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EFFECT OF NANO SWEET POTATO RESIDUE CELLULOSE ON BLOOD GLUCOSE LEVEL OF ATHLETES

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ABSTRACT

This study aimed to investigate the regulatory mechanism of nano sweet potato residue cellulose in lowering blood glucose and its effect on blood glucose level of athletes based on the research of the antidiabetic effect and molecular mechanism of nano sweet potato residue cellulose. Diabetes models were built to explore the effect of nano sweet potato residue cellulose in lowering blood glucose level of diabetic rats as well as its functional mechanism. In addition to reducing fasting blood glucose level of diabetic rats, nano sweet potato residue cellulose also had a regulatory effect on blood lipid of diabetic rats; it was conducive to easing body's blood sugar regulation mechanism and improving glucose tolerance. Through the restraint effect on glucose, nano sweet potato residue cellulose can reduce the intestinal absorption of glucose and inhibit postprandial hyperglycemia; with relatively high viscosity values, it can increase intestinal peristalsis and hinder the diffusion of glucose and lipids; by reducing intestinal absorption of glucose and lipid, it can increase athletes' blood glucose excretion, which is a synergistic effect of lowering blood glucose.

1. Introduction

Sweet potatoes are rich in starch, dietary fiber, glycoprotein, minerals and vitamins which make for balanced and high nutritional value (Ma and Mu, 2016; Bernstein, et al., 2016). As we know, with the improvement of living standards and changes in diet, a lot of "civilized diseases", such as diabetes, hypertension and obesity, have become more frequent, especially among the people whose dietary fiber intake is insufficient (Altug et al., 2009). Therefore, dietary fiber (DF) is of great significance to human health (Zamot, et al., 2015). Since the body structure of rats is similar to that of human, we used rats as models to study the effect of nano sweet potato residue cellulose in lowering blood glucose, so as to analyze its impact on athletes' blood glucose level.

Previous studies showed that nano sweet potato residue cellulose could significantly inhibit the activity of amylase and pancrelipase (Zhu et al., 2015; Ji et al., 2015). Another study indicated that the decrease in activity of amylase and pancrelipase could reduce the hydrolysis of starch and lipids, while high viscosity values helped to delay and reduce gastrointestinal absorption of glucose and lipid (Zhang et al., 2015). It was reported that dietary fiber could not only elevate serum insulin level, but also reduce and balance postprandial blood glucose level to avoid violent fluctuation of blood glucose level (Marquard et al., 2016). In 2014, Wu et al. performed a vitro experiment which showed that DF inhibited the effect of a-amylase on starch and prolonged enzymolysis time, thus slowing glucose release (Yunshan et al., 2014). Gui et al. (2014) found that barley

husk played a role in regulating metabolism by reducing the activity of amylase, lipase and chymotrypsin in human small intestine (Gui et al., 2014). This study analyzed the possible mechanism of nano sweet potato residue cellulose lowering blood glucose as well as its effect of on blood glucose level of athletes.

2. Materials and methods

2.1. Experimental materials and instruments

Experimental materials included sweet potato residues (Chew and Ong, 2016), sweet potato residue cellulose, nano sweet potato residue cellulose, microcrystalline sweet potato residue cellulose and healthy male rats.

Experimental instruments included electronic balance, numerical control ultrasonic cleaner, desk-type high speed centrifuge, ultrapure water machine, ultra low temperature freezer, blood glucose tester, refrigerated microcentrifuge, gel imaging system (Lu, et al., 2013) and slicing machine.

Experimental reagents included sodium hydroxide, corn starch, anhydrous calcium carbonate, potassium sulfate, potassium citrate, ether, citric acid, potassium chloride, petroleum ether (Peng et al., 2011), glucose, serum low-density lipoprotein kit, rat serum insulin kit and total protein extraction kit.

2.2. Experimental methods

2.2.1. Model building

Forty male rats (each weighting about 190 g) were selected and separately fed in stainless steel cages at room temperature (25 °C). After one-week feeding, they were divided into five groups randomly according to their weights. One group was selected as the blank group and fed with basic diet, while the remaining four groups of rats were fed with only water for 12 h; citric acid-sodium citrate buffer solution was used for the preparation of streptozocin (STZ) solution (2mg/mL) which was injected into each fasting rat (with a dosage of 60mg/kg). After injection, all rats were free to eat and drink. After three days, blood was drawn from rats' tails for determination of fasting blood glucose. The rats whose blood glucose values were greater than 11.1mmol/L were confirmed of having diabetics; the ones that did not meet the standard were given another injection of STZ solution.

The model diabetic rats were randomly divided into four groups: model control group (MC group), group of ordinary sweet potato residue cellulose (OC group), group of microcrystalline sweet potato residue cellulose (MCC group) and group of nano sweet potato residue cellulose (CNC group). Feed formulation for each group is shown in Table 1. During the experiment, rats in each group were free to drink and eat, with their daily feed intake and weight recorded; fasting blood glucose values were measured every two weeks; the test cycle lasted for 4 weeks.

2.2.2. Determination of fasting blood glucose

Respectively, in the first week, the second week and the fourth week, the rats fasted for 12 hours before their blood was drawn from the tail and dropped on the reaction end of blood glucose test strip; then the rats' fasting blood glucose values were determined by a glucometer (Kim et al., 2010).

2.2.3. Determination of glucose tolerance

After fasting for 12 hours, glucose solution was injected into rats' stomachs, and their blood glucose values were measured at 0 min, 30 min, 60 min and 120 min; area under the curve (AUC) was calculated according to the measured results, and sugar tolerance level was compared.

2.2.4.Determination of glycosylated serum protein

Serum glucose can have nonenzymatic glycation reaction with N-terminal amino of albumin and other serum proteins, forming macromolecule ketone amine structure (Unwin et al., 2010).

Table 1. Feed formulation for the experiment

Ingredients	CON	Diabetes group			
		MC	OC	MCC	CNC
Corn starch	550	550	450	450	450
Casein	200	200	200	200	200
Soybean oil	100	100	100	100	100
Cane sugar	100	100	100	100	100
Mixed minerals	35	35	35	35	35
Mixed vitamin	10	10	10	10	10
L-cystine	3	3	3	3	3
Choline chloride	2.5	2.5	2.5	2.5	2.5
Sweet potato residue cellulose	-	-	100	-	-
Microcrystalline sweet potato residue cellulose	-	-	-	100	-
Nano sweet potato residue cellulose	-	-	-	-	100

2.2.5. Determination of serum lipid

Serum total cholesterol (TC), triglyceride (TG), high density lipoprotein (HDL-C) and low density lipoprotein (LDL-C) were detected with the kit and determined with a full automatic biochemical analyzer.

2.2.6. Determination of serum insulin

Specimens, standard and detection antibody were added into coated microtiter for incubation and thoroughly washed. Substrate tetramethylbenzidine (TMB) was used for coloration; catalyzed by peroxidase, TMB turned blue and eventually turned yellow under the action of acid. Insulin was positively correlated with the shade of color. Absorbance at the wavelength of 450 nm was measured with Elisa and sample concentrations were calculated.

2.3. Data analysis method

The test data were compiled by Excel and then analyzed by statistical software SPSS 17.0. The results were shown in the form of mean ± standard deviation. When p was less than 0.05, there was significant difference.

3. Results and discussions

3.1 Changes in feed intake of diabetic rats affected by nano sweet potato residue cellulose

As shown in Figure 1, in the four groups of diabetic rats (except the blank group), feed intake increased significantly ($p < 0.05$); meanwhile, feed intake also decreased with the decrease of cellulose particle size, yet the decrease range was insignificant ($p < 0.05$). Therefore, we assumed that the differences in particle size of sweet potato residue cellulose could not affect feed intake of rats (Keiko, et al., 2007).

3.2 Changes of fasting blood glucose in diabetic rats affected by nano sweet potato residue cellulose

As shown in Figure 2, compared to the rats (in blank group) whose fasting blood glucose values were within the normal range, the rats in other groups had higher blood glucose level (higher than 11mmol/L). In the second week, except the rats in blank group, the rats in other groups had decreased blood glucose level due to the difference in particle size of sweet potato residue cellulose; in CNC group, blood glucose values of diabetic rats decreased significantly ($p < 0.05$).

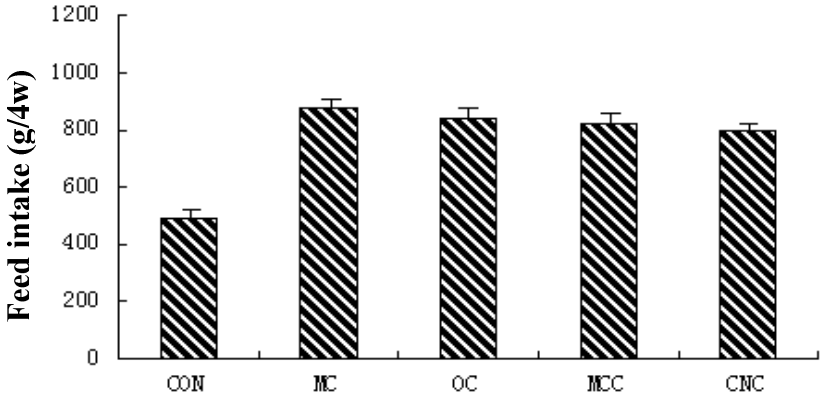

Figure 1. Changes in feed intake of diabetic rats affected by nano sweet potato residue cellulose
Note: CON refers to blank group; MC refers to model control group, OC refers to the group of ordinary sweet potato residue cellulose; MCC refers to the group of microcrystalline sweet potato residue cellulose; CNC refers to the group of nano sweet potato residue cellulose. Experiment data were shown in the form of mean ± standard deviation (n = 8).

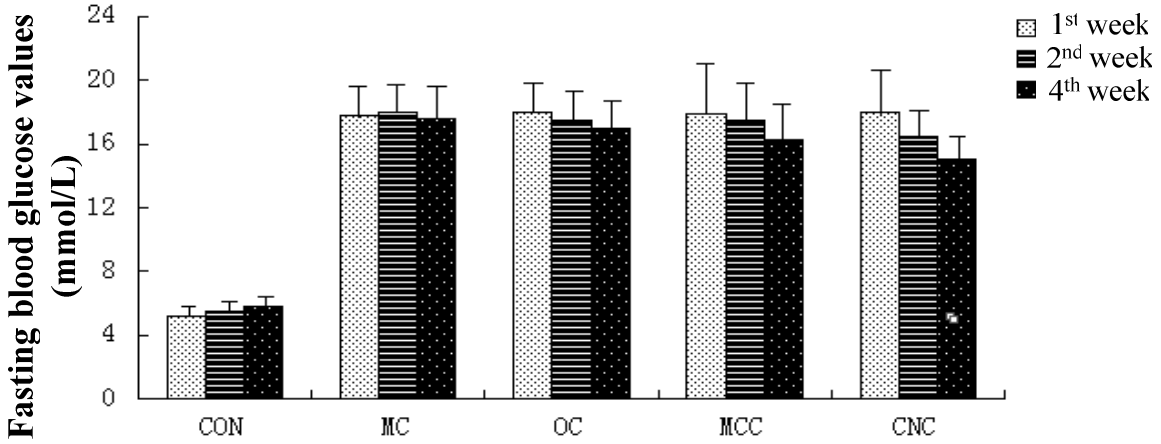

Figure 2. Changes of fasting blood glucose in diabetic rats affected by nano sweet potato residue cellulose
Note: CON refers to blank group; MC refers to model control group, OC refers to the group of ordinary sweet potato residue cellulose; MCC refers to the group of microcrystalline sweet potato residue cellulose; CNC refers to the group of nano sweet potato residue cellulose. Experiment data were shown in the form of mean ± standard deviation (n = 8).

In the fourth week, except blank group and control group, blood glucose values declined significantly in the other groups ($p < 0.05$). Therefore, it was considered that nano sweet potato residue cellulose could inhibit the increase of fasting blood glucose in rats.

3.3. Changes of glucose tolerance in diabetic rats affected by nano sweet potato residue cellulose (Defronzo, et al., 2011)

According to Figure 3, in the first minute, blood glucose values of rats in diabetic groups were higher than 11mmol/L, while blood glucose values of the rats in blank group were 5.68mmol/L. Thirty minutes after intragastric infusion of glucose (of certain concentration), blood glucose level increased significantly in each group; 60 min after the infusion, there was a decline trend; 120 min after the infusion, blood glucose level of the rats in blank group decreased to 6.12 mmo1/L. When a large amount of glucose was consumed all at once, under the effect of intracorporal regulation mechanism, intestinal tract could absorb almost all the glucose, resulting in rapid increase of blood glucose. Accordingly, it was considered that sweet potato residue cellulose helped to ease glucose regulation mechanism in the body and improve glucose tolerance.

3.4. Changes of glycosylated serum protein in diabetic rats affected by nano sweet potato residue cellulose

According to Figure 4, except in blank group, glycated serum protein content of the experimental diabetic rats in other groups increased significantly ($p < 0.05$). In comparison with model control group, glycated serum protein content of the rats in MCC group decreased by 0.2mmol/L, while glycated serum protein content of the rats in CNC group decreased by 0.28mmol/L. It can be seen from the data that glycated serum protein content decreased more significantly in CNC group than in MCC group ($p < 0.05$), based on which we considered that the effect on glycosylated serum protein content was enhanced with the decline in particle size of sweet potato residue cellulose (Yoshitomo, et al., 2003).

3.5 Changes of serum lipids in diabetic rats influenced by nano sweet potato residue cellulose

As can be seen from Table 2, in comparison with blank group, the concentrations of TC, TG and LDL-C were obviously higher in serum of the rats in other groups ($p < 0.05$), while the concentration of HDL-C reduced significantly in serum of the rats in other groups in comparison with blank control group ($p < 0.05$). Except blank control group, TC, TG and LDL-C concentrations decreased in the remaining groups since the rats were fed with sweet potato residue cellulose (of different particle sizes). Among the experimental rats, there was no obvious decrease in OC group, while a significant downward trend was found in CNC group ($p < 0.05$). Thus, it was considered that lipids of diabetic rats could be regulated by nano sweet potato residue cellulose to some extent (Teng, et al., 2012).

3.6 Changes of serum insulin in diabetic rats affected by nano sweet potato residue cellulose

According to Figure 5, serum insulin was in a significant decreasing trend in the rats of model control group, in comparison with other groups ($p < 0.05$). After the rats were fed with different particle size of sweet potato residue cellulose, serum insulin began to rise again in each group (except blank control group and model control group). The increasing trend was especially significant in CNC group ($p < 0.05$).

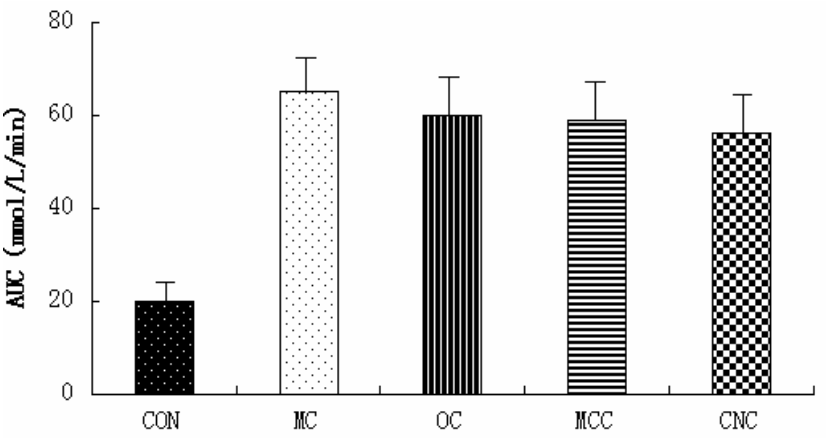

Figure 3. Changes of glucose tolerance in diabetic rats affected by nano sweet potato residue cellulose
Note: CON refers to blank group; MC refers to model control group, OC refers to the group of ordinary sweet potato residue cellulose; MCC refers to the group of microcrystalline sweet potato residue cellulose; CNC refers to the group of nano sweet potato residue cellulose.

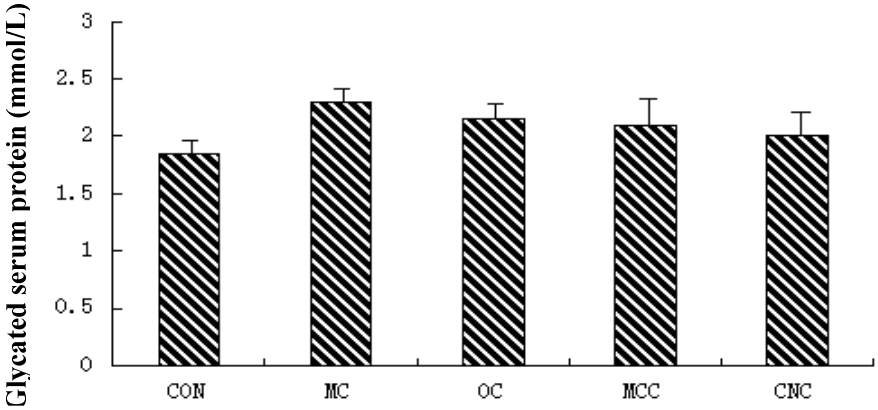

Figure 4. Changes of glycosylated serum protein in diabetic rats affected by nano sweet potato residue cellulose
Note: CON refers to blank group; MC refers to model control group, OC refers to the group of ordinary sweet potato residue cellulose; MCC refers to the group of microcrystalline sweet potato residue cellulose; CNC refers to the group of nano sweet potato residue cellulose. Experiment data were shown in the form of mean ± standard deviation (n = 8).

Table 2. Changes of serum lipids in diabetic rats influenced by nano sweet potato residue cellulose

Indexes (mmol/L)	Blank group	Diabetic group			
	CON	MC	OC	MCC	CNC
TC	1.3±0.18	1.5±0.12	1.4±0.08	1.4±0.09	1.4±0.07
TG	0.3±0.05	0.4±0.05	0.4±0.08	0.4±0.05	0.4±0.04
HDL-C	0.6±0.07	0.4±0.05	0.4±0.07	0.4±0.08	0.5±0.11
LDL-C	0.1±0.02	0.2±0.05	0.2±0.03	0.2±0.03	0.2±0.03

Note: CON refers to blank group; MC refers to model control group, OC refers to the group of ordinary sweet potato residue cellulose; MCC refers to the group of microcrystalline sweet potato residue cellulose; CNC refers to the group of nano sweet potato residue cellulose. Experiment data were shown in the form of mean ± standard deviation (n = 8).

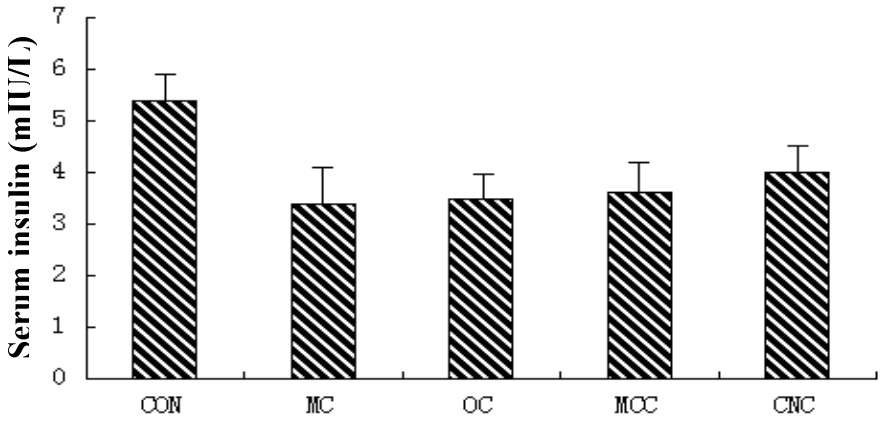

Figure 5. Changes of serum insulin in diabetic rats affected by nano sweet potato residue cellulose
Note: CON refers to blank group; MC refers to model control group, OC refers to the group of ordinary sweet potato residue cellulose; MCC refers to the group of microcrystalline sweet potato residue cellulose; CNC refers to the group of nano sweet potato residue cellulose.

4. Conclusions

Good eating habits and nutritional balance are of great significance to the prevention of diabetes (Mokhtari, et al., 2013). Dietary fiber can keep the balance of postprandial blood glucose and contribute to regulating blood glucose level for athletes (Wu et al., 2015; Li et al., 2015).

In this study, based on diabetic models of rats, we explored the effect of nano sweet potato residue cellulose on lowering blood glucose level of diabetic rats (Khanra et al., 2015). The results showed that the effect of sweet potato residue cellulose on regulating blood glucose was more significant with the decrease of particle size. The content of serum insulin and hepatic glycogen increased significantly in CNC group ($p < 0.05$). Nano sweet potato residue cellulose not only helped to decrease fasting blood glucose, glycosylated serum protein content, serum TC, TG and LDL-L content ($p < 0.05$), but also led to a decrease in liver fat concentration, content of TC and TG, which indicated that nano sweet potato residue cellulose had favorable effects on improving pancreatic tissue morphology as well as reducing blood glucose (Kovac, et al., 2015; Cheng, et al., 2010).

In summary, nano sweet potato residue cellulose can reduce fasting blood glucose and improve glucose tolerance mainly by slowing down the body's absorption of glucose; moreover, it increases insulin secretion and the body's sensitivity to insulin; in addition, it promotes the synthesis of hepatic glycogen and regulates the balance of glucolipid metabolism in liver (Zheng et al., 2015). Athletes can take nano sweet potato residue cellulose to lower blood glucose level effectively.

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