMF pizza base	50 (103.01 g)	1797±316.05[c]	36.67±5.66[c]
Pizza			
RWF pizza	50 (121.73g)	3000±374.17[b]	61.22±5.40[b]
BMF pizza	50 (145.67 g)	2157±238.62[c]	43.43±5.17[c]

* Values expressed are mean ± standard deviation of ten observations
* Means in each column having different superscripts differ significantly ($p<0.05$)

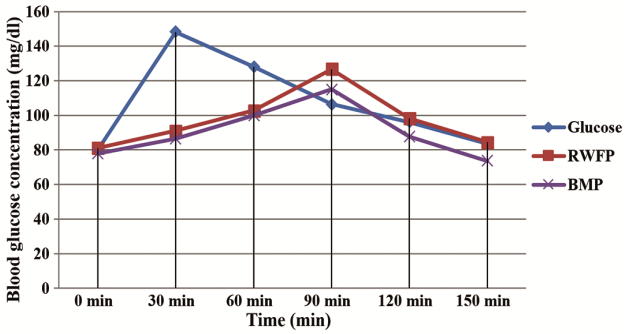

Fig. 2 — Blood glucose response curve for RWF pizza (RWFP) and BMF pizza (BMP) against glucose

gradual decrease until 150 min (Fig. 2). As shown in Table 2, incremental area under curve (IAUC) of glucose (4898±383.91) was significantly larger as compared to IAUC of other products. Analyzed IAUC values were used to calculate the GI of RWF pizza base and BMF pizza base; RWF pizza and BMF pizza. In the present study BMF pizza base (GI: 36.67) and BMF pizza (GI: 43.43) were categorized as low GI (≤ 55) products, whereas RWF pizza (GI: 58.06) and RWF pizza (GI: 61.22) were categorized as medium GI products (55-69) as per the classification given by Atkinson *et al.*[27].

Effect of RWF pizza base and BMF pizza base diet on body weight and lipid profile of experimental rats

The data summarized in Table 3, demonstrated that all the tested groups showed improved weight gain with different degrees after feeding different experimental diets for 28 days. Rats fed with basal diet (C1) and BMF pizza base diet (P2) showed lowest weight gain while rats fed with high fat diet (C2) and RWF pizza base diet (P1) exhibited maximum weight gain. Intake of RWF pizza base diet (P1) resulted in significantly (<0.05) higher weight gain than BMF pizza base diet (P2).

The effect of different experimental diets on the lipid profile of tested rats has been concluded in Table 4. Basal diet given to group C1 had the best effect among all the experimental diets in improving lipid profile followed by high fat diet with drug atorvastatin (group M) and BMF pizza base diet (group P2). On the contrary, high fat diet given to group C2 was recorded to impose the most adverse effect on lipid profile followed by RWF pizza base diet given to group P1. Comparison of P1 and P2 group showed that intake of BMF pizza base diet (P2) had significantly better effect on lipid profile as it significantly (<0.05) decreased triglyceride level, total cholesterol, LDL cholesterol, VLDL cholesterol but increased the HDL cholesterol level when compared with RWF pizza base diet (P1).

Discussion

Barnyard millet is one of the oldest millet crops indigenous to semi-arid and tropical regions of Asia and Africa. This drought-resistant and multipurpose crop is used for food and fodder for people and animals living in these regions[28]. In terms of nutritional importance, nutritionally superior to most commonly consumed cereal grains *viz.;* wheat, maize and rice. It is documented to have 6-13 % protein, 2-4.7% of total ash, 12.6-14% of dietary fibre, 5-15.2 mg/100 g of iron, 3 mg/100 g of zinc content and 86.7 mg/mL DPPH activity[29,30]. Therefore, addition of barnyard millet flour resulted in remarkably nutritious pizza base in the present study, specifically in terms of crude protein, crude fibre, dietary fibre, iron, zinc and antioxidant activity. In a previous study Glicerina *et al.*[10] prepared soy and fibre incorporated pizza base and reported significantly lower nutritional value than the BMF pizza base formulated in the present study. Gupta *et al.*[9] also formulated soy protein isolate and psyllium husk added

Table 3 — Effect of different experimental diets on body weight of rats

Group	Initial weight (g)	Final weight (g)	Gain in weight (g)
C1	223.43±15.99	242.57±14.99	19.14±2.79^{b}
C2	234±21.26	262±21.01	28±1.63^{a}
M	227.14±20.55	246.57±19.07	21.14±1.57^{b}
P1	229.43±15.57	256.29±15.72	27.14±1.95^{a}
P2	232.57±12.95	253.14±13.41	19.44±2.27^{b}

* Values expressed are mean ± standard deviation of seven observations
* Means in each column having different superscripts differ significantly ($p<0.05$)
*C1: on basal diet, C2: on high fat diet, M: on standard hypolipidemic drug, P1: on refined wheat flour pizza base diet, P2: on barnyard millet incorporated pizza base diet
*n=7 in each group

Table 4 — Effect of different experimental diets on the lipid profile of rats

Group	Total cholesterol (mg/dL)	Triglycerides (TG) (mg/dL)	HDL Cholesterol (mg/dL)	LDL Cholesterol (mg/dL)	VLDL Cholesterol (mg/dL)
C1	136.74±1.37^{e}	113.73±2.55^{d}	57.58±0.97^{a}	56.42±1.82^{e}	22.75±0.52^{d}
C2	338.27±21.06^{a}	267.10±81.07^{b}	35.39±4.72^{c}	249.46±9.57^{a}	53.42±16.21^{b}
M	151.90±11.88^{d}	116.79±0.33^{d}	46.71±2.19^{b}	81.83±9.63^{d}	23.36±0.06^{d}
P1	301.82±16.72^{b}	285.13±46.79^{a}	38.24±5.36^{c}	206.55±12.71^{b}	57.03±9.36^{a}
P2	202.06±27.82^{c}	173.37±19.13^{c}	44.33±1.31^{b}	123.06±25.31^{c}	34.67±3.83^{c}

* Values expressed are mean ± standard deviation of seven observations
* Means in each column having different superscripts differ significantly ($p<0.05$)
C1: on basal diet, C2: on high fat diet, M: on standard hypolipidemic drug, P1: on refined wheat flour pizza base diet, P2: on barnyard millet incorporated pizza base diet
*n=7 in each group
*HDL: High-density lipoprotein, LDL: Low-density lipoprotein, VLDL: Very-low-density lipoprotein

pizza base with similar nutrient composition. In some of the previous studies, baked products like muffins, breads and cookies exhibited significant increase in nutrient content on incorporation of barnyard millet[31,32]. Gulia and Kawatra[13] in a recent study prepared pearl millet and chia seeds based pizza base and observed comparatively higher moisture, fat, crude fiber and calcium content.

Several researchers have illustrated beneficial effects of various nutrients in controlling postprandial hyperglycemia and improving insulin sensitivity in diabetic patients. Intake of high protein diet from plant sources due to amino acid stimulation of insulin secretion[33] and delayed starch digestion[34] lowers the postprandial hyperglycemia and decreases the risk of type-2 DM[35]. Soluble dietary fiber owing to its ability to delay carbohydrate digestion and absorption reduces postprandial blood glucose levels[36]. Therefore, keeping the beneficial health effects of dietary fibre in mind ICMR has suggested intake of 40 g/2000kcal/day of dietary fibre for long-term good health[37]. In addition, the WHO Committee on chronic degenerative diseases has suggested consumption of 30 g dietary fiber each day, for prevention of life threatening degenerative diseases[38].

Other than protein and dietary fibre, sufficient zinc intake because of its oxidative stress lowering property has also been recognized to improve the insulin sensitivity among type-2 DM patients[39].

Zinc is a vital element required for insulin synthesis in pancreatic β-cells. It also functions as a co-factor for significant antioxidant enzymes necessary for antioxidant defence system of body *viz*, superoxide dismutase, glutathione peroxidase. Hence, its deficiency may interrupt insulin production and promote oxidative stress[40].

In addition, the phenolic components present in barnyard millet have been illustrated to possess antioxidant capacity and inhibitory effects on α-glucosidase and α-amylase enzymes that are associated with postprandial hyperglycaemia[41].

In the present study BMF pizza base (GI: 36.67) and BMF pizza (GI: 43.43) were categorized as low GI (≤ 55) products, whereas RWF pizza (GI: 58.06) and RWF pizza (GI: 61.22) were categorized as medium GI products (56-69)[21]. However, Vijaykumar *et al.*[42] formulated noodles with 20% barnyard millet flour and observed significant reduction in the GI value of noodles (84.6) as compared to the GI value of market noodle (93.3). In a similar study, slightly higher GI (59) and predicted GI (68.43) values were reported for barnyard millet based health food and flat bread by Surekha *et al*.[43] and Sharma and Gujral[44], respectively. Foods

with low GI are considered to confer benefit as they result in remarkably low glycemic response after ingestion, in comparison to medium GI (56-69) and high GI (≥70) foods. Intake of low GI foods (≤55) not only improves the glycemic control but also lower the chances of type-2 diabetes and CVDs[45].

Barnyard millet is considered an exceptional dietary fibre source which may be the reason for its hypolipidemic property[26]. The hypolipidemic property of dietary fiber is correlated to the ability of SDF to undergo bacterial fermentation in colon and produce compounds like acetate, propionate and butyrate, which inhibit cholesterol synthesis. Regarding hypolipidemic property of barnyard millet incorporated food products, none of the studies have been carried out till date. To best of authors' information, this is the first study that focuses on analyzing the suitability of barnyard millet for development of hypolipidemic food product. However, Ugare *et al*.[30] in his work investigated the effect of dehulled and heated barnyard millet grains intake for 28 days, among non-diabetic and diabetic volunteers and reported substantial drop in glucose level with improved lipid profile among participants. In another study, Surekha *et al*.[43] prepared a health food using barnyard millet which had hypolipidemic and hypoglycemic properties.

Conclusions

BMF was found highly suitable for the formulation of nutritious pizza base. BMF pizza base with 40% BMF had significantly ($p<0.05$) higher amount of protein, total ash, crude fibre, TDF, iron, zinc and total antioxidant activity than RWF pizza base. BMF pizza base with 8.89% of dietary fiber met the standard of fiber rich food product (≥6%). BMF pizza base and pizza were found as low GI foods (≤55) whereas RWF pizza base and pizza were found to have medium GI (56-69). In addition, administration of BMF pizza base diet was found to be more effective in improving lipid profile in experimental rats as compared to RWF pizza base diet.

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Conflict of Interest

The authors have declared that they have no conflict of interest.

Author Contributions

RS and SS planned the current research work. RS conducted all the experiments, calculations and results analysis. RS and PT contributed in manuscript writing under the critical supervision of SS.

References

1 World Health Organization, Global report on diabetes, WHO, (Geneva), 2016, p. 90.
2 International Diabetes Federation, IDF diabetes atlas, International Diabetes Federation. (Brussels), 2015, p. 144.
3 American Diabetes Association, Cardiovascular disease and risk management, *Diabetes Care*, 39 (1) (2016) 60-71.
4 Sarwar N, Gao P, Seshasai S R, Gobin R, Kaptoge S, *et al.,* Emerging risk factors collaboration diabetes mellitus, fasting blood glucose concentration, and risk of vascular disease: a collaborative meta-analysis of 102 prospective studies, *Lancet*, 375 (9733) (2010) 2215-2222.
5 Zafar M I, Mills K E, Zheng J, Regmi A, Hu S Q, *et al.,* Low glycemic index diets as an intervention for diabetes: A systematic review and meta-analysis, *Am J Clin Nutr*, 110 (4) (2019) 891-902.
6 Nielsen S J, Siega-Riz A M & Popkin B M, Trends in energy intake in U. S. between 1977 and 1996: similar shifts seen across age groups, *Obes Res*, 10 (5) (2002) 370-378.
7 Gallus S, Tavani A & La Vecchia C, Pizza and risk of acute myocardial infarction, *Eur J Clin Nutr*, 58 (11) (2004) 1543-1546.
8 Bora P, Ragaee S & Marcone M, Effect of parboiling on decortication yield of millet grains and phenolic acids and in vitro digestibility of selected millet products, *Food Chem,* 274 (2019) 718-725.
9 Gupta C S, Jeyarani T & Rajiv J, Rheology, fatty acid profile and quality characteristics of nutrient enriched pizza base, *J Food Sci Technol*, 52 (5) (2015) 2926-2933.
10 Glicerina V, Balestra F, Capozzi F, Dalla Rosa M & Romani S, Influence of the addition of soy product and wheat fibre on rheological, textural and other quality characteristics of pizza, *J Texture Stud*, 49 (4) (2018) 415-423.
11 Sumana A & Aruna M, Formulation and quality evaluation of agathi (*Sesbania grandiflora* (L.) Poir) leaves enriched pizza base a healthier substitute for the regular pizza base, *Int J Home Sci*, 3(2) (2017) 383-386.
12 Kumar R, Chandrashekar S, Kathalsar A K & Prabhasankar P, Multi-fabaceae flour for gluten-free pizza base: Rheology, processing, microstructural, and physico-sensory characteristics, *J Food Process Preserv*, 46 (2) (2022) e16239.
13 Gulia S & Kawatra A, Evaluation of pizza base prepared with pearl millet and Chia seeds: A healthy alternative, *Pharma Innov J,* 7 (7) (2022) 7.
14 Difonzo G, Troilo M, Allegretta I, Pasqualone A & Caponio F, Grape skin and seed flours as functional ingredients of pizza: Potential and drawbacks related to nutritional, physicochemical and sensory attributes, *LWT*, 175 (2023) 114494.

15 Chauhan G S, Zillman R R & Eskin N A M, Dough mixing and bread making properties of quinoa-wheat flour blends, *Int J Food Sci Technol*, 27 (6) (1992) 701-705.

16 Shrestha R, *Suitability of finger millet & barnyard millet incorporated pizza base in diabetes and cardiovascular diseases*, Thesis (2017) Doctor of Philosophy, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India. URL:http://krishikosh.egranth.ac.in/handle/1/5810055863.

17 AOAC, Official methods of analysis of Association of Official Analytical Chemists, 17th edn, (Washington, DC), 2000.

18 Raghuramulu N, Nair K M & Kalyanasundaram S, A manual of laboratory techniques, National Institute of Nutrition, (ICMR Hyderabad), 2003.

19 Asp N G & Johansson C G, Techniques for measuring dietary fibre: Principle aims of method and comparison of results obtained by different techniques, In: *The Analysis of Dietary Fiber in Food*, edited by James W P T Theander, O Eds & Marcel Dekker, (New York), 1981, p. 173.

20 Brand-Williams W, Cuvelier M E & Berset C L W T, Use of a free radical method to evaluate antioxidant activity, *LWT-Food Sci Technol*, 28 (1) (1995) 25-30.

21 Gibson R S, Anthropometric assessment of growth. In principles of nutritional assessment, (USA: Oxford University Press), 1999, p. 165-170.

22 Gopalan C, Ramasastri B V & Balasubramanian S C, Nutritive value of Indian Foods, National Institute of Nutrition, Indian Council of Medical Research, (Hyderabad), 2007.

23 Wolever T M S, Effect of blood sampling schedule and method of calculating the area under the curve on validity and precision of glycemic index values, *Brit J Nutr*, 91 (2) (2004) 295-301.

24 Nvl S R, Aveti, Ganga Raju M & Anjum M, Anti-hyper-lipidemic activity of methanolic extract of Syzygium alternifolium bark against high-fat diet and dexamethasone-induced hyperlipidemia in rats, *Asian J Pharm Clin Res*, 8 (6) (2015) 165-168.

25 Omole J O & Ighodaro O M, Comparative studies of the effects of egg yolk, oats, apple and wheat bran on serum lipid profile of wistar rats, *Int Sch Res Notices,* (2012). http://dx.doi.org/10.5402/2013/730479

26 FSSAI, 2018, Food Safety and Standards (Advertising and Claims) Regulations (FSSAI, New Delhi), 2018, p. 27.

27 Atkinson F S, Foster-Powell K & Brand-Miller J C, International tables of glycemic index and glycemic load values: 2008, *Diabetes Care*, 31 (12) (2008) 2281-2283.

28 Raju P, Chockalingam V, Vetriventhan M & Gnanamalar R P, Shanmugasundaram R & Ramalingam J, Genetic variability of early flowering and yield contributing traits in Barnyard Millet (*Echinochloa frumentacea* (Roxb). Link] grown at different altitudes, *Indian J Exp Biol*, 60 (02) (2022) 131-136.

29 Longvah T, Ananthan R, Bhaskarachary K & Venkaiah K, Indian Food Composition Tables, National Institute of Nutrition (ICMR), (Hyderabad, India), 2017.

30 Ugare R, Chimmad B, Naik R, Bharati P & Itagi S, Glycemic index and significance of barnyard millet (*Echinochloa frumentacae*) in type II diabetics, *J Food Sci Technol*, 51 (2) (2014) 392-395.

31 Goswami D, Gupta R K, Mridula D, Sharma M & Tyagi S K, Barnyard millet based muffins: Physical, textural and sensory properties, *LWT - Food Sci Technol*, 64 (1) (2015) 374-380.

32 Verma S, Srivastava S & Tiwari N, Comparative study on nutritional and sensory quality of barnyard and foxtail millet food products with traditional rice products, *J Food Sci Technol*, 52 (8) (2015) 5147-5155.

33 Srilakshmi B, *Dietetics*, (New Age International Publication, India), 2011, p. 307-334.

34 Beasley J M & Wylie-Rosett J, The role of dietary proteins among persons with diabetes, *Curr Atheroscler Rep*, 15 (9) (2013) 348.

35 Malik V S, Li Y, Tobias D K, Pan A & Hu F B, Dietary protein intake and risk of type 2 diabetes in US men and women, *Am J Epidemiol*, 183 (8) (2016) 715-728.

36 Weickert M O & Pfeiffer A F, Metabolic effects of dietary fiber consumption and prevention of diabetes, *J Nutr*, 138 (3) (2008) 439-442.

37 Indian Council of Medical Research, Nutrient requirements and recommended dietary allowances for Indians, A report of the expert group of the Indian council of medical research, National Institute of Nutrition (Hyderabad), 2010.

38 WHO, A J, & Consultation F E, Diet, Nutrition and the Prevention of Chronic Diseases, Report of a Joint WHO/FAO Expert Consultation, *World Health Organ Tech Rep Ser*, 916 (i–viii) (2003) 1-149.

39 Cruz K J C, Oliveira A R S & Marreiro D N, Antioxidant role of zinc in diabetes mellitus, *World J Diabetes*, 6 (2) (2015) 333.

40 Tebboub I, & Kechrid Z, Effect of ginger on zinc, lipid profile and antioxidants levels in blood and liver of streptozotocin induced diabetic rats fed on zinc deficiency diet, *Indian J Exp Biol*, 59 (03) (2021) 168-176.

41 Pradeep P M & Sreerama Y N, Impact of processing on the phenolic profiles of small millets: Evaluation of their antioxidant and enzyme inhibitory properties associated with hyperglycemia, *Food Chem,* 169 (2015) 455-463.

42 Vijayakumar T P, Mohankumar J B & Srinivasan T, Quality evaluation of noodles from millet flour blend incorporated composite flour, *J Sci Ind Res*, 69 (2010) 48-54.

43 Surekha N, Chimmad B V & Naik R S, Hypoglycaemic and hypolipidemic efficacy of barnyard millet (*Echinochloa frumentacea* Link) based health food, *AJHS,* 8 (2) (2013) 383-387.

44 Sharma B & Gujral H S, Modulation in quality attributes of dough and starch digestibility of unleavened flat bread on replacing wheat flour with different minor millet flours, *Int J Biol Macromol*, 141 (2019) 117-124.

45 Augustin L S, Kendall C W, Jenkins D J, Willett W C, Astrup A, *et al.,* Glycemic index, glycemic load and glycemic response: an International Scientific Consensus Summit from the International Carbohydrate Quality Consortium (ICQC), *Nutr Metab Cardiovas Dis*, 25 (9) (2015) 795-815.