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Characterization of oat bran β-glucan with special reference to efficacy study to elucidate its health claims for diabetic patients

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Abstract

The present study was designed to characterize oat bran for their biological attributes. The results showed that bran of Avon variety contained high TDF, SDF, β-glucan and extractability of β-glucan than bran of oat variety Sargodha-81. The extrusion process exhibited the highest extractability of β-glucan (45.37%) followed by cooking (37.28%) and baking methods (32.45%). Moreover, the glucose level reduction was found significantly different when raw and processed oat bran diets fed to normal, hypercholesterolemic and diabetic rats. The highest reduction was recorded when fed on diet containing 30% processed oat bran. The processed oat bran exhibited more reduction as compared to raw oat bran. Furthermore, addition of 20% oat bran in wheat grits porridge was found to have significant effect ($p < 0.05$) on appearance, mouth feel and overall acceptability. Convincingly, it is recommended that processed oat bran may be introduced in diet-based remedy to rheostat lifestyle-related disorders.

Keywords: oat; characterization; β-glucan; hypercholesterolemic; diabetes; health benefits.

Practical Application: Oat bran may be used in diet-based antidiabetic remedy.

1 Introduction

With the growing public awareness about diet and health, research facts are mounting on the potential of utilizing dietary fiber (DF) with valuable functional effects (Devries, 2004). The β-glucan is alternative and appropriate source of dietary fiber that can be added to foods. The β-glucan contains both soluble and insoluble components of dietary fiber but oat β-glucan is classified as soluble fiber (Association of Official Analytical Chemists, 2006). The β-glucan content of oat varies from 3 to 7% (Wood & Beer 1998) and for barley 3 to 11% (Pereira et al., 2000), makes them good origin of β-glucan in the diet. Thus β-glucan extractability and processing effects are important determinants of its bioactivity (Brown & Gordon, 2001). The processing is a prerequisite to prepare tasty meals and is considered important for the content, composition and bioavailability of nutrients. The oat and oat products are most effective in reducing peak blood glucose response due to the high extractability and molecular weight of β-glucan and high viscosity. However, in the same study the pasta and bread exhibited significant depolymerization of β-glucan and showed low bioactivity. The knowledge of the processes induced by changes in the β-glucan content and chemistry is therefore of prime importance to prepare healthy food. The structure of processed oat bran is also important to the sensory quality of food products as well as in food process engineering (Pereira et al., 2000).

The oat bran rich in β-glucan has been shown to lower blood glucose and cholesterol level. Food and Drug Administration (FDA) in the USA allows the use of a generic health claim for oat and oat products mentioning the cholesterol lowering m effect of soluble fiber (β-glucan) and the reduction in the risk of coronary heart disease (Food and Drug Administration, 1997). The potential physiological mechanisms behind the efficacy of β-glucan are suggested to be its ability to retard the absorption rate of food in the intestine due to increased viscosity, in this way balancing the post-prandial glucose and insulin response (Wood et al., 2000) . Thus, keeping in mind, the factors discussed above, the present study was designed to explicate the effect of processing techniques on extractability of oat bran β-glucan and to elucidate the health claims of oat bran β-glucan.

2 Materials and methods

2.1 Materials

Two oat varieties namely Avon and Sargodha-81 grown commercially were procured from Ayub Agricultural Research Institute (AARI), Faisalabad-Pakistan. The outer hull from inner

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groat of each variety was separated. The lighter oats are separated and groats are taken for further processing. The groats obtained after dehulling was milled through Quaderumate Senior Mills. The oat bran was separated from flour in several grinding and sieving operations to a coarse fraction (bran) and fine fraction (endosperm flour).

2.2 Total dietary fiber

The samples of whole oat flour and bran were subjected for analysis to total dietary fiber by following AACC (American Association of Cereal Chemists, 2000) method No. 32-05.

2.3 Soluble and insoluble dietary fiber

The samples of whole oat flour and bran were subjected for analysis to soluble and insoluble dietary fiber by following AACC (American Association of Cereal Chemists, 2000) method No. 32-05.

2.4 Determination of β-glucan content

The flour and bran samples were tested for total β-glucan content by employing Megazyme assay kit as outlined by McCleary & Codd (1991). Finally, glucose oxidase/peroxidase (GOPOD) reagents were added and incubated at 50°C for 20 min and measured the absorbance on a spectrophotometer (IREMCO, Model 2020, Germany) at 510 nm within 1 h.

2.5 Extractability of β-glucan

The extractability of β-glucan was estimated by the method described by McCleary & Codd (1991) using the β-glucan enzymatic assay kit (Megazyme Intl.) with some modifications to accommodate the liquid extract.

2.6 Efficacy studies

The Sprague Dawley rats were procured from National Institute of Health (NIH) Islamabad and housed in Animal Room of National Institute of Food Science and Technology, UAF. These different efficacy trials were conducted in different studies as described below.

Study I: normal rats

The efficacy trials were conducted initially on normal rats. They were acclimatized by feeding basal diet for a period of one week. Then these rats were divided into three groups comprising of 10 rats each in group. The diets prepared from the selected treatments were fed for a period of 8 weeks (Table 1).

The feed & water intake were monitored on daily basis, while body weights were recorded weekly throughout the experimental period. Blood samples were collected through cardiac puncture and EDTA coated tubes were used for serum collection (Tsuchihashi et al., 2001). Serum samples were further analyzed for various assays by using Microlab-300.

Study II: induced hypercholesterolemia

The rats were fed on high cholesterol diet containing cholesterol (2%) and cholic acid (0.5%) to induce hypercholesterolemia. After one week, lipid profile of each rat was monitored to assess induction of hypercholesterolemia.

Study III: induced diabetic mellitus

Diabetic mellitus was induced in the rats by injecting Streptozotocin (STZ) @ 65mg/kg body weight, dissolved in 0.05M citrate buffer (pH 4.5), intravenously. The blood glucose of each rat was monitored after injecting STZ to check the glucose response

The following parameters were recorded separately in all rat modeling studies.

2.7 Efficacy tests

Serum glucose

The blood glucose concentration was measured by the method described by Thomas & Labor (1992).

Serum insulin

In each study, serum samples were tested for insulin level by following the method of Besch et al. (1987).

2.8 Statistical analysis

The data obtained through different experiments subjected to statistical analysis using Statistical Package (Costat-2003, Co-Hort, v 6.1.). The levels of significance ($p \leq 0.05$ & $p \leq 0.01$) were determined (ANOVA) using 2-factor factorial CRD by following the principles outlined by Steel et al. (1997).

Table 1. Treatment plan for efficacy study to elucidate the effect of raw and processed oat bran on diabetic and hypercholesterolemic rats.

	Study I				Study II				Study III			
Raw oat bran groups (ROB)	1	2	3	4	1	2	3	4	1	2	3	4
	D0	D1	D2	D3	D0	D1	D2	D3	D0	D1	D2	D3
Processed oat bran groups (POB)	1	2	3	4	1	2	3	4	1	2	3	4
	D0	D1	D2	D3	D0	D1	D2	D3	D0	D1	D2	D3

Study I: Normal rats, Study III: Induced diabetic mellitus, Study III: Induced diabetic mellitus; 10 rats/group (Total 240 rats); D0: control Diet (placebo); D1: Diet with 10% processed oat bran, D2: Diet with 20% processed oat bran, D3: Diet with 30% processed oat bran.

3 Results and discussions

3.1 Total dietary fiber (TDF)

The results regarding total dietary fiber (TDF) content of whole oat flour have been presented in Table 2. The results indicated that whole oat flour of AVON variety yielded higher TDF content (12.88%) than variety SARGOHA-81 (12.07%). The variation in TDF may be attributed to difference in genetic makeup. The TDF of whole oat flour normally ranges from 12.2 to 16.8% have been reported by different researchers (Usman et al., 2010).

3.2 Soluble dietary fiber

The results with respect to soluble dietary fiber in whole oat flour have been presented in Table 2. The soluble dietary fiber content in variety SARGODHA-81 (4.92%) was found relatively lower than the whole oat flour of variety AVON (5.61%). The results regarding soluble dietary fiber found in the present study are well supported by the findings of Vasanthan et al. (2002) who observed variation from 4.75 to 6.51% in soluble dietary fiber content of different oat varieties. Higher amounts of soluble dietary fiber are beneficial from health point of view. The consumption of SDF is usually associated with the lowering of LDL, total cholesterol, and triglycerides. It also improves glucose metabolism and insulin response. The present study suggests that soluble dietary fiber is higher in oat bran than whole oat flour which possibly makes oat more beneficial for health benefits.

3.3 Insoluble dietary fiber

The results regarding insoluble dietary fiber content in whole oat flour are presented in Table 2. The results indicated that whole oat flour of variety AVON contained almost similar insoluble dietary fiber content (7.27%) as oat variety SARGODHA-81 (7.15%). The results found for insoluble dietary fiber are in consistent with the findings of Usman et al. (2010) who reported 7.92% insoluble dietary fiber content in whole oat flour. The results of the present study are also supported by the findings of other authors such as Vasanthan et al. (2002), Helm & Francisco (2004). The variation in fiber is mainly attributed to genetic differences in varieties as well as their grain size, shape and bran thickness. The previous studies have shown that insoluble dietary fiber content in oat bran varies from 7.11% to 9.51% (Keogh et al., 2003). The results regarding insoluble dietary fiber in the present study are supported by the findings of Helm & Francisco (2004) and Manthey et al. (1999) who found that the insoluble dietary fiber content of oat bran in different oat varieties varied from 7.35% to 8.02%.

3.4 β-glucan content

The β-glucan content in whole oat flour of two varieties given in Table 2 showed that whole oat flour of variety AVON possessed relatively higher β-glucan content (4.35%) as compared to the oat variety SARGODHA-81 (4.02%). These results are supported by the previous findings of Papageorgiou et al. (2005) who reported that oat flour contains 2.1 to 3.9% of β-glucan in different oat varieties.

The oat bran of AVON variety possessed higher (5.59%) β-glucan content as compared to SARGODHA-81 (4.63%) (Table 2). These results are in line to those reported by Immerstrand et al. (2009) who found 7.2% β-glucan content in bran of oat variety.

3.5 Extractability of β -glucan

It is obvious from the results given in Table 2 that the extraction of β-glucan in whole oat flour of variety AVON (36.63%) was relatively higher than the whole oat flour of variety SARGODHA-81 (34.42%). The results of present studies are in agreement by the findings of Faraj et al. 2006 who found variation in the extraction of β-glucan of whole oat flour from 34.4 to 36.13%. The results of the present study are also in line with the findings of Temelli 2005 who reported variation in extraction of β-glucan of whole oat flour ranges from 33.5% to 36.3%.

3.6 Effect of processing on extractability of β-glucan

The extractability of β-glucan shown in (Figure 1) is affected by different process techniques. The extrusion process yielded the highest extractability of β-glucan followed by cooking and baking as compared to un-processed samples

The β-glucan is an integral part of cellulose and other noncellulosic polysaccharides in the cell wall and during cooking it is released from the matrix (Buckeridge et al., 2004). The present study resulted in highest extractability when samples were subjected to extrusion process followed by cooking and baking. These results are in agreement with Andersson et al. (2004) who found more extractability of β-glucan after processing of raw oat bran. The mechanism involved in lowering of cholesterol in the blood and glycemic response is related to the viscosity

Table 2. Dietary fiber content of whole oat flour and oat bran.

Parameters	Whole oat flour (%)		Oat bran (%)	
	Avon	Sargodha-81	Avon	Sargodha-81
Total dietary fiber	12.88 ± 0.16	12.07 ± 0.13	16.23 ± 0.56	15.11 ± 0.11
Soluble dietary fiber	5.61 ± 0.17	4.92 ± 0.15	7.92 ± 0.14	6.57 ± 0.20
Insoluble dietary fiber	7.27 ± 0.27	7.15 ± 0.16	8.31 ± 0.31	8.54 ± 0.2
β-glucan content	4.35 ± 0.35	4.02 ± 0.19	5.59 ± 0.38	4.63 ± 0.12
Extractability of β-glucan	36.63 ± 0.12	34.42 ± 0.13	43.88 ± 0.13	40.15 ± 0.15

Values are expressed as means ± standard deviation.

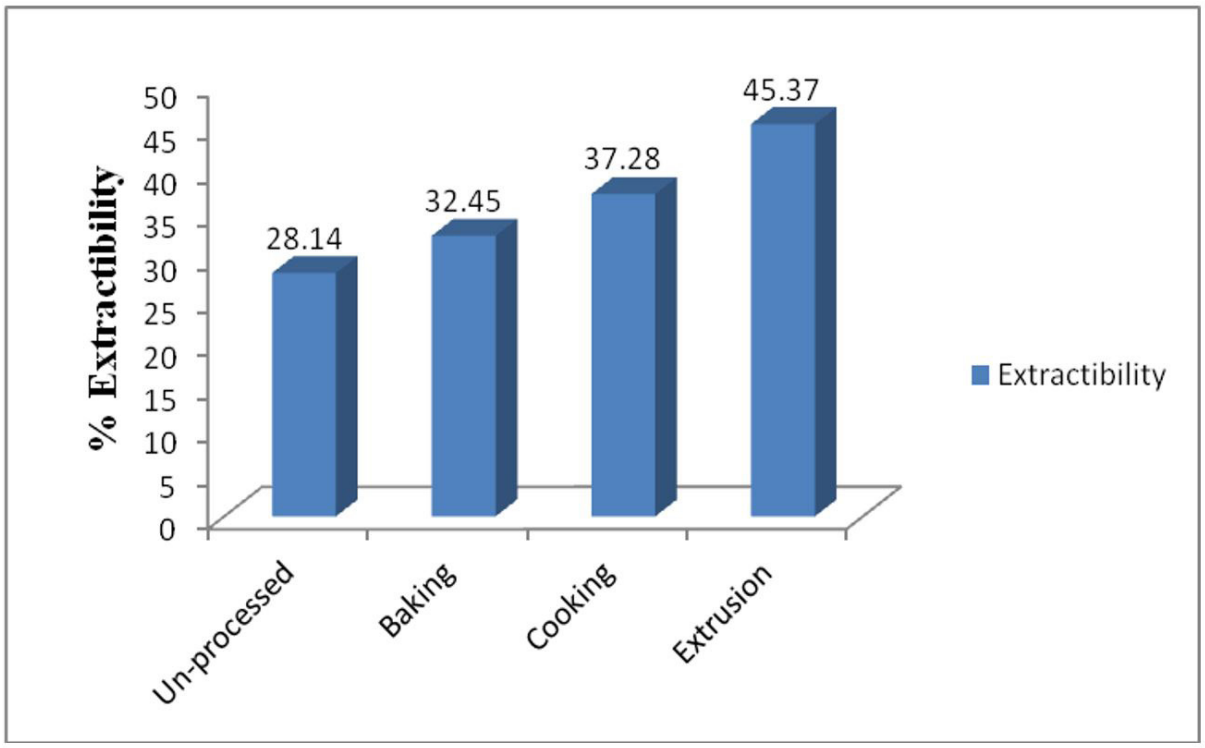


Figure 1. Effect of different processing techniques on extractability of β-glucan.

of β-glucan. In the present study the extractability of β-glucan was found maximum when extrusion process was employed followed by cooking and baking. These results showed that extrusion process can possibly better option to achieve health benefits owing to higher extractability of β-glucan.

3.7 Efficacy studies

Efficacy trials were conducted to elucidate the functional worth of raw and processed oat bran against various lifestyle-related disorders in Sprague Dawley rats modeling. The trials were conducted in rodents rather than humans due to their easy handling, organized supervision, controlled diet and environmental conditions. The biological trial was comprised of three different kind of studies on the basis of different diets pattern i.e. study I (normal diet), study II (high cholesterol diet) and study III (streptozotocin injected rats). The respective diet was given to the rat groups with simultaneous provision of functional diets (control, D_1, D_2 and D_3) in each study.

Effect of raw and processed oat bran diets on insulin (mg/dL) content of normal rats, hypercholesterolemic and diabatic rats

Study I

The results regarding plasma glucose level have been shown in Table 3. The results showed that glucose level was significantly affected by the diets containing different levels of raw or processed oat bran fed to rats. The results further indicated that glucose level ranged from 97.98 to 94.04 mg/dL and 98.02 to 93.88 mg/dL among the rats when fed on raw and processed oat bran diets, respectively.

It is evident from Figure 2a that normal rats fed on diets containing 10, 20 and 30% raw oat bran resulted decrease of 1.4, 2.89 and 5.06% in glucose level, respectively over the normal rats fed on control diet. The normal rats fed on the diets containing 10, 20 and 30% processed oat bran showed decreasing glucose level by 2.03, 3.59 and 6.27%, respectively as compared to normal rats when fed on control diet. The diets containing 30% processed oat bran showed more reduction in normal rat's glucose level than diets containing 30% raw oat bran.

Study II

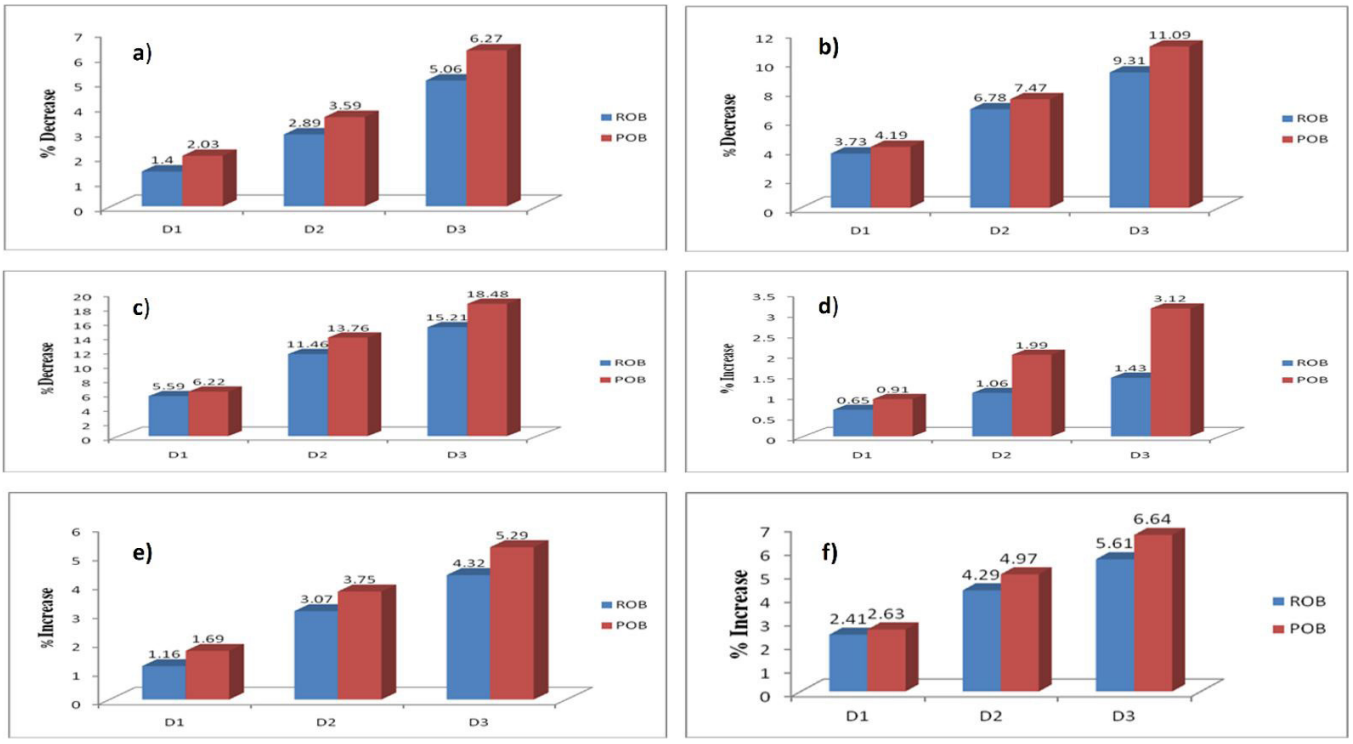
The results pertaining to glucose level of hypercholesterolemic rats fed on diets containing raw and processed oat bran revealed that diets containing raw and processed oat bran significantly affected the glucose level in hypercholesterolemic rats. However, the glucose level did not vary significantly within the experimental years and due to their interaction with the diets containing either raw or processed oat bran. The level of glucose in the control rats was found significantly the highest and glucose level varied from 119.93 to 108.76 mg/dL and 116.97 to 104.00 mg/dL among the hypercholesterolemic rats fed on diets containing different levels of raw and processed oat brans, respectively.

It is obvious from Figure 2b that hypercholesterolemic rats fed on diets containing 10, 20 and 30% raw oat bran decreased the glucose level by 3.73, 6.78 and 9.31%, respectively over the hypercholesterolemic rats fed on control diet. The plasma glucose level in hypercholesterolemic rats fed on processed

Table 3. Effect of raw and processed oat bran diets on glucose (mg/dL) content of normal rats, hypercholesterolemic and diabatic rats.

Diets	Study I		Study II		Study III	
	ROB	POB	ROB	POB	ROB	POB
Control	97.98a	98.02a	119.93a	116.97a	254.03a	260.32a
10%	96.70b	96.89a	115.46b	112.07ab	239.83b	244.13b
20%	95.15bc	95.66ab	111.80c	108.23bc	224.93c	224.50c
30%	94.04c	93.88c	108.76d	104.00c	215.38d	212.20cd

Study I: Normal rats, Study II: Induced diabetic mellitus, Study III: Induced diabetic mellitus; Values are given Mean ± SE. Means carrying same letters do not differ significantly.



ROB: Raw oat bran, **POB**: Processed oat bran, $\mathbf{D_0}$: Control diet (without active ingredients), $\mathbf{D_1}$: Diet containing 10% oat bran, $\mathbf{D_2}$: Diet containing 20% oat bran, $\mathbf{D_3}$: Diet containing 30% oat bran

Figure 2. Percent reduction in glucose of normal rats at 8th week as compared to control (a); Percent reduction in glucose of hypercholesterolaemic rats (b), Percent reduction in glucose of diabetic rats (c), Percent increase in Insulin of normal rats (d), Percent increase in Insulin of hypercholesterolaemic rats (e), Percent increase in Insulin of diabetic rats (f).

oat bran showed decline of 4.19, 7.47 and 11.09% in diets containing 10, 20 and 30% processed oat bran, respectively as compared to hypercholesterolemic rats fed on control diet. The highest reduction in plasma glucose level was recorded in the hypercholesterolemic rats when fed on processed oat bran as compared to hypercholesterolemia rats fed on raw oat bran.

Study III

The results showed significant effect on serum glucose level of diabetic rats when fed on various levels of raw and processed oat bran diets. However, the experimental years as well as their interaction with diets showed non-significant effect on glucose level of diabetic rats. The results in Table 2 indicated that glucose level was found significantly the highest in the control diet. The variation in glucose level from 254.03 to 215.38 mg/dL and 260.32 to 212.20 mg/dL was recorded among the diabetic rats when fed on diets containing various levels of raw and processed oat brans, respectively.

It is obvious from Figure 2c that diabetic rats fed on diets containing 10, 20 and 30% raw oat bran exhibited decline of 5.59, 11.46 and 15.21%, respectively in glucose level as compared to diabetic rats fed on control diet. The diabetic rats fed on diets containing 10, 20 and 30% processed oat bran showed decrease of 6.22, 13.76 and 18.48% in glucose level, respectively over the diabetic rats fed on control diet. The results showed maximum reduction in glucose level (18.48%) when diabetic rats were fed on 30% processed oat bran and same level this reduction was 15.21% in the glucose level when fed on raw oat bran. Consequently, the processed oat bran diets fed to diabetic rats appeared more effective in decreasing glucose level than raw oat bran diets.

Effect of raw and processed oat bran diets on insulin (mg/dL) content of normal rats, hypercholesterolemic and diabatic rats

Study I

The results regarding insulin level of normal rats fed on raw and processed oat brans have been presented in Table 4. The results indicated that insulin level was not affected significantly among normal rats when fed on different diets containing either raw or processed oat brans. Similarly, the experimental years and their interaction with diets were also found to exert non-significant effect on insulin level of normal rats. The insulin level ranged from 55.14 to 55.93 mg/dL and 55.19 to 56.91 mg/dL among the normal rats fed on diets containing different levels of raw and processed oat bran, respectively.

It is obvious from the Figure 2d that normal rats when fed on diets containing 10, 20 and 30% raw oat bran showed an increase in insulin level by 0.65, 1.06 and 1.43%, respectively as compared to normal rats fed on control diet. Similarly, the normal rats when fed on diets containing 10, 20 and 30% processed oat bran exhibited an increase 0.91, 1.99 and 3.12%, respectively in insulin level than the normal rats when fed on control diet. The increase in the level of insulin found to be highest in normal rats when fed on diet containing 30% processed oat bran. However, increase in insulin level was found upto 1.43% when normal rats fed on diet containing 30% raw oat bran.

Study II

The results with respect to insulin level in hypercholestrolemic rats have been shown in Table 4. The results showed that diets containing either raw or processed oat brans significantly affected the insulin level of hypercholestrolemic rats. However, the experimental years and their interaction with the diets exerted non-significant effect on insulin level of hypercholestrolemic rats. The results in Table 4 showed that insulin level was found significantly to be lower in the hypercholesterolemic rats when fed on control diet however, the insulin level ranged from 51.81 to 54.05 mg/dL and 52.56 to 55.34 mg/dL among the rats when fed on various levels of raw and processed oat brans, respectively. The hypercholesterolemic rats fed on diets containing 10, 20 and 30% raw oat bran showed 1.16, 3.07 and 4.32% increase, respectively in insulin as compared to hypercholesterolemic rats fed on control diet (Figure 2e). Similarly, the hypercholesterolemic rats fed on diets containing 10, 20 and 30% processed oat bran exhibited 1.69, 3.75 and 5.29% increase in insulin, respectively over hypercholesterolemic rats fed on control diet. The hypercholesterolemic rats fed on diet containing 30% processed oat bran showed higher increase in insulin level (5.29%) as compared raw oat bran which showed 4.32% increase in insulin level at same level. So, processed oat bran has shown more effective in increasing insulin level than raw oat bran diets fed to hypercholestrolemic rats.

Study III

The results for insulin of diabetic rats are presented in Table 4 which showed that diabetic rats fed on diets containing raw or processed oat bran showed significant effect in the insulin level. However, the insulin level was not affected statistically by the years of experimentation and their interaction with the diets. The insulin level was recorded significantly the highest in the diabetic rats when fed on control diet. The insulin level varied from 39.03 to 41.22 mg/dL and 39.16 to 41.76 mg/dL among the diabetic rats when fed on various levels of raw and processed oat brans, respectively.

It is obvious from the Figure 2f that diabetic rats fed on diets containing 10, 20 and 30% raw oat bran showed 2.41, 4.29 and 5.61% increase in their insulin level, respectively over diabetic rats fed on control diet. Similarly, the diabetic rats fed on diets containing 10, 20 and 30% processed oat bran resulted in 2.63, 4.97 and 6.64% increase, respectively in insulin level of diabetic rats over the diabetic rats when fed on control diet. The results further showed that diets containing either raw or processed oat bran fed to diabetic rats increased the insulin level but at same level processed oat bran was more effective in increasing insulin value than raw oat bran in diabetic rats.

It is obvious from the present study that addition of raw and processed oat bran significantly improved the insulin level in all the studies conducted on different types of rats i.e normal, hypercholesterolemic and diabetic. Earlier studies indicated that food containing high amount of sucrose or fructose led to hyperinsulinemia resulting in insulin resistance that resembles type 2 diabetes. Furthermore, such foods led to hypertriglyceridemia by increasing the formation of glycerol-3-phosphate, which is a precursor of lipid synthesis. The increased in blood triglycerides level will decreases the number of insulin receptors and ultimately reduce the insulin sensitivity and hyperinsulinemia would occur. Additionally, type 2 diabetes and obesity will occur by eating diets rich in fructose that decreases the serum adiponectin level, which is a adipose-specific plasma hormone linked to development of such diseases. The diseases such as obesity, hyperlipidemia, hyperinsulinemia, high VLDL and low HDL levels are linked with the prevalence of cardiovascular diseases.

Table 4. Effect of raw and processed oat bran diets on insulin (mg/dL) content of normal rats, hypercholesterolemic and diabatic rats.

Diets	Study I		Study II		Study III	
	ROB	POB	ROB	POB	ROB	POB
Control	55.14	55.19	51.81c	52.56b	39.03c	39.16c
10%	55.50	55.69	52.90b	53.45c	39.97b	40.19b
20%	55.73	56.31	53.45ab	54.23b	40.78b	40.78b
30%	55.93	56.91	54.05a	55.34a	41.22a	41.76a

Study I: Normal rats, Study III: Induced diabetic mellitus, Study III: Induced diabetic mellitus; Values are given Mean ± SE. Means carrying same letters do not differ significantly.

The oat bran containing β-glucan compound has ability to improve insulin resistance and glucose tolerance as reported by Battilana et al. (2001). These effects of β-glucan are due to its ability to stimulate adipocyte uptake of glucose. The decrease of insulin level with oat bran in present findings is supported by the work of Delaney et al. (2003) as they elucidated reduction in blood insulin in Sprague Dawley rats with oat beta glucan. The oat bran suppresses the blood glucose and insulin level following carbohydrate ingestion in rats, might be due to its ability to inhibit the activity of amylase an enzyme vital for the breakdown of starch (Wu & Wei., 2009).

The oat bran mitigates high insulin levels; hypo insulinemic capability may be attributed due to its ability to improve insulin sensitivity. The findings of Ripsin et al. (1992) explicated that insulin level was decreased by oat bran containing diets fed to human subject at different levels. They observed that deficient adiponectin level is one of the factors contributing towards insulin resistance. Similarly, Behall et al. (2004) observed significant reduction for this trait fed on high fat diet with oat bran. The effect oat bran on insulin can partially be attributed to decrease in weight gain and body fat. The oat bran containing β-glucan may improve insulin sensitivity by increasing glucose disposal in the muscle and decreasing expression of gluconeogenic enzymes (phosphoenolpyruvate carboxykinase and glucose-6-phosphatase) in the liver. Wood et al. (2000) further observed that oat bran delaying in glucose absorption from the small intestine may possibly rout by which be possible reason to improve insulin resistance. Oat bran β-glucan increases tyrosine phosphorylation of the insulin receptor and the insulin receptor substrate and reduces gene expression of the gluconeogenic enzyme (Jenkins et al., 2002). They also speculated that β-glucan increases insulin sensitivity by inhibiting protein kinase C and increasing insulin receptor substrate mediated signaling. It is stated from the above all discussion that functional diets containing active ingredient β-glucan are valuable against hyperglycemia and hyperinsulinemia thus suitable in dietary treatment for attenuation of these physiological threats.

4 Conclusions

The efficacy trials conducted to explore the functional properties of diets containing raw and processed oat bran to ameliorate lifestyle disorders like diabetes prevalent globally. The glucose reduction was found significantly different when diets containing raw and processed oat bran fed to normal, hypercholesterolemic and diabetic rats. The highest glucose reduction was found when rat fed on diet containing 30% processed oat bran. The processed oat bran showed maximum reduction in glucose as compared to raw oat bran. However, percentage of decreasing glucose was recorded in an ascending order i.e. diabetic > hypercholesterolemic > normal. The increase in the level of insulin was found significantly differed when diets containing raw and processed oat bran fed to hypercholesterolemic and diabetic rats. However, it showed non-significant affect when diets containing raw and processed oat bran fed to normal rats. The highest insulin level increase was found when rats in all the studies fed on diet containing 30% processed oat bran. The processed oat bran showed maximum increase in insulin as compared to raw oat bran. However, percentage of increase insulin level was found in an ascending order i.e. diabetic > hype rcholesterolemic > normal. Conclusively, oat bran has functional worth against various physiological threats. The diet containing processed oat bran performed better in the management of mitigating serum glucose and insulin level. It is suggested that processed oat bran may be introduced in diet-based therapy to control lifestyle-related disorders.

References

American Association of Cereal Chemists – AACC International. (2000). *Approved methods of the AACC* (10th ed.). *Methods 32-23*. St. Paul, MN: AACC International. https://doi.org/10.1094/aaccintmethods.

Andersson, A. A., Armö, E., Grangeon, E., Fredriksson, H., Andersson, R., & Åman, P. (2004). Molecular weight and structure units of (1→ 3, 1→ 4)-β-glucans in dough and bread made from hull-less barley milling fractions. *Journal of Cereal Science*, 40(3), 195-204. http://dx.doi.org/10.1016/j.jcs.2004.07.001.

Association of Official Analytical Chemists – AOAC. (2006). *Official methods of analysis of association of officials of analytical chemists* (18th ed.). Arlington: AOAC Press. https://doi.org/10.1016/0003-2670(91)87088-o.

Battilana, P., Ornstein, K., Minehira, K., Schwarz, J. M., Acheson, K., Schneiter, P., Burri, J., Jéquier, E., & Tappy, L. (2001). Mechanisms of action of β-glucan in postprandial glucose metabolism in healthy men. *European Journal of Clinical Nutrition*, 55(5), 327-333. http://dx.doi.org/10.1038/sj.ejcn.1601160. PMid:11378805.

Behall, K. M., Scholfield, D. J., & Hallfrisch, J. (2004). Diets containing barley significantly reduce lipids in mildly hypercholesterolemic men and women. *The American Journal of Clinical Nutrition*, 80(5), 1185-1193. http://dx.doi.org/10.1093/ajcn/80.5.1185. PMid:15531664.

Besch, W., Woltanski, K. P., Keilacker, H., Diaz-Alonso, J. M., Schulz, B., Amendt, P., Kohnert, K. D., & Ziegler, M. (1987). Measurement of insulin in human sera using a new ria kit. 1. insulin determination in the absence of insulin antibodies—conventional assay and micro modification. *Experimental and Clinical Endocrinology,* 90(3), 264-270. http://dx.doi.org/10.1055/s-0029-1210700. PMid:3330034.

Brown, G. D., & Gordon, S. (2001). Immune recognition: a new receptor for β-glucans. *Nature*, 413(6851), 36-37. http://dx.doi.org/10.1038/35092620. PMid:11544516.

Buckeridge, M. S., Rayon, C., Urbanowicz, B., Tiné, M. A. S., & Carpita, N. C. (2004). Mixed linkage (1→ 3),(1→ 4)-β-d-glucans of grasses. *Cereal Chemistry*, 81(1), 115-127. http://dx.doi.org/10.1094/CCHEM.2004.81.1.115.

Delaney, B., Nicolosi, R. J., Wilson, T. A., Carlson, T., Frazer, S., Zheng, G. H., Hess, R., Ostergren, K., Haworth, J., & Knutson, N. (2003). β-Glucan fractions from barley and oats are similarly antiatherogenic in hypercholesterolemic Syrian golden hamsters. *The Journal of Nutrition*, 133(2), 468-475. http://dx.doi.org/10.1093/jn/133.2.468. PMid:12566485.

Devries, J. W. (2004). Dietary fiber: the influence of definition on analysis and regulation. *Journal of AOAC International*, 87(3), 682-706. http://dx.doi.org/10.1093/jaoac/87.3.682. PMid:15287669.

Food and Drug Administration – FDA. (1997). *FDA allows whole oat foods to make health claim on reducing the risk of heart disease*. Retrieved from http://www.cfsan.fda.gov/~lrd/tpoats.html

Helm, C. V., & Francisco, A. D. (2004). Chemical characterization of Brazilian hulless barley varieties, flour fractionation, and protein

concentration. *Scientia Agrícola*, 61(6), 593-597. http://dx.doi.org/10.1590/S0103-90162004000600005.

Immerstrand, T., Bergenståhl, B., Trägårdh, C., Nyman, M., Cui, S., & Öste, R. (2009). Extraction of β-glucan from oat bran in laboratory scale. *Cereal Chemistry*, 86(6), 601-608. http://dx.doi.org/10.1094/CCHEM-86-6-0601.

Jenkins, A. L., Jenkins, D. J. A., Zdravkovic, U., Würsch, P., & Vuksan, V. (2002). Depression of the glycemic index by high levels of β-glucan fiber in two functional foods tested in type 2 diabetes. *European Journal of Clinical Nutrition*, 56(7), 622-628. http://dx.doi.org/10.1038/sj.ejcn.1601367. PMid:12080401.

Keogh, G. F., Cooper, G. J., Mulvey, T. B., McArdle, B. H., Coles, G. D., Monro, J. A., & Poppitt, S. D. (2003). Randomized controlled crossover study of the effect of a highly β-glucan–enriched barley on cardiovascular disease risk factors in mildly hypercholesterolemic men. *The American Journal of Clinical Nutrition*, 78(4), 711-718. http://dx.doi.org/10.1093/ajcn/78.4.711. PMid:14522728.

Manthey, F. A., Hareland, G. A., & Huseby, D. J. (1999). Soluble and insoluble dietary fiber content and composition in oat. *Cereal Chemistry*, 76(3), 417-420. http://dx.doi.org/10.1094/CCHEM.1999.76.3.417.

McCleary, B. V., & Codd, R. (1991). Measurement of (1 → 3),(1 → 4)-β-D-glucan in barley and oats: a streamlined enzymic procedure. *Journal of the Science of Food and Agriculture*, 55(2), 303-312. http://dx.doi.org/10.1002/jsfa.2740550215.

Papageorgiou, M., Lakhdara, N., Lazaridou, A., Biliaderis, C. G., & Izydorczyk, M. S. (2005). Water extractable (1→ 3, 1→ 4)-β-D-glucans from barley and oats: an intervarietal study on their structural features and rheological behaviour. *Journal of Cereal Science*, 42(2), 213-224. http://dx.doi.org/10.1016/j.jcs.2005.03.002.

Pereira, M. A., Pins, J. J., Raatz, S. K., Gross, M., Slavin, J. L., & Seaquist, E. R. (2000). The effect of whole grains on body weight and insulin sensitivity in overweight hyperinsulinemic adults. *Diabetes*, 49(5), A40-A40.

Ripsin, C. M., Keenan, J. M., Jacobs, D. R. Jr., Elmer, P. J., Welch, R. R., Van Horn, L., Liu, K., Turnbull, W. H., Thye, F. W., Kestin, M., Hegsted, M., Davidson, D. M., Davidson, M. H., Dugan, L. D., Demark-Wahnefried, W., & Beling, S. (1992). Oat products and lipid lowering: a meta-analysis. *Journal of the American Medical Association*, 267(24), 3317-3325. http://dx.doi.org/10.1001/jama.1992.03480240079039. PMid:1317928.

Steel, R. G. D., Torrie, J. H., & Dickey, D. A. (1997). *Principles and procedures of statistics. A biometrical approach* (3rd ed.). New York: McGraw Hill Book Co., Inc.

Thomas, L., & Labor, U. (1992). Enzymateischer kinetischer colorimetrischer test (GOD-PAP). *Biocon Diagnostik. Hecke*, 8(34516), 169-174.

Tsuchihashi, K., Ueshima, K., Uchida, T., Oh-mura, N., Kimura, K., Owa, M., Yoshiyama, M., Miyazaki, S., Haze, K., Ogawa, H., Honda, T., Hase, M., Kai, R., & Morii, I., and the Angina Pectoris-Myocardial Infarction Investigations in Japan (2001). Transient left ventricular apical ballooning without coronary artery stenosis: a novel heart syndrome mimicking acute myocardial infarction. *Journal of the American College of Cardiology*, 38(1), 11-18. http://dx.doi.org/10.1016/S0735-1097(01)01316-X. PMid:11451258.

Usman, S., Nazir, S., Ali, S., Nasreen, Z., & Najim, A. (2010). Determination of biochemical composition of avena sativa (oat) and to estimate the effect of high fiber diet on hypercholesterolemic rats. *Bangladesh Research Publications Journal*, 4(4), 312-319.

Vasanthan, T., Gaosong, J., Yeung, J., & Li, J. (2002). Dietary fiber profile of barley flour as affected by extrusion cooking. *Food Chemistry*, 77(1), 35-40. http://dx.doi.org/10.1016/S0308-8146(01)00318-1.

Wood, P. J., & Beer, M. U. (1998). Functional oa t product. In G. Mazza. *Functional food, biochemical and processing aspects* (pp. 1-37). Phennsylvania: Technomic Publishing Lancaster.

Wood, P., Beer, M. U., & Butler, G. (2000). Evaluation of role of concentration and molecular weight of oat β-glucan in determining effect of viscosity on plasma glucose and insulin following an oral glucose load. *British Journal of Nutrition*, 84(1), 19-23. http://dx.doi.org/10.1017/S0007114500001185. PMid:10961156.

Wu, C. D., & Wei, G. (2009). Tea as a functional food for oral health. In M. Wilson (Ed.), *Food constituents and oral health* (pp. 396-417). Cambridge: Woodhead Publishing. http://dx.doi.org/10.1533/9781845696290.2.396.