Available online on 15.04.2020 at http://jddtonline.info

Journal of Drug Delivery and Therapeutics

Open Access to Pharmaceutical and Medical Research

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Effect of Durum Wheat Bran on Glucose and Lipid Metabolism in Diabetic Rats

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ABSTRACT

Introduction: Durum wheat bran is obtained from wheat milling, it's considered as an excellent source of insoluble dietary fibre. **Objective:** The aim of this paper was to evaluate the effect of wheat bran (WB) on glucose and lipid metabolism in normal and diabetic rats. **Materials and Methods:** Twenty-four female rats of "Wistar" were divided into four groups each containing six rats. The first group (NCR) was fed by a control diet while the second group (NCRE) was fed by the experimental diet based on durum wheat bran. For the third and fourth group after streptozotocin (STZ) injection, they were fed by a control diet (DCR) and experimental diet (DRE) respectively. The Blood Glucose (g/L) and weight (g) of these groups was measured at the end of each week for a period of four weeks, the serum lipid parameters in the fasting condition, such as TC, TG, LDL-C and HDL-C were evaluated at the end of the experience. **Results:** WB was high in dietary fibre (41%). The results show a significant decrease in blood glucose ($p<0.04$) and body weight ($p<0.05$) in DRE group compared to DCR group and non-diabetic groups. No significant difference was observed for cholesterol and triglyceride levels, a difference of $p<0.05$ for HDL-C was observed between the diabetic experimental diet group and the non-diabetic control diet group. For LDL-C, the difference was observed between the diabetic experimental group and the non-diabetic experimental group ($p<0.001$). **Conclusion:** Our results indicated that WB exerting a glycemic and a serum lipid regulation effect in experimental diabetic rats.

Keywords: durum wheat bran, dietary fibre, blood glucose, weight, diabetic

Article Info: Received 26 Jan 2020; Review Completed 21 March 2020; Accepted 27 March 2020; Available online 15 April 2020

Cite this article as:

Tarfaoui L, Menadi N, Meziani S, Zairi M, Bekhaled I, Benalia A, Boukhatmi F, Sennous K, Demmouche A, Effect of Durum Wheat Bran on Glucose and Lipid Metabolism in Diabetic Rats, Journal of Drug Delivery and Therapeutics. 2020; 10(2-s):30-34 http://dx.doi.org/10.22270/jddt.v10i2-s.4000

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INTRODUCTION

Diabetes is a chronic metabolic disorder that represents a major public health problem; it's localized throughout the world, 422 million people worldwide had diabetes.The prevalence of diabetes has increased over the last years and is rising faster in low- and middle-income countries, which is 8.5%. The prevalence in Algeria is 10.5% [1].

This metabolic disease is characterized by chronic hyperglycemia caused by two major disorders, abnormal insulin secretion and/or insulin resistance. Factors that contribute to the development of this metabolic dysfunction may include a diet with a high glycemic index, obesity, and lack of physical activity[2]. Numerous studies have shown that nutrition is fundamental for the prevention of these metabolic diseases and that the intake of dietary fibre in the daily diet is associated with a reduction in risk factors characterised by a slower absorption of carbohydrates that reduces hyperglycaemia and an improvement in total cholesterol, HDL, LDL-C and blood pressure [3].

Fibers are a structural part of plant founded in different plant foods, especially in vegetables, fruits and grains. Fiber may be a discrete group of carbohydrate found almost exclusively in plants. Most dietary fibers are polysaccharides are starched, a long chain of glucose molecules linked along side beta bonds, the human body lacks enzymes to interrupt beta bonds; therefore fiber isn't digested and absorbed. The undigested fiber passes into the lower intestine where intestinal bacteria can ferment the fibers [4] among their beneficial properties; a reduction in postprandial glycaemia or insulinemia, a reduction in total cholesterol or LDL, fermentability by the colonic flora and an increase in stool volume [5,6]. A daily intake of 25 g for adult women and 38 g for adult men is suggested by the international recommendation [7]. Cereals, especially wheat, are considered as an important source of insoluble fibre.This fibre is mainly concentrated in the outer layers of the grain (pericarp and seed coat), which is the wheat bran (a by-product obtained after refining) [8].

Many epidemiological and intervention studies have demonstrated the benefits of daily dietary fibre consumption for human health [9,10]. The consumption of grains rich in fibre may reduce cardiovascular disease, diabetes and cancer [11]. The aim of this study is to evaluate the effect of dietary high-fibre WB in diabetic rats.

MATERIALS AND METHODS

The sample of durum wheat bran (*Triticum durum*) was collected in the raw state from the cereal and derivatives processing company in Sidi Bel Abbés (Western Algeria). It was produced from a contaminant-free culture in accordance with the periodics carried out by the laboratory of the wheat processing company. The determination of the fibres was carried out according to the method described by the French Association for Standardization [12].

Twenty-four albino rats (*Rattus norvegicus*), adult female, Wistar strain, aged between 12-14 weeks, weight 200-230 g have been hosted in cages under standard environmental conditions with free access to water and food. The experiment has been approved by the Ethics Council of the Faculty of Natural and Life Sciences of the University Djilali Liabes of Sidi Belabbes.

Induction of diabetes

Diabetes was induced by a single intraperitoneal injection of Streptozotocine (STZ) (60 mg/kg b.wt), freshly prepared in 0.1M sodium citrate buffer (pH 4.5) after overnight fasting [13]. Rats with a fasting blood glucose value of more than 2.5 g/l and significant glycosuria are considered diabetic and are selected for the experiment, while rats from other groups were injected with citrate buffer (0.1 M)

Experimental design

The twenty-four rats received an experimental and control diet during the four weeks. The guidelines of feed and nutritiont for rodents have been respected [14]. The ingredients are mixed to obtain final formulations (Table 1). The rats were randomly divided into four groups of six animals each. Group 1: Normal rats (NCR) received the control diet, Group 2: Normal rats (NCRE) received the experimental diet, Group 3: Diabetic rats (DCR) received the control diet and Group 4: Diabetic rats (DRE) received the experimental diet. All diets were given orally after the 4th day of STZ administration for 30 days. After 12 h of fasting, the blood sample was taken from the caudal vein for the blood glucose test and measured with a blood glucose meter (DIAGNO-CHEK Smart). The body weight of the rats was measured using an electronic precision scale. Sf-400 with a margin of error of less than 0.01 grams on 0, 7, 14 , 21 and 27 day of the study.

At the end of the experiment, the animals were fasted overnight, anaesthetized and sacrificed in accordance with ethical conditions. Blood samples were taken from the posterior vena cava in heparin tubes. The blood was centrifuged at 3000 rpm for 15 minutes to recover serum for the determination of serum glucose, lipid profile (total cholesterol (TC), triglycerides (Try), high density lipoprotein cholesterol (HDL-C), and low density lipoprotein cholesterol (LDL-C)). The assays were measured by colorimetric enzyme kits according to the manufacturer's protocols (Spinreact).

Statistical Analysis:

Statistical analysis was performed using IBM SPSS, version 22.0. All the results were expressed as mean ± SEM for six rats in each group, and statistical analysis was performed by one-way analysis of variance (ANOVA) followed by Tukey's Post-Hoc test. The analysis of the weight and blood glucose results is performed by the ANOVA repeated measures multivariate tests. Differences are considered significant if $P < 0.05$*; highly significant if $P < 0.01$** and highly significant if $P < 0.001$*** [15].

Table 1 Composition of the control and experimental diet

Ingredient	Control diet (g/kg)	Experimental diet (g/kg)
Cornstarch	465.69	465.69
Casein |>85% protein	140	140
Dextrinized cornstarch (90-94% tetrasaccharides)	155	155
Sucrose	100	100
corn oil	40	40
Wheat bran	--	350
Fibre	50	--
Mineral mix (AIN-93G-MX]	35	35
Vitamin mix (AIN-93-VX)	10	10
DL Methionine	3	3

RESULTS

Effect of control and experimental diet on body weight in normal and diabetic rats fed for four weeks (g)

The results of the total fibre present in Wb are in order of 41.00% / dry weight. Wb induced significant body weight loss ($p<0.05$) in diabetic rats receiving the experimental diet (202.50 g ± 33.45 vs 170.50 g± 18.47) (Table 2).

Table 2 Effect of control and experimental diet on body weight in normal and diabetic rats fed for **four** weeks (g)

Groups	1st	2nd	3rd	4th
NCR	223.50 ± 3.44	213.83 ± 6.40	216.33 ± 6.83	226.00 ± 7.29
NCRE	217.16 ± 17.84 NS	180.83 ± 14.44*	190.83 ± 15.51*	210.0 ± 16.81NS
DCR	196.50 ± 20.24 NS	179.66 ± 8.52*	189.16 ± 10.20*	196.66 ± 17.79*¶
DRE	202.50 ± 33.45 NS	188.16 ± 22.98*	180.00 ± 22.13*	170.50 ± 18.47***¶

NCR Normal rats received the control diet. **NCRE**: Normal rats received the experimental diet. **DCR** Diabetic rats received the control diet. **DRE** Diabetic rats received the experimental diet * P<0.05, * *P<0.01, ***P<0.001 Significant difference NCR vs. other groups ¶ P<0.05, ¶¶ P<0.01, ¶¶¶ P<0.001 Significant difference DCR vs. DRE. NS : Not significant

Effect of control and experimental diet on blood glucose in normal and diabetic rats fed for four weeks (g/l)

A very significant ($p<0.04$) decrease in blood glucose was observed from the fourth week in diabetic rats on the Wb diet compared to the other groups (4.20g/L ± 0.40 vs 3.10g/L±0.49) (Table 3).

Table 3 Effect of control and experimental diet on blood glucose in normal and diabetic rats fed for four weeks (g/l)

Groups	1st	2nd	3rd	4th
NCR	0.88 ± 0.11	0.75± 0.08	0.80± 0.11	0.80± 0.11
NCRE	0.65± 0.14NS	0.76±0.12NS	0.73±.09NS	0.73±0.09NS
DCR	3.96±0.75***	5.30±0.28***	5.18±0.24***	5.28±0.32***¶¶¶
DRE	4.20±0.40***	5.35±0.32***	4.40±0.40***	3.10±0.49***¶¶¶

NCR Normal rats received the control diet. **NCRE**: Normal rats received the experimental diet. **DCR** Diabetic rats received the control diet. **DRE** Diabetic rats received the experimental diet * P<0.05, * *P<0.01, ***P<0.001 Significant difference NCR vs. other groups ¶ P<0.05, ¶¶ P<0.01, ¶¶¶ P<0.001 Significant difference DCR vs. DRE. NS: Not significant

Effect of control and experimental diet on plasma lipid in normal and diabetic rats fed for four weeks (mg/dl)

No significant differences were found for the parameters total cholesterol (TC) and triglycerides (TG) throughout the experimental period between diabetic rats receiving the control and experimental diets. For high density lipoprotein cholesterol (HDL-C), a very significant difference ($p<0.01$) was found between non-diabetic rats on the control diet and diabetic rats on the experimental diet (1.18 ± mg/dl0.16 .vs 0.23mg/dl ±0.01).However, the results for low density lipoprotein cholesterol (LDL-C) levels showed a very significant difference ($p<0.001$) between diabetic rats on the experimental diet and non-diabetic rats on the experimental diet (0.93 mg/dl ± 0.40 vs. 0.10 mg/dl± 0.04) (Table 4).

Table 4 Effect of control and experimental diet on plasma lipid components in normal and diabetic rats fed for four weeks (mg/dl)

Groups	TC (mg/dl)	TG (mg/dl)	HDL (mg/dl)	LDL (mg/dl)
NCR	1.01±.08	0.38 ± 0.20	1.18 ± .16	0.46 ± 0.30
NCRE	1.91± 0.73*	0.57± 0.16 NS	1.37±.0.83NS	0.93 ± 0 .40NS
DCR	0.33 ±0.08 NS	0 .57±0.24 NS	0.26± 0.04***	0.04± 0.02* ¶¶
DRE	0.29 ± .06NS	0.84 ± 0.46 NS	0.23±0 .01***	0.10 ± 0.04*¶¶

NCR Normal rats received the control diet. **NCRE**: Normal rats received the experimental diet. **DCR** Diabetic rats received the control diet. **DRE** Diabetic rats received the experimental diet * P<0.05, * *P<0.01, ***P<0.001 Significant difference NCR vs. other groups ¶ P<0.05, P<0.01, P<0.001 Significant difference DCR vs. DRE. NS: Not significant

DISCUSSION

The increasing incidence of diabetes worldwide is prompting researchers to find molecules that target therapy for this metabolic disorder and to explain their mechanisms. A healthy diet, rich in dietary fibre such as Wb, can help to regulate the metabolism. Dietary fiber has an important role in the intestine by delaying digestion and absorption of food, by regulating a number of metabolic hormones; they can reduce the postprandial glycemic response and insulin concentrations [16]. Wb is high in fibre (41.00 % / dry weight). This result is similar to that described in the literature [5,6]. In our study, the variation in body weight of rats is a very important parameter. A significant difference in the body weight of the diabetic rats compared to the non-diabetic rats was observed. The results of this experiment indicate a significant decrease ($P<0.05$) of 15.84% in the body weight of diabetic rats compared to non-diabetic rats. This is consistent with [17], who showed that the consumption of fibre and in particular cereal bran reduces body weight. However, a slow and steady weight frequency increase of 1.34% and 3.22% was observed respectively in non-diabetic rats fed with the control diet and non-diabetic rats fed with the experimental diet throughout the experiment. It can be explained that a consumption of dietary fiber slows gastric emptying which can promote satiety because the insoluble fiber of Wb has a high hygroscopicity and increases the food volume of the stomach which reduces appetite [18].

The evolution of glycemia in all groups of rats shows a clear increase in blood glucose levels after the induction of diabetes by streptozotocin, which is confirmed by the literature [13]. During the first three weeks; no decrease in blood glucose levels was observed; it was after the fourth week that we found a significant decrease ($P<0.04$) in blood glucose levels in diabetic rats on the Wb diet compared to the other groups. While in the group of diabetic rats with a control diet, hyperglycaemia was observed after induction of diabetes, and it persisted throughout the experiment with a frequency of 33.33%. A significant difference ($P <0.001$) in blood glucose is observed between the non-diabetic group with control diet and the group with experimental diet from the third week. The same results were found by [19]. During colonic fermentation of soluble fibres by the intestinal microbiota, the short-chain fatty acids (SCFAs) generated has the advantage of activating the expression of Intestinal Neoglucogenesis (IGN) genes by complemental mechanisms [20]. The effect of Wb on hormones that regulate postprandial appetite is less well investigated, a recent animal study has investigate the effect of Wb on glucagon-like peptide-**1** (GLP-1) secretion showed no effect on body weight, body fat mass and glucose or insulin resistance. However, this study demonstrated the impact of Wb on inflammation, including the reduction of inflammatory cytokines [21]. Another clinical study over a period of six months, include the comparison of two diets, one with a 50g / day of fiber and the other 15g / day of fiber, an improvement in daily blood glucose levels was observed [22]. At the end of the experiment, the results relating to the plasma lipid profiles of all the groups of diabetic rats on the control and experimental diets showed that no significant difference in cholesterol levels was observed. Similar results were found by [23].

However, a significant difference ($p<0.04$) in cholesterol levels in the non-diabetic group compared to the non-diabetic experimental group. This is according to the results founded by [24].

No significant differences were recorded for triglyceride levels, which are founded also by [23]. A study realized on male rats receiving a diet enriched in 10% of oligofructose, showed a significant difference ($p< 0.01$) in the triglyceride level. HDL levels, a very significant difference ($p < 0.01$) was found between non-diabetic rats on the diet and diabetic rats on the experimental diet [25]. Our results are similar to those published by [23, 24]. The LDL results showed a very significant difference ($p<0.001$) between diabetic rats on the experimental diet and non-diabetic rats on the experimental diet. According to a systemic study and a metanalysis of 45 prospectives studies and 21 clinical studies, an increased consumption of whole grain cereals for 4 to 16 weeks significantly improves an individual's lipid profile by reducing total cholesterol by 0.83 mmol/L and LDL cholesterol by 0.72 mmol/L [26]. The minor differences in HDL and LDL levels found may be due to a diet supplemented with wheat bran in the short term, whereas in the other studies, the duration of dietary exposure was longer.

The action of soluble fibres on the lipid profile can be explained by a decrease in the absorption of bile acids and can interrupt their loss and also their de novo synthesis in the liver, as they can participate in the modulation of the intestinal flora causing a decrease in acetate and cholesterol synthesis by increasing the synthesis of probionate and therefore less release of LDL. In a study of 573 subjects on a dietary fibre diet, found a decrease in lipid profile ($p<0.01$) which is a good indicator for cardiovascular disease [27].

CONCLUSION

Durum wheat bran is one of the most widely used cereal by-products in the Maghreb region and in most countries. High dietary fiber content confirms the beneficial effects of Wb on glucose and lipid metabolism. The valorization of Wb, which is widely available at the national level, is essential in its therapeutic and economic aspects.

Conflict of Interest

The authors have no conflict of interest. We did not receive any financial support for this study.

Acknowledgements

The authors would like to express their gratitude to all of the participants for valuable assistance in this study. All authors read and approved the final manuscript.

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