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Hypoglycemic and Hypolipidemic Effect of Barnyard Millet Consumption in Type 2 Diabetic Subjects

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A B S T R A C T

In the present study, the hypoglycemic and hypolipidemic effects of barnyard millet (PRJ-1) were assessed in diabetic patients (30) for a period of three months. The nutritional analysis of the millet was also done and the results on proximate composition were: Crude protein (12g), Crude fat (3.97g), crude fibre (8.50g), Total ash (2.33g), Carbohydrate (73.17g) and physiological energy (376 kcal) whereas mineral composition of barnyard millet was calcium (24.58mg), iron(4.87mg), zinc(5.55mg), magnesium (89.19mg), chromium (0.054mg) and phosphorus (231.5mg). The values of total dietary fibre (13.2g), resistant starch (14.23g), tannin (78%) and total antioxidant activity (62.15) were appreciably good as these components play a major role in reducing diabetic complications. The glycemic index of barnyard millet in the study came as 35.9 categorizing it under the group of low glycemic index foods. The results on hypoglycemic and hypolipidemic studies on diabetes patients revealed a significant decrease in blood glucose (both fasting and post-prandial, glycosylated haemoglobin) and lipid level (except HDL and VLDL level) after supplementation of barnyard millet. The results suggest that barnyard millet being high in nutritional value with hypoglycemic and progressive hypolipidemic properties makes it a safe option for diabetic subjects.

Introduction

In recent years diabetes and cardiovascular diseases have become most prevalent diseases with higher incidence rates. The awareness about diabetes has become important because it is associated with various other complications like cardiovascular diseases, nephropathy, retinopathy etc. Cardiovascular risk factors such as obesity, hypertension and dyslipidaemia are common in type 2 diabetic patients. According to the latest data from WHO (2016), 422 million adults are living with diabetes mellitus globally which has increased from the previous estimate of 381 million reported by International Diabetes Federation (2013). The chances of developing type 2 diabetes depend on various modifiable and non-modifiable risk factors. The non-modifiable risk factors include age, family history etc, whereas change in lifestyle risk factors *viz;* eating habits, physical activity and

weight management are some of the modifiable risk factors. These lifestyle changes affect the chances of developing type 2 diabetes. For a diabetic patient, having control over eating habits is mandatory. Diet is one of the single most effective ways to keep diabetes in control (Leon and Maddox, 2015).

As far as diet is concerned, millets have an important role in helping control diabetes. Millets are a group of highly variable small-seeded grasses, widely grown as cereal crops or grains. Millets had received increasing spotlight in combating diabetes as a dietary option (Muthamilarasana *et al.,* 2016). The diet containing millet protein increases insulin sensitivities, and reduce blood glucose level as well as triglyceride level (Nishizawa *et al.,* 2009). The presence of slowly digestible starch and leucine in millets also had positive effect on health of diabetic subjects (Liu *et al.,* 2006; FAO, 1995). Compared to other cereal crops such as wheat and maize, millets are high in nutritional content, gluten free, and have low glycemic index. Barnyard millet (*Echinochloa frumentacaea*) is known by several names *viz*; Japanese barnyard millet, *Sawan, Ooda, Oodalu, Jhangora* and *Madira*. It is the fastest multipurpose crop with high yield in short duration. Barnyard millet contains good amount of protein with high digestibility. It is an excellent source of dietary fibre (13 percent) with good amounts of soluble and insoluble fibres. The dietary fibre is an important component of barnyard millet that could be considered in the management of disorders like diabetes mellitus, obesity, hyperlipidemia etc (Veena, 2003). Dietary fibre infers hypoglycemic effect and hypolipidemic effect due to their ability to retard food digestion and nutrient absorption which has an important influence on lipid and carbohydrate metabolism. The carbohydrate present in barnyard millet is digested slowly and this property makes it natures best gift for people suffering from diabetes. The protein content of barnyard millet is 12% having 81% digestibility. It contains 58.56% carbohydrate having slow digestibility of 25.88 per cent. Barnyard millet also contains phytochemicals like polyphenols which are responsible for low glycemic index value of barnyard millet; an important property in management of hyperglycemia and hyperlipidemia. In diabetes consumption of rice is restricted due to its higher glycemic index. The unique property of barnyard millet is that it can be consumed similar to rice making it an ideal rice- substitute.

Materials and Methods

Locale of study and procurement of sample

The present study has been carried out in the department of Foods and Nutrition, College of Home Science, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India. For the present investigation, PRJ-1 variety of barnyard millet was procured from Pauri Garhwal, Uttarakhand. Barnyard millet was cleaned and ground into flour in *Atta* Flour Mill and sieved through 40 mesh sieves.

Nutrient analysis of barnyard millet

Proximate analysis

The proximate composition of barnyard millet was determined as per AOAC (1995) procedure. This involves the determination of the per cent of moisture, crude protein, total ash, crude fat, crude fibre, carbohydrate by difference and physiological energy.

Mineral estimation

Among minerals calcium, iron, zinc, magnesium and chromium were estimated

using atomic absorption spectrophotometer according to the method given by AOAC (1995).Estimation of phosphorus was done by method given by Fiske and Subbarow (1925).

Estimation of total dietary fibre, resistant starch, tannin and total antioxidant activity

Estimation of dietary fibre of barnyard millet was determined using the method given by Asp and Johanson (1981). Resistant starch yield was determined by using the glucose oxidase assay given by McCleary *et al.*, (2002) with slight modification.

Estimation of tannin and total antioxidant activity

Tannic acid was estimated by colorimetric method according to the procedure given by AOAC (1970). The antioxidant activity of barnyard millet was estimated using the method of Zhang and Hamauzu (2004) with some modifications.

Sensory quality evaluation of *jeera jhangora*

The name *jeera jhangora* was given to the product prepared using PRJ-1 variety of barnyard millet. It was prepared similar to *jeera* rice. Except oil, *jeera* and salt no other ingredient was used in preparing *jeerajhangora* to get true value of glycemic index of barnyard millet. The amount of ingredients used in preparation of *jeera jhangora* was given in Table 1. The sensory quality of *jeera jhangora* was done using 9-point Hedonic scale and score card method given by Amerine *et al.,* (1965).

Glycemic index evaluation of *jeera jhangora*

For evaluation of glycemic index study 10 normal female adult human volunteers of age group between 24-26 years were selected from Golden Jublee Hostel, G.B.P.U.A&T, Pantnagar, Uttarakhand. Written consent of the subjects was taken to participate in the study. The subjects were given general instructions to avoid any physical exertion, medication, fast and feast during the experimental period. On the first day glucose tolerance test (GTT) for glucose was conducted on overnight fasted subjects. A 50 g glucose dissolved in 200 ml water was given to the subjects. The subjects were instructed to finish glucose solution within 15 minutes. The blood glucose level was measured at 0, 30-, 60-, 90,120- and 150-min using glucometer. On alternate day *jeera jhangora* (raw amount 77.5 g) containing 50 g of available carbohydrate were served to the same subjects with 200 ml water. The blood glucose was measured initially and at 30, 60, 90, 120 and 150 min of finishing the product.

Glycemic index (GI) of barnyard millet was calculated according to the formula given by Wolever (1990).

$$GI = \frac{\text{Incremental area under blood glucose response curve for food product}}{\text{Corresponding area after equicarbohydrate portion of glucose}} \times 100$$

Clinical trialof barnyard millet (cooked as rice) supplementation on diabetic subjects

Clinical trial and feeding intervention were done for a period of 3 months on diabetic female subjects selected from Rajkeeya Sanyukt Chikitsalaya (government hospital), Premnagar, Dehradun, Uttarakhand. The permission regarding the clinical trial was granted by Dr.Abha Mamgai (Chief medical officer), Department of Medical, Health and Family Welfare, Dehradun, Uttarakhand. The selection and intervention were done under the supervision of Dr. R.S. Rastogi (M.B.B.S.) registered medical physician of Rajkeeya Sanyukt Chikitsalaya, Dehradun.

Selection of the study population and their flow through each stage during the course of the study has been presented in Fig. 1.

The experimental group was supplemented with 100gram of barnyard millet for daily consumption. The barnyard millet was cooked similar to rice and consumed by the subjects with any pulse or legume simply as *Dal-chawal*. The cooked volume of 100 g barnyard millet was enough for fulfilling the portion size requirement at one meal.

Results and Discussion

Proximate composition of barnyard millet (PRJ-1)

As shown in Table 2 the results on nutritional composition depict that barnyard millet have appreciably good nutrient content. The moisture content of PRJ-1 variety of barnyard millet was 11.86 per cent which was in line with the values 11.17 and 11.93 per cent given by Mittal *et al.,* (2004) and Verma *et al.,* (2014), respectively. The crude protein and crude fat content in PRJ-1 variety of barnyard millet was found to be 10.58 and 3.5 per cent, respectively. Approximately similar values for crude protein (10.52%) and crude fat (3.56 %) were also reported by Ugare*et al.,* (2014). Crude fibre content of PRJ-1 variety of barnyard millet was 7.5 per cent. According to Ugare *et al.,* (2014) and Thathola and Srivastava (2010) the crude fibre content of barnyard millet is 6.62 and 8.13 per cent, respectively.

The total mineral content of barnyard millet (variety PRJ-1) was 2.06 per cent. The value of carbohydrate for barnyard millet variety PRJ-1 was 64.50 g/100 g. Gopalan *et al.,* (2007) reported carbohydrate content in barnyard millet as 65.5 g/100g. The physiological energy of PRJ-1 was 332 Kcal/100g. Studies done by Verma *et al.,* (2014) and Veena *et al.,* (2005) reported energy value for barnyard millet as 333 and 318 Kcal/100g respectively.

Mineral composition of barnyard millet

The results on mineral composition as shown in Table 2 depicts that the calcium content of PRJ-1 variety of barnyard millet was 21.67 mg per cent which was found higher than 20.5 mg per cent reported by Haddimanni and Malleshi (1993). Veena *et al.,* (2005) and Verma *et al.,* (2014) in their study reported calcium content in barnyard millet as 24. 43 and 23.16 mg per cent, respectively. The iron content of PRJ-1 variety of barnyard millet was 4.28 mg per cent. Analysis revealed that zinc content of barnyard millet was 4.90 mg per 100 g approximately double to 2.6 mg per cent given by FAO (1995).Gopalan *et al.,* (2007) reported zinc content in barnyard millet as 3 mg/100g. The magnesium content of barnyard millet (variety PRJ-1) was 78.62 mg per cent less than 82 mg per cent, reported by Gopalan *et al.,* (2007). The chromium and phosphorus content of PRJ-1 variety of barnyard millet was 0.048 and 204.12 mg per cent.

Total dietary fibre, resistant starch, tannin and total antioxidant content of barnyard millet

Among millets, barnyard millet is one of the richest sources of dietary fibre which makes it functional food in prevention of various degenerative diseases like diabetes, cardiovascular disease etc (http://www.whfoods.com). PRJ-1 variety of barnyard millet has significantly higher total dietary fibre content (13.2%) out of which 8.7 per cent was insoluble and 4.5 per cent was soluble fraction (Table 3). Soluble fibre is soluble in water. The PRJ-1 variety of barnyard millet has resistant starch content of 14.23 per cent. Studies indicate superiority of

barnyard millet (minor millets) as compared to traditional food grains in exhibiting hypoglycemic effect (Krishnakumari and Thayumanavan, 1997). The tannin and total antioxidant content of barnyard millet was 78 and 62.15 per cent respectively.

Sensory quality and glycemic index of *jeera jhangora*

Sensory evaluation is important criteria in judging the acceptability of food product. The overall acceptability of *jeera jhangora* prepared using PRJ-1 of barnyard millet was 7.8 and falls under "Good" category of score card.

The glycemic index result reveals that the highest peak was observed after 30 minutes of intake of glucose, *jeera jhangora* (variety PRJ-1). Thathola and Srivastava (2010) reported that the peak for blood glucose level for the barnyard millet biscuits occurred at 30 minutes. As shown in Table 4 the area under blood glucose response curve of barnyard millet was significantly lower (1805.3 mg min/100 ml) as compared to glucose (5009.2 mg min/100 ml).Joshi and Srivastava (2016) also reported that the area under blood glucose response curve was lowest for *khichdi* (1793.5mg min/100ml) prepared using barnyard millet. Dietary fibre present in food is responsible for delayed gastric emptying which results in slow absorption of macronutrients resulting in lower postprandial blood glucose and insulin levels (Jenkins *et al.*, 1978). The physiological function of resistant starch is similar to dietary fibre. Resistant starch resists the action of endogenous mammalian enzymes and reaches to the large bowel. Figure 2 also depicts that spike in blood glucose level was significantly higher for glucose than barnyard millet.

According to Brand – Miller *et al.,* (1999) the foods having glycemic index less than 55 are considered low glycemic index foods. Foods having glycemic index between 56-69 are considered as medium glycemic index foods whereas foods having glycemic index more than 70 and above are considered as high glycemic index foods. Consumption of high-glycemic index (GI) foods result in more rapid as well as higher increase in blood glucose levels as opposed to consumption of low-glycemic (GI) index foods(Ludwig, 2002).Glycemic index of *jeera jhangora* prepared using barnyard millet came up to be 35.9±2.35 categorizing it under the group of low glycemic index foods thus making it suitable for the consumption of diabetic subjects.

Hypoglycemic and hypolipidemic effect of barnyard millet supplementation on diabetic subjects

The feeding intervention of barnyard millet on diabetic subjects showed positive effect especially on blood glucose levels for two months. The fasting and postprandial blood glucose level of experimental group showed significant decrease from 162.3mg/dl to 128.86mg/dl and 233.53mg/dl to 175.20mg/dl, respectively after 2 months of barnyard millet supplementation. Surekha *et al.,* (2013) also reported7 per cent decrease in blood glucose level after supplementing barnyard millet-based health mix in seven normal subjects for a period of 28 days. According toItagi *et al.,* (2013) the hypoglycemic effect of barnyard millet is due to presence of higher proportion of complex carbohydrates, slow rising sugars and resistant starch. Similarly, glycosylated haemoglobin value also showed significant decrease from 8.44 to 7.56 % as depicted in Table 5. Regarding the lipid profile, except HDL and VLDL cholesterol all other parameters showed significant change as depicted in Table 6.

Table.1 Ingredients used in preparation of *jeerajhangora*

Ingredients	Amount
Barnyard millet	100 g
Salt	1.10 g
Jeera	0.50 g
Oil	½ tsp
Water	130 ml

Table.2 Nutrient composition of barnyard millet (variety PRJ-1)

S.No	Nutrients (per 100g)	As is basis	Dry wt basis
1	Moisture (g)	11.86±0.03	-
2	Crude protein (g)	10.58±0.20	12±0.23
3	Crude fat (g)	3.5±0.05	3.97±0.08
4	Crude fibre (g)	7.5±0.01	8.50±0.01
5	Total ash (g)	2.06±0.03	2.33±0.03
6	Carbohydrate (g)	64.50±0.02	73.17±0.04
7	Physiological energy (Kcal)	332±0.02	376±0.03
8	Calcium (mg)	21.67±0.03	24.58±0.05
9	Iron (mg)	4.28±0.02	4.87±0.03
10	Zinc (mg)	4.90±0.01	5.55±0.01
11	Magnesium (mg)	78.62±0.02	89.19±0.04
12	Chromium (mg)	0.048±0.03	0.054±0.04
13	Phosphorus (mg)	204.12±0.02	231.58±0.03

All results are mean±SD for three individual determinations

Table.3 Total dietary fibre, resistant starch and total antioxidant content of barnyard millet

S.no.		Per 100g
1	Total dietary fibre (g) Insoluble Soluble	13.2±0.03 8.7±0.04 4.5±0.01
2	Resistant starch (g)	14.23±0.07
3	Tannin (%)	78±0.04
4	Total antioxidant activity (%)	62.15±0.27

All results are mean±SD for three individual determinations

Table.4 Area under blood glucose response curve for glucose and barnyard millet (*jeera jhangora*)

S.No	Food product	Area(mg min/100ml) (mean±SD)
1. **2.**	**Glucose** **Barnyard millet (*Jeerajhangora*)** PRJ-1	5009.2± 326.2 1805.3±260.5
	t-value **S/NS**	 S

S= significant difference, NS = non significant

Table.5 Effect of barnyard millet supplementation on the blood glucose and glycosylated heamoglobin (HbA1C) level of diabetic subjects (mean±SD)

S.No.	Blood parameters		Baseline	Ist month	IInd month	S.Em	CD at 5%	III Month #	t-test*	S/NS
1	Blood glucose (Fasting) (mg/dl)	EG	162.33±39.44	134.80±7.43	128.86±9.96	2.67	3.94^{s}	143.66±8.32	3.97	S
		CG	168.33±15.81	174.18±10.96	172.60±20.48	1.99	1.96	NA		
		t-value	0.54	4.36	7.48					
		S/NS	NS	S	S					
2	Blood glucose (Post pradial) (mg/dl)	EG	233.53±70.03	183.73±34.31	175.20±34.45	3.38	6.29^{s}	186.33±20.24	2.67	S
		CG	238.53±23.24	263.74±68.21	248.24±51.36	1.56	7.59	NA		
		t-value	0.23	3.51	4.24					
		S/NS	NS	S	S					
3	Glycosylated heamoglobin HbA1C (%)	EG	8.44±0.63	7.86±0.56	7.56^{30,60}±0.65	0.15	0.51	7.67±0.70	0.53	NS
		CG	8.54±0.59	8.27±0.57	8.58±0.61	0.13	0.93	NA		
		t-value	0.62	3.68	5.87					
		S/NS	NS	S	S					

= in third month experimental group acts as self control (no supplementation was given),
* = difference between the values after 60 day of supplementation and 30 days of discontinued supplementation.
S& NS stands for significant and non significant difference, respectively, EG = Experimental group (n=15),CG= Control group (n=15), 30,60= non significant difference in Ist month and IInd month

Table.6 Effect of barnyard millet supplementation on blood lipid profile of experimental group (mean ±SD)

S.No.	Blood lipid profile	Groups	Baseline Value	Ist month	IInd month	S.Em	CD at 5%	IIIrd month #	t-test*	S/NS
1	Triglyceride (mg/dl)	EG	180.40±38.65	169.94±26.08	164.64±25.26	1.32	3.24^{s}	171.7±26.26	2.77	S
		CG	179.77±5.13	176.96±7.19	178.98±6.79	1.66	4.74	NA		
		t-value	0.73	2.31	3.23					
		S/NS	NS	S	S					
2	Total cholesterol (mg/dl)	EG	206.31±83.32	179.90±35.25	168.54±28.02	3.44	9.36^{s}	170.37±19.54	0.19	NS
		CG	199.10±14.53	201.10±24.30	224.98±13.79	4.69	13.40	NA		
		t-value	0.87	3.23	6.68					
		S/NS	NS	S	S					
3	HDL cholesterol (mg/dl)	EG	39.60±0.78	40.48±1.17	41.88±3.07	0.93	2.66^{ns}	41.62±5.35	0.12	NS
		CG	36.75±2.82	33.52±3.92	33.97±5.05	1.04	2.97	NA		
		t-value	0.72	5.48	6.30					
		S/NS	NS	S	S					
4	VLDL cholesterol (mg/dl)	EG	35.66±6.66	34.39±5.21	32.92±5.05	1.46	4.19^{ns}	34.34±5.25	0.68	NS
		CG	34.35±1.02	34.19±1.43	34.39±1.35	0.33	0.94	NA		
		t-value	0.71	0.13	0.98					
		S/NS	NS	NS	NS					
5	LDL cholesterol (mg/dl)	EG	130.74±25.66	105.63±33.43	93.74±22.33	3.64	7.24^{s}	94.41±21.35	0.42	NS
		CG	128.46±14.96	133.23±23.66	156.62±14.99	4.91	4.63	NA		
		t-value	0.98	2.66	5.16					
		S/NS	NS	S	S					
6	TC/HDL	EG	5.20±0.91	4.44±1.16	4.02±0.94	0.23	0.36^{s}	4.17±0.83	0.61	NS
		CG	5.41±0.59	5.99±1.29	6.62±0.98	0.25	0.73	NA		
		t- value	1.8	3.77	6.65					
		S/NS	NS	S	S					
7	LDL/HDL	EG	3.30±0.62	2.59±1.03	2.23±0.65	0.17	0.29^{s}	2.34±0.75	0.81	NS
		CG	3.98±0.54	3.97±1.18	4.61±0.84	0.23	0.23	NA		
		t-value	1.16	2.56	7.37					
		S/NS	NS	S	S					

= in third month experimental group acts as self control (no supplementation was given)

* = difference between the values after 60 day of supplementation and 30 days of discontinued supplementation.

S& NS stands for significant and non significant difference, respectively

EG = Experimental group (n=15), CG= Control group (n=15)

Fig.1 Study design of clinical trial on diabetic subjects

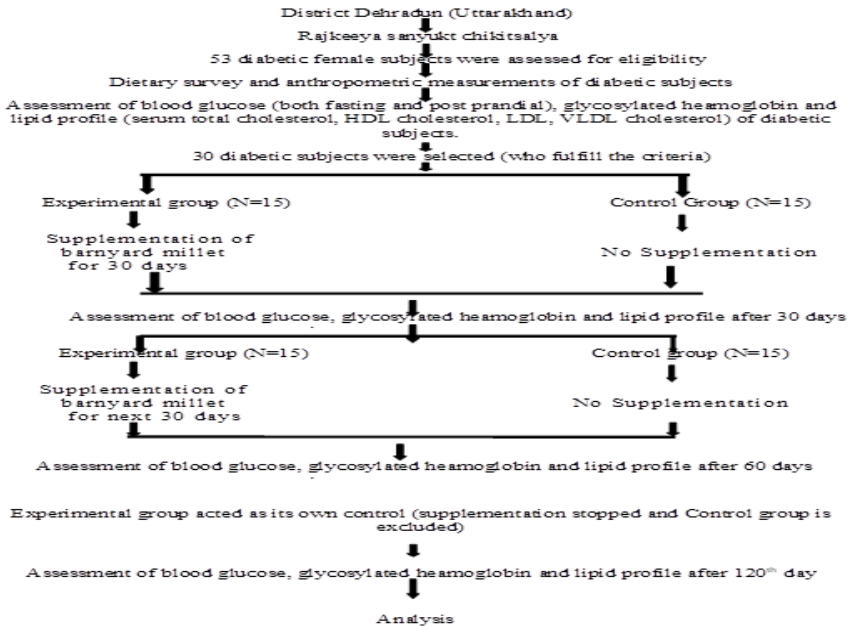
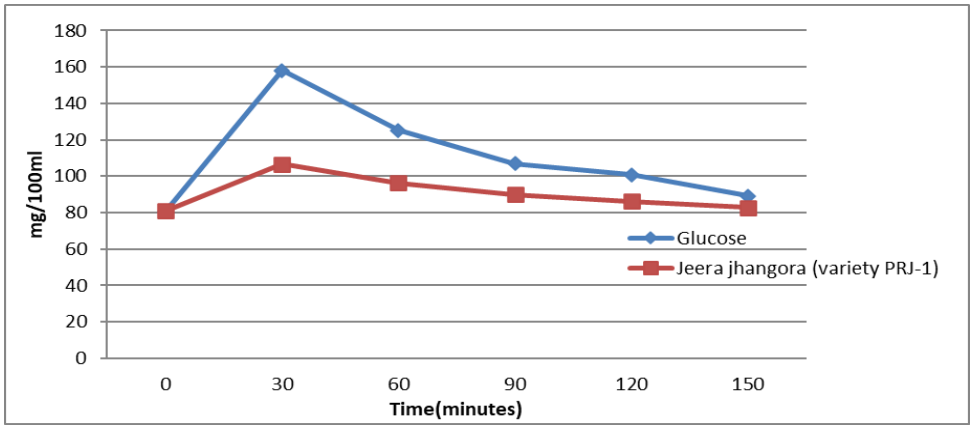


Fig.2 Blood glucose response curve for barnyard millet in comparison to glucose load of 50g



According to Bisoi *et al.*, (2012) dietary fibre plays an important role in imparting hypolipidemic effect by their ability to retard food digestion and nutrient absorption and thus influencing lipid and carbohydrate metabolism.

There was again an significant increase in fasting (143.66mg/dl) and postprandial blood glucose (186.33mg/dl) levels of experimental group, after one month when supplementation of barnyard millet was discontinued. The results indicate strong effect of barnyard millet in controlling diabetes. Regarding lipid profile only triglyceride level (171.7mg/dl) indicates significant increase after barnyard millet supplementation was discontinued. The positive change was also observed in HDL, LDL, TC/HDL ratio, but was not statistically significant. Control group and experimental group also show significant difference in blood glucose and blood lipid (except HDL) levels after the feeding intervention was started.

The results clearly suggest the positive effect of barnyard millet supplementation on blood glucose level and lipid profile of diabetic subjects. The hypoglycemic and hypolipidemic effect of barnyard millet is due to various nutritional factors present in it *viz*; dietary fibre, resistant starch, antioxidant activity, presence of minerals like magnesium, chromium etc., but the major effect is due to its total dietary fibre content. Total dietary fibre content of barnyard millet slows down the release of glucose in the blood and hence prevented the blood glucose spike as opposed high spike caused by consumption of high glycemic index food like rice. The results suggest that barnyard millet supplementation if continued for a longer period of time can show significant change in lipid profile (especially HDL and VLDL). Besides, barnyard millet is superior to other cereal grains in terms of nutritive value such as protein, minerals, fibre, vitamins and antioxidants and it is also cooked similar to rice which makes it a nutritious substitute of rice for diabetic people.

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