Effect of multigrain porridge on postprandial glucose level in diabetic individuals

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Abstract---A metabolic disorder called diabetes mellitus is brought on by issues with insulin production, action, or both. Chronic hyperglycemia is caused by insulin deficiency with aberrant carbohydrate, lipid and protein metabolism. Postprandial glucose level is the glucose level after a meal. This test is done to observe how the

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body responds to sugar and carbohydrates after eating. To lower postprandial glucose level in diabetic individuals, multigrain porridge has been regarded as the most effective mean. Multigrain porridges were prepared with millet, barley, sorghum and whole wheat. All these grains are loaded with soluble and insoluble fiber, antioxidant, phytochemicals, proteins, essential vitamins and minerals. Barley, sorghum and millet have low glycemic index because of a high proportion of fiber, which helps to keep blood sugar level stable after eating. The current study was planned to evaluate the postprandial glucose and cholesterol lowering effect of multigrain porridges in diabetic individuals. Multigrain porridges were prepared by grinding all grains into raw porridge form then boiling in water and adding half to one cup of milk. The raw materials were subjected to proximate analysis, mineral analysis, antioxidant assay, dietary fiber analysis, sensory analysis and efficacy study. Sensory analysis of multigrain porridges revealed that T_{10} and T_4 on the basis of color, texture, consistency, aroma, taste and overall acceptability are the best treatment plans. Efficacy study was carried out for 30 days by administrating multigrain porridges to diabetic individuals. Their postprandial glucose and cholesterol level were studied at the 0, 15 and 30th day of the study. Then, the parameters were subjected to statistical analysis for checking the effect. It was observed that postprandial glucose level and cholesterol level in diabetic individuals served with wheat porridge and multigrain porridges decreased from day 0 to day 30.

Keywords---chronic hyperglycemia, postprandial glucose, multigrain, porridges, cholesterol.

Introduction

Diabetes mellitus is an endocrine condition brought by complications with insulin secretion and exertion or both. Chronic hyperglycemia is caused by insulin deficiency with aberrant carbohydrate, lipid, and protein metabolism. Untreated diabetes can cause hyperglycemia with ketoacidosis or non-ketotic hyperosmolar syndrome, both of which are life-threatening consequences[1]. Diabetes affected adults' number 537 million aged (20 to 79 years) globally in 2021 accounting tenth of a person, on average. By 2030, this figure is projected to reach 643 million and by 2045, it will reach 783 million. Diabetes killed 6.7 million people in 2021, approximately one in every five seconds. In Pakistan, the prevalence of diabetes has risen considerably, with 33 million adults now suffering from the disease. In Pakistan, Impaired Glucose Tolerance affected an additional 11 million people, as a result of this, they are more likely to get type 2 diabetes. In Pakistan, more than a quarter of adults with diabetes (26.9%) are undiagnosed [2].

The glucose level after eating a meal is called the postprandial glucose level. This test determines how the body reacts to sweets and carbohydrates after eating. As your stomach digests your meal, the level of glucose in your blood (also known as blood sugar) rises rapidly. Postprandial glucose level is a blood test that is used to

identify whether you have diabetes or not. Your body produces insufficient insulin to maintain a healthy blood sugar level if you have diabetes. This indicates that your blood sugar levels are too high, which can lead to major health issues such as heart, nerve, kidney, and eye damage over time [3].

According to the American Diabetes Association, the typical blood sugar ranges for a person without diabetes are as follows: Fasting blood sugar level: fewer than 100 mg/dL (in the morning, before eating), between 90 and 130 mg/dL one hour following a meal, between 90 and 110 mg/dL two hours following a meal [2]. Barley is high in niacin, which raises the level of HDL and lowers the level of LDL cholesterol. It's a low-cost grain that is readily available. It has both soluble and insoluble fiber, rich in protein, minerals, B and E vitamins as well as flavonoids or anthocyanins[4]. Due to its high fiber contents, magnesium, a cofactor of various enzymes involved in carbohydrate metabolism, lowers the blood glucose level in people with Type 2 diabetes [5].

The output of millets (Pennisetum glaucum), a type of cereal grain, ranks fourth in the world. Different types of millet have a low glycemic index (GI), release sugars slowly, and can therefore be utilized in therapeutic diets[6]. After wheat, rice, maize, and barley, sorghum (Sorghum bicolor) is the fifth most popular cereal in the world. Sorghum includes phytochemicals that have a substantial impact on human health, including phenolic acids, anthocyanins, and tannins. Recent research revealed that sorghum lowers cholesterol, possesses anticarcinogenic qualities, and lowers the risk of cardiovascular disease. Estimated glycemic indices are greatly reduced by the tannins in sorghum, which also inhibit the function of digestive enzymes (EGI). Furthermore, phenolic chemicals, particularly 3-de-oxy-anthocyanidins and tannins, are abundant in most sorghum types[7]. Dietary fiber helps to reduce blood sugar levels by slowing down stomach emptying, slowing enteric transit, and sugar uptake [8].

Consuming whole cereal grains is advantageous to one's health in epidemiological studies. Micronutrients, phytonutrients as well as dietary fiber, mostly found in the bran and germ layer, are credited with the health benefits of cereal grains [9]. In managing diabetes mellitus, the diet has been acknowledged as being quite important. A diet high in fiber and low in fat is now recommended for Type 2 diabetes to enhance glycemic control and lower plasma cholesterol levels. A vital supply of fibrous food can significantly reduce blood levels of triglycerides, cholesterol, and glucose. To increase the nutritional profile of various food products, it is necessary to investigate the obscure sources of dietary fiber [10].

In Pakistan, the number of persons with high cholesterol and low-density lipoprotein, in particular, is rising quickly. Little has been done to change the diet, modify it, or enhance the nutritional worth of frequently consumed items to combat this hazard. The goal of the current study is to increase dietary fiber consumption by enhancing porridge made from barley, sorghum, and millet, which are all high in fiber. The main purpose of the study includes the preparation of multigrain porridge with millet, barley, and sorghum, quality evaluation of multigrain porridge, and to evaluate the effect of multigrain porridge on a diabetic's postprandial glucose level.

Materials and Methods

Analysis of Raw Materials

The raw material whole wheat, barley, millet, and sorghum was bought from the SB Mart in Faisalabad and then cleaned well for analysis.

Proximate analysis

The moisture content of raw material was assessed by the standard methods [11]. After the material was heated to 100°C for 16–18 hours to reach its constant weight, it was cooled in a vacuum desiccator. The formula used to calculate moisture content is as follows:

$$Moisture (\%) = Final weight (g)\text{-}Initial weight (g)$$

The protein content of raw material was determined by the Kjeldahl method [11]. Sulphuric acid (95-98 percent pure), sodium hydroxide (40 percent), 0.1 N sulphuric acid (for titration), boric acid solution (4 percent), and three drops of methyl red indicator was the reagents used in the operation. A digestion combination (100 g K2SO4, 10 g CuSO4, 5 g FeSO4) (5.0 g) was also utilized. Weighing the raw material, was then moved into the digesting flask. The flask was filled with 35.0 mL of sulphuric acid and 5.0 g of the digestion mixture. After digestion, when a light green color had been achieved, the mixture was allowed to chill for a while. The volume was then increased to 150.0 ml by adding distilled water. 10.0 mL of the digested material and 10.0 mL of NaOH were distilled together in a conical flask (40 %). The distillate was then combined with drops of methyl red indicator (2–3 drops) and 10.0 mL of boric acid (4 percent), and this process was repeated until the yellow-red color of the boric acid was achieved. A pink hue was the desired result for the titration, which was done with 0.1 N sulfuric acid. Crude protein is calculated by the following formula:

$$Nitrogen (\%) = [(1.4V \times N) /W]$$

Where:
V = acid used in the titration (ml)
N = standard acid normality
W = sample weight (g)

$$Crude protein (\%) = \% Nitrogen \times 6.25$$

The fat content of raw material was analyzed by the method of Soxhlet extraction [11]. Hexane, ethyl acetate, and methanol were used as solvents. The raw material was separated from the soluble components using each of these solvents. Using a Soxhlet extractor and 500mL of extractant, 2g of each raw material was extracted for 6 hours. Three fractions of hexane, ethyl acetate, and methanol were obtained by separating organic solvents from the extracts using a rotary evaporator. Evaluation of crude fiber was done by using a fat-free sample by standard method [11]. 1.25% of sulphuric acid was used for the digestion of the sample and then 1.25% sodium hydroxide was added. To make the sample free of acid, its washing

was carried out with distilled water and muslin cloth, filtration was done. After filtration, the sample which was left on the muslin cloth was taken, weighed, and placed in a muffle furnace for ignition, for 3-5 hours at a temperature of 550-650. When grey or white colored ash was attained then it was removed from the furnace and weighed. The following formula was used for the determination of fiber content.

Crude fiber (%) =   Sample weight before ashing–Weight of sample after ashing

The Ash content of raw material was analyzed by a method described [11]. Weighing the raw material, it was then placed in the muffle furnace for an 18-hour burn at 550°C. The weighing was done again after ashing. NFE content was determined using the subsequent formula described [11].

NFE (%) = 100 % – (moisture + crude protein + crude fat + ash) %

Mineral analysis

Mineral content was determined by using plasma atomic emission spectroscopy [11]. Three chemicals—nitric acid, hydrofluoric acid, and hydrochloric acid—were used as reagents. In a Teflon beaker, 2 mL of 70% nitric acid was used to ash the raw ingredients. After that, 0.5 mL of hydrofluoric acid was added, and the beaker was capped and moved to a sand bath so that heat could produce a clear solution. By taking off the cap, the mixture evaporated. After drying, 2 mL of HCl was added, and 25 mL of 2.0 M HCl was used for extraction.

DPPH scavenging activity

Through slight alteration in the method of 1,1 diphenyl-2-picrylhydrazyl hydrate (DPPH) explained by free radical scavenging activity was measured [12]. 2 mL of DPPH solution (0.1 mmol/L in methanol) mixed with concentrations of methanolic extract ranging from 20-100 µg/mL. For 30 min reaction mixture was allowed to stand at 37oC. The Ultraviolet-visible spectrophotometer was used to measure the absorbance at 517 nm as compared to the methanol blank. Ascorbic acid was taken as standard. The percentage of free radical scavenging activity was calculated using the following equation:

% free radical scavenging activity = [(AB-AA) / AB] × 100

FRAP (Ferric Reducing Antioxidant Power Assay)

The method was used to measure FRAP [13]. One milligram of 100 grams of grated grains was combined with 2.5 milliliters of sodium phosphate buffer solution (0.2 M, pH 6.6) and 2.5 milliliters of 1% potassium ferricyanide and incubated for 20 minutes at 500C. The mixture was treated with trichloroacetic acid (2.5 mL, 10%). Finally, the absorbance of the grains was measured using a UV-visible spectrophotometer (JANEWAY, 96500, UK) at 700 nm by mixing 2.5 mL of the supernatant solution with 2.5 mL distilled water and 0.5 mL FeCl3 (0.1%). Using the calibration curve (y=0.0063x+0.148, R2=0.99(p=<0.01)).

Dietary fiber analysis

The total, soluble and insoluble dietary fiber contents of raw materials [13]. Method No. 32-07.01 was followed for the analysis of soluble dietary fibers (SDF) [11]. Duplicate samples were gelatinized by thermally stable α amylase. The samples were then digested with amyl glucosidase and protease to remove the starch and protein. Protein contents using a crucible filter enzyme mixture in a filtration flask and washed with distilled water. After that, 320 ml of warmed 95% EtOH was added and permitted to precipitate at room temperature for 60mins and filtered by 120 ml of EtOH (78% and 79%) and acetone. Then, the residues were dried and weight and used for ash and protein contents. Insoluble dietary fibers (IDF) was analyzed by following Method No. 32-07.01 [11]. Same procedure followed as in SDF but residues were washed with 10 ml of distilled water and two times with 10 ml 0f 95% EtOH and acetone. Again, Method No. 32-07.01 was followed for total dietary fibers (TDF) analysis [11]. The soluble fiber was precipitated by adding 4 volumes of 95% ethanol (preheated at 600C). Residues were first filtered and then washed by using ethanol (95% and 78%) and acetone. After that, they were dried and weight. The whole procedure was followed for the blank sample. TDF was calculated as

$$\text{Dietary fiber (\%)} = \frac{R1+R2/2-P-A-B}{m1+m2/2} \times 100$$

Where:
m1= sample weight 1, m2= sample weight 2, R1= residue weight from m1, R2= residue weight 2 from 2, P= protein weight from R2, A= ash weight from R1, B=blank, BR1+BR2/2-BP-BA
Whereas, BR=blank residues, BP= blank protein from BR, BA= blank ash from BR2

Composite Treatments of Raw Porridges

Barley, millet, and sorghum were used in the formation of raw porridges, and wheat was taken as the control group as shown in table 3.1. Ten concentrations of these grated grains were then mixed and weighed accordingly.

Table 1
Treatments used in study

Treatment	Whole Wheat %	Barley %	Sorghum %	Millet %
T_0 act as control group with 100% whole wheat	100	-	-	-
T_1 includes 100% barley	-	100	-	-
T_2 includes 100% sorghum	-	-	100	-
T_3	-	-	-	100

includes 100% millet				
T_4 includes 50% barley, 50% sorghum	-	50	50	-
T_5 includes 50% sorghum, 50% millet	-	-	50	50
T_6 includes 50% barley, 50% millet	-	50	-	50
T_7 includes 50% barley, 25% sorghum, 25% millet	-	50	25	25
T_8 includes 25% barley, 50% sorghum, 25% millet	-	25	50	25
T_9 includes 25% barley, 25% sorghum, 50% millet	-	25	25	50
T_{10} includes 33% barley, 33% sorghum, 33% millet		33	33	33

Preparation of Multigrain Porridges

All formulations were converted into cooked porridge form by using conventional method as mentioned in the table 3.1. Grated grains were heated or boiled in water and half to one cup of milk was added into it.
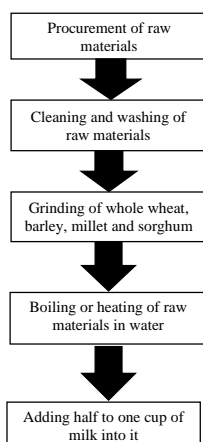

Figure 1. Flow Chart of Multigrain Porridges development

Sensory evaluation

Multigrain porridges were evaluated olfactory under controlled lighting and temperature conditions. All of the samples were assessed using a hedonic scale, which has a nine-point scale. Based on the color, aroma, taste, texture, mouth feel, holding ability, and gen acceptability, 1 is for extremely dislike, 2 is for dislike very much, 3 is for dislike moderately, 4 is for slightly dislike, 5 is for neutral, 6 is for like slightly, 7 is for like moderately, 8 is for like very much and 9 is for like extremely as shown in Appendix 1 [14].

Selection of Best Formulation

Based on sensory evaluation, the two best formulations along with the control were selected for the further efficacy study.

Table 2
Clinical study plan

Groups	Descriptions
Group A (G_0)	Control group
Group B (G_1)	Dietary modification (T_4 multigrain porridge based on barley and sorghum)
Group C (G_2)	Dietary modification (T_3 multigrain porridge based on barley, sorghum and millet)

Human trial

Intentionally, 15 diabetic patients; five in each group were distributed randomly. In this trial, dietary interventions were performed. Commercially available kits were used to analyze at the Riffah lab. In the bio-evaluation trial (30 days), three groups were studied. The experimental subjects were provided with multigrain porridges each day for breakfast. At the initiation, 0 days before the start of the trial, the blood sample was taken for evaluating the postprandial glucose level of each patient and same procedure was followed for 15th and 30th day [15]. The aforementioned parameters were examined;

- Cholesterol: Cholesterol levels were determined using the procedure outlined [16].
- Postprandial glucose: The serum glucose levels of the collected blood samples were assessed [16].

Statistical Analysis

A statistical analysis was done on the findings for each parameter, to get a conclusion. The level of significance ($p<0.05$) was calculated after doing the ANOVA. The HSD test was also used to perform mean separations [17].

Results and Discussion

The chemical constituents, minerals, antioxidants, and dietary fiber of the raw materials were examined. Composite flours were prepared by blending different concentration levels of barley, millet, and sorghum. Different analyses including proximate, mineral, DPPH scavenging, FRAP, and dietary fiber were performed. Multigrain porridges were prepared from all the compositions of multi mix to find out the best composition showing suitability for lowering the postprandial glucose level in diabetic individuals. Furthermore, multigrain porridges were also subjected to sensory evaluation (color, texture, consistency, taste, aroma, and then overall acceptability).

Analysis of Raw Materials
Proximate analysis

Mean values for proximate composition (moisture, ash, crude fat, crude protein, and crude fiber) of wheat, barley, sorghum, and millet flour are given in figure 2. Higher moisture was observed in barley followed by sorghum, whole wheat, and millet. Ash content was high in sorghum followed by barley, millet, and whole wheat. Crude fat was high in millet followed by sorghum, whole wheat, and barley. Crude protein was high in barley followed by whole wheat, millet, and sorghum. The crude fiber was high in barley followed by sorghum, whole wheat, and millet, and NFE contents were found higher in wheat followed by millet, sorghum, and barley having results similar to previous study [18, 19].

Mineral analysis

Mean values for the mineral analysis (calcium, iron, magnesium, zinc) of grated whole wheat, barley, sorghum, and millet were given in fig. 3. The highest calcium content was found in millet followed by whole wheat, barley, and sorghum. The highest iron content was found in whole wheat followed by millet, sorghum, and barley. Following barley in terms of magnesium content were whole wheat, sorghum, and millet. Zinc was high in millet followed by whole wheat, sorghum, and barley. The results obtained were similar to the study given [20, 21].

Antioxidant assay

Mean values for antioxidant assay (DPPH, FRAP) of grated whole wheat, barley, sorghum, and millet were given in fig. 4. Higher content of DPPH was observed in sorghum followed by millet, barley, and whole wheat. While higher content of FRAP was observed in millet followed by sorghum, whole wheat, and barley. The results obtained were similar to the study given [22].

Dietary fiber analysis

Mean values for dietary fiber analysis (soluble dietary fiber, insoluble dietary fiber, and total dietary fiber) of grated whole wheat, barley, sorghum, and millet were given in fig. 5. Highest TDF was observed in sorghum followed by barley, millet, and whole wheat. SDF contents were high in whole wheat, followed by sorghum, barley, and millet. While IDF contents were high in barley followed by millet,

sorghum, and whole wheat. The results obtained were similar to the study given [23].

Sensory analysis

The modern phase of product development involves consumer acceptance and sensory characteristics. In food items, the sensory assessment is the essential quality criterion. The color, texture, consistency, taste, aroma, and overall acceptability of the multigrain porridges made from wheat, barley, sorghum, and millet were evaluated using a 9-point hedonic scale as evaluated in previous studies [24, 25]. Color is a key feature of food that is regarded as a quality index to assess its acceptance. Results obtained indicated that treatments are highly significant. Figure 6. shows the mean values of treatments. The table showed that the values calculated were in the range of 8.17 to 4.33. T0 acted as a control and 9 composite treatments of different flours were used. The highest mean value was depicted by T10 and the lowest mean value was depicted by T3 and these results are similar to the previous studies [26].

Results obtained indicated that treatments are highly significant. Figure 6. shows the mean values of treatments. The table showed that the values calculated were in the range of 8.33 to 5.17. T0 acted as a control and 9 composite treatments of different flours were used. The highest mean value was depicted by T4 and the lowest mean value was depicted by T3. Earlier, it was found that texture quality is directly linked with the structural and mechanical properties of food. This is described as the physical property of those characteristics that are linked to the feeling of touch, deformation, and flow of food under force hence measured accordingly [25]. Table 4.9 expresses the analysis of variance for treatments of multigrain porridge. Results obtained indicated that treatments are highly significant. Figure 6. shows the mean values of treatments calculated were in the range of 8.33 to 5.31. T0 acted as a control and 9 composite treatments of different flours were used. The highest mean value was depicted by T4, and T10, and the lowest mean value was depicted by T3 and T9 and results were similar to previous studies [27].

Results obtained through ANOVA indicated that treatments are highly significant. Figure 6. shows the mean values of treatments. The table displayed calculated values in the range of 8.33 to 3.33. T0 acted as a control and 9 composite treatments of different flours were used. The highest mean value was depicted by T0 and the lowest mean value was depicted by T3 and T9 [28, 29]. Results obtained indicated that treatments are highly significant. Figure 6. shows the mean values of treatments estimated values in the range of 7.33 to 4.30. T0 acted as a control and 9 composite treatments of different flours were used. The highest mean value was depicted by T0 and the lowest mean value was depicted by T3 and T5 [27, 28]. Results obtained indicated that treatments are highly significant. Figure 6. shows the mean values of treatments calculated were in the range of 8.33 to 3.17. T0 acted as a control and 9 composite treatments of different flours were used. The highest mean value was depicted by T10 and the lowest mean value was depicted by T3 as evaluated in previous studies [28, 30].

Selection of Best Treatment

Based on organoleptic properties such as color, texture, consistency, taste, aroma, and overall acceptability two best treatments were selected. The treatment T0 with 100% of grated whole wheat is controlled and written as T1 for statistical studies. The treatment T4 with 50% of grated barley and 50% of grated sorghum (written as T2 for statistical studies and the treatment T10 with 33% of grated barley, 33% of grated sorghum, and 33% of grated millet (written as T3 for statistical studies) were selected by the panelists based on overall acceptability , this selection was similar to previous study's selection [30].

Impact of Multigrain Porridges on Cholesterol and Postprandial Glucose Levels in Diabetic Individuals

The human feeding trial was led to estimate the effect of multigrain porridges on postprandial blood glucose level and cholesterol levels [31].

Postprandial glucose and cholesterol level

The mean square values for postprandial glucose and cholesterol level showed a significant effect of treatment on groups and study intervals. The mean values for postprandial glucose and cholesterol levels in fig. 7. showed decreasing trend from G0 to G1 and G2 and their mean values. The results showed that postprandial glucose and cholesterol levels decreased from day 0 to day 15 to day 30 in diabetic individuals served with wheat porridge. In G1 diabetic individuals served with multigrain porridge containing barley and sorghum, postprandial glucose and cholestrol levels decreased from day 0 to day 15 to day 30. In G2 diabetic individuals served with multigrain porridge containing barley, sorghum, and millet, postprandial glucose level and cholesterol decreased from day 0 to day 15 to day 30.

Whole grain cereals contain large amounts of dietary fiber that ultimately promote health. Grains are full of antioxidants and rich in fiber that help to normalize the blood glucose level by slow absorption of glucose and cholesterol. Consumption of an adequate number of whole grains is related to lower chances of obesity. Moreover, it reduces weight gain by improving serum lipid and glucose concentrations as described in previous studies [15]. Many recent human studies conducted on whole grains revealed that increased consumption of whole grains help to lower cholesterol level. Grains are full of antioxidants and rich in fiber that help to lower the cholesterol level. This represents that eating whole grains helps in maintaining a lipid profile as evaluated in previous study [31].

Proximate Composition

	Moisture %	Ash %	Crude fat %	Crude protein %	Crude fiber %	NFE %
Whole wheat	7.18	1.68	3.51	11.9	3.5	72.23
Barley	11.62	2.55	2.29	12.81	7.01	63.72
Sorghum	9.5	3.32	5.05	11.2	5.8	65.13
Millet	7.1	2.02	5.52	11.83	2.03	71.5
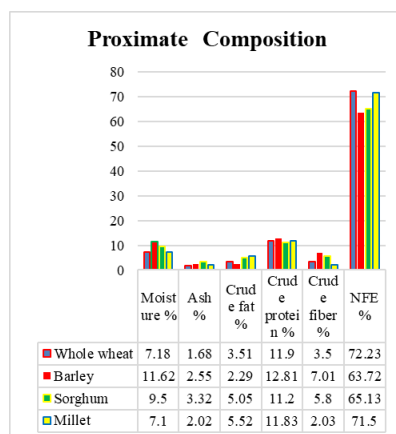
Fig 2. Proximate composition of grated whole wheat, barely, sorghum and millet (%)

Minneral Composition

	Calcium %	Iron %	Magnesium %	Zinc %
Whole wheat	35.51	97.51	19.3	37.52
Barley	29.04	1.2	38.1	1.46
Sorghum	15.3	4.02	17.4	2.5
Millet	36.4	12	1.03	39.5
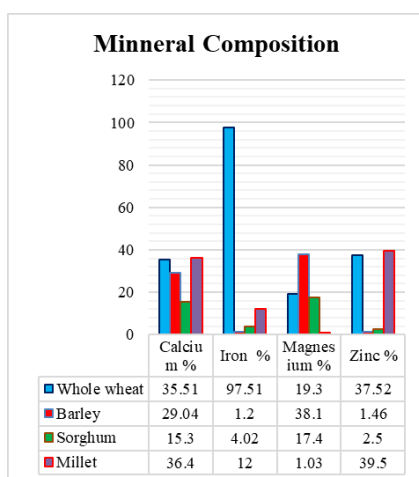
Fig 3. Mineral composition of grated whole wheat, barley, sorghum and millet (mg/100g)

Antioxidants

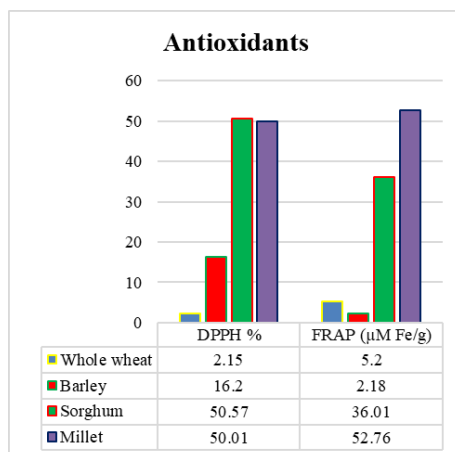|	DPPH %	FRAP (µM Fe/g)
Whole wheat	2.15	5.2
Barley	16.2	2.18
Sorghum	50.57	36.01
Millet	50.01	52.76

Fig 4. Antioxidant assay of grated whole wheat, barley, sorghum and millet (%)

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Dietary Fiber

	Whole wheat	Barley	Sorghum	Millet
Soluble dietary fiber %	9.87	4.52	9.5	1.2
Insoluble dietary fiber %	1.63	13.1	11.4	12.01
Total dietary fiber %	11.55	17.62	20.9	13.21
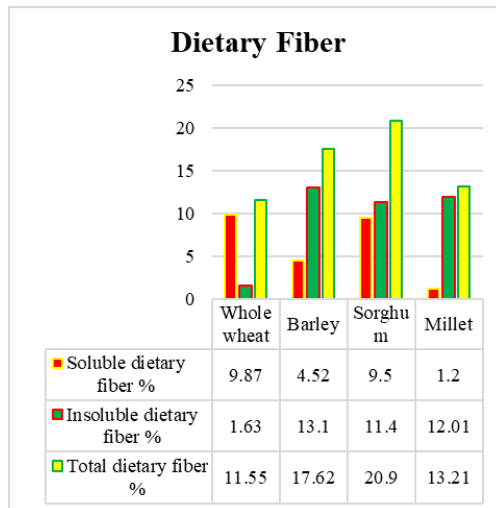
Fig 5. Dietary fiber contents of grated whole wheat, barley, sorghum and millet (mg/100g)

Sensory Evaluation

	T0 (act as control group with 100% whole wheat)	T1 (includes 100% barley)	T2 (includes 100% sorghum)	T3 (includes 100% millet)	T4 (includes 50% barley, 50% sorghum)	T5 (includes 50% sorghum, 50% millet)	T6 (includes 50% barley, 50% millet)	T7 (includes 50% barley, 25% sorghum, 25% millet)	T8 (includes 25% barley, 50% sorghum, 25% millet)	T9 (includes 25% barley, 25% sorghum, 50% millet)	T10 (includes 33% barley, 33% sorghum, 33% millet)
Color	8	7.5	6.17	4.33	8	7.17	7.5	6.33	6.5	6.17	8.17
Texture	7.33	8.17	5.33	5.17	8.33	7.17	7.33	7.33	6.83	5.33	7.5
Consistency	7.33	7.17	7.19	5.31	8.33	6	7.17	6.33	6.17	5.33	8.33
Taste	8.33	6.33	5.33	4.33	7.17	3.33	7.17	6.17	6.33	4.33	8.17
Aroma	7.36	6.33	5.33	4.3	6.17	4.33	6.17	6.33	5.17	5.33	7.17
Overall acceptability	8.17	7.17	5.33	3.17	7.33	4.17	7.17	6.33	5.17	4.5	8.33

Fig 6. Mean values for sensory evaluation of multigrain porridges

Study Interval on Postprandial Glucose (mg/dL)

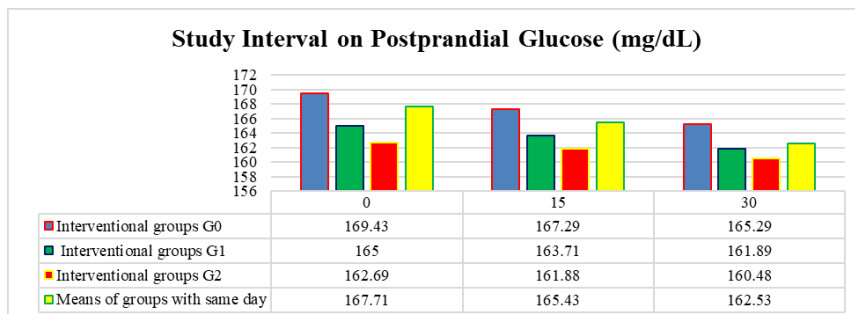|	0	15	30
Interventional groups G0	169.43	167.29	165.29
Interventional groups G1	165	163.71	161.89
Interventional groups G2	162.69	161.88	160.48
Means of groups with same day	167.71	165.43	162.53

Fig 7. Effect of treatments and study interval on postprandial glucose (mg/dL)

Conclusion

Many countries nowadays face problems of diabetes, vitamin and mineral deficiencies, and many other health-risking disorders. In the typical era of health disorders, there is a dire need for innovative health as well as nutrition-promoting food products. Multigrain porridge can be a superb opportunity that can meet the caloric as well as nutritional needs of diabetic individuals and people of any age. Multigrain porridge can have the potential to help in combating free radicals by antioxidant capacity and are rich in fiber that helps to normalize the blood glucose level by slow absorption of glucose as well as lowers cholesterol level by increasing good fat such as unsaturated fats (PUFA). The study focused on the nutritional contents of multigrain porridges and their effect on postprandial glucose and cholesterol level in diabetic individuals. It is concluded that multigrain porridge may provide nutritional benefits beyond health benefits and reduces postprandial glucose and cholesterol level in diabetic individuals.

References

1. Association AD. Diagnosis and classification of diabetes mellitus. Diabetes care. 2014;37(Supplement_1):S81-S90.
2. Atlas D. International diabetes federation. IDF Diabetes Atlas, 7th edn Brussels, Belgium: International Diabetes Federation. 2015;33.
3. Shukla AP, Iliescu RG, Thomas CE, Aronne LJ. Food order has a significant impact on postprandial glucose and insulin levels. Diabetes care. 2015;38(7):e98-e9.
4. Sullivan P, Arendt E, Gallagher E. The increasing use of barley and barley by-products in the production of healthier baked goods. Trends in Food Science & Technology. 2013;29(2):124-34.
5. Idehen E, Tang Y, Sang S. Bioactive phytochemicals in barley. Journal of food and drug analysis. 2017;25(1):148-61.
6. McSweeney MB, Ferenc A, Smolkova K, Lazier A, Tucker A, Seetharaman K, et al. Glycaemic response of proso millet-based (Panicum miliaceum) products. International Journal of Food Sciences and Nutrition. 2017;68(7):873-80.
7. Amarakoon D, Lou Z, Lee WJ, Smolensky D, Lee SH. A mechanistic review: potential chronic disease-preventive properties of sorghum. Journal of the Science of Food and Agriculture. 2021;101(7):2641-9.
8. de Morais Cardoso L, Pinheiro SS, Martino HSD, Pinheiro-Sant'Ana HM. Sorghum (Sorghum bicolor L.): Nutrients, bioactive compounds, and potential impact on human health. Critical reviews in food science and nutrition. 2017;57(2):372-90.
9. Saleh AS, Wang P, Wang N, Yang S, Xiao Z. Technologies for enhancement of bioactive components and potential health benefits of cereal and cereal-based foods: Research advances and application challenges. Critical reviews in food science and nutrition. 2019;59(2):207-27.
10. Bindra D, Manju D. Formulation and evaluation of foods from composite flour blends of sorghum, pearl millet and whole wheat for suitability in diabetic diet. Int J Home Sci. 2019;5:220-9.
11. Anonymous, editor Approved methods of the American association of cereal chemists1995: AACC USA.

12. Chandra D, Chandra S, Sharma A. Review of Finger millet (Eleusine coracana (L.) Gaertn): A power house of health benefiting nutrients. Food Science and Human Wellness. 2016;5(3):149-55.

13. Zhao C-N, Tang G-Y, Cao S-Y, Xu X-Y, Gan R-Y, Liu Q, et al. Phenolic profiles and antioxidant activities of 30 tea infusions from green, black, oolong, white, yellow and dark teas. Antioxidants. 2019;8(7):215.

14. Punia S, Sandhu KS, Kaur M. Quantification of phenolic acids and antioxidant potential of wheat rusks as influenced by partial replacement with barley flour. Journal of Food Science and Technology. 2020;57(10):3782-91.

15. Olagunju AI. Multigrain porridge possesses superior nutritional quality, its consumption alleviates hyperglycemia, hypercholesterolemia and oxidative stress in obese-diabetic wistar rats. Journal of Food Biochemistry. 2022:e14309.

16. Kim JY, Paik JK, Kim OY, Park HW, Lee JH, Jang Y, et al. Effects of lycopene supplementation on oxidative stress and markers of endothelial function in healthy men. Atherosclerosis. 2011;215(1):189-95.

17. Ranganathan H, Ganapathy DM, Jain AR. Cervical and incisal marginal discrepancy in ceramic laminate veneering materials: A SEM analysis. Contemporary clinical dentistry. 2017;8(2):272.

18. Muthamilarasan M, Dhaka A, Yadav R, Prasad M. Exploration of millet models for developing nutrient rich graminaceous crops. Plant Science. 2016;242:89-97.

19. Kumar SR, Sadiq MB, Singh G, Anal AK. Formulation of nutritional and ready to mix gluten-free porridge from proso millet (Panicum miliaceum) little millet (Panicum sumatrense) and legume faba bean (Vicia faba). Journal of Food Science and Technology. 2022;59(7):2821-9.

20. Owheruo JO, Ifesan BO, Kolawole AO. Physicochemical properties of malted finger millet (Eleusine coracana) and pearl millet (Pennisetum glaucum). Food Science & Nutrition. 2019;7(2):476-82.

21. HUSSAIN A. Formulation, processing and evaluation of multigrain porridge mix from underutilised crops of Ladakh. Journal of Hill Agriculture. 2018;9(4):435-41.

22. Yang L, Zhang H, Cheng L, Gu Z, Hua D, Qi X, et al. Effect of extrusion on the hydrophilic antioxidant capacity of four whole grains. Journal of Food and Nutrition Research. 2014;2(2):80-7.

23. Dobhal A, Awasthi P. Comparison of nutritional profile of barley flour and refined wheat flour. 2021.

24. Hussain A, Kaul R. Nutritional, sensory and storage studies of instant multigrain porridge mix. Food Science Research Journal. 2019;10(1):94-100.

25. Anjali P, Lal EA, Ajinkya D. Value addition and quality evaluation of dietary fibre rich, multigrain cookies. Journal of Pharmacognosy and Phytochemistry. 2019;8(1):1802-4.

26. Mishra R, Singh SP, Singh Y. Quality Assessment of Multigrain Porridges. 2021.

27. Pawar P, Sawate A, Kshirsagar R, Kulkarni A. Studies on development and organoleptic evaluation of porridge mix. 2020.

28. Hussain A. Characterization and Storage Studies of Instant Multigrain Porridge Made from Underutilised Crops of Ladakh. International Journal of Food and Fermentation Technology. 2020;10(2):119-127.

29. Nagaraju R, Sobhana PP, Thappatla D, Epparapalli S, Kandlakunta B, Korrapati D. Glycemic index and sensory evaluation of whole grain based multigrain Indian breads (rotis). Preventive Nutrition and Food Science. 2020;25(2):194-203.
30. Dhital A. PREPARATION OF PORRIDGE FROM GERMINATED MULTIGRAIN AND ITS NUTRITIONAL EVALUATION: Department of Nutrition and Dietetics Central Campus of Technology Institute …; 2021.
31. Sobhana PP, Kandlakunta B, Nagaraju R, Thappatla D, Epparapalli S, Vemula SR, et al. Human clinical trial to assess the effect of consumption of multigrain Indian bread on glycemic regulation in type 2 diabetic participants. Journal of Food Biochemistry. 2020;44(11):e13465.