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Original Research Article

Bionanocomposite Prevents Body Weight Gain in High Calorie Diet-Obese Rats

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ABSTRACT

Background: During the last years, changes in lifestyle, changes in the food system, reduced physical activity seem to be the major drivers of the rise of the global epidemic of obesity. Due to obscure etiology, the treatment of obesity is difficult. Medicinal herbal supplements are being extensively utilized due to their effectiveness in managing many chronic disorders and exert less to no toxic side-effects in comparison with many chemically synthesized drugs. The aim of the present work was to study the effect of bionanocomposite on the body weight gain in experimental obesity, which was induced by the high-calorie diet.

Results: Our results suggest the development of obesity in rats who consumed high-calorie diet. The consumption of high-calorie diet leads to changes in food behavior and changes in key physiological and biochemical parameters. This study investigated the inhibitory effect of bionanocomposite (BNC) on body weight gain in high-calorie diet- (HCD-) induced obese rats. Male rats were fed by a HCD ad libitum which containing BNC (2%) ((HCD for 11 weeks + BNC (2%) for 11 weeks), respectively. The consumption of high-calorie diet animals with the addition of 2% bionanocomposite does not lead to excessive growth of the body weight of rats.

Conclusions: Bionanocomposite prevents body weight, body weight gain, specific rate of body mass gain in high calorie diet- obese rats. However, more in-depth studies are necessary to use bionanocomposite in the prevention of obesity.

Key words: Bionanocomposite; Fenugreek; Obesity; High calorie diet; Animal model; Body weight; Prevention

INTRODUCTION

The high prevalence of obesity is a global public health problem due to its association with several diseases, [1,2] and reduced lifespan. [3] It arises as a result of complex interaction of genetic, life style, dietary habitus, energy expenditure, nutritional and metabolic factors, as the adipocyte metabolism. [4,5] Key facts of obesity: worldwide obesity has more than doubled since 1980; in 2014, more than 1.9 billion adults, 18 years and older, were overweight; of these over 600 million were obese; 39% of adults aged 18 years and over were overweight in 2014, and 13% were obese; most of the world's population live in countries where overweight and obesity kills more people than underweight; 42 million children under the age of 5 were overweight or obese in 2013. [6]

Standard treatment options for obesity include reducing caloric intake and increasing energy expenditure. Often accompanied by an adaptive decrease in metabolic rate, making further body weight loss and/or maintenance difficult. [7]

Adherence to behavioral changes is generally poor, hindering the effectiveness of such programs. [8] Specifically, 50% of individuals who initiate an exercise program discontinue within 6 months. [8] For these reasons, many obese individuals are turning to pharmaceuticals to treat obesity. Current pharmaceutical approaches focus on methods to reduce food intake, either via the central nervous pathways or via the gastrointestinal tract. New drugs include sibutramine, a selective serotonin and norepinephrine reuptake inhibitor that elicits dose-dependent body weight reduction in obese individuals, [9] and orlistat, a specific inhibitor of gastric and pancreatic lipase activity that reduces gastrointestinal fat absorption by ~30% and also has demonstrated efficacy in achieving body weight loss in obese individuals. [10] Unfortunately, sibutramine (Sibutramine, which acts on the brain to inhibit deactivation of the neurotransmitters, thereby de-creasing appetite was withdrawn from the United States and Canadian markets in October 2010 due to cardiovascular side effects) and orlistat exhibits common adverse events in 10% to 30% of users. [11-14] A nutritional based intervention is being hailed as an inexpensive alternative to aid weight loss, and weight management.

Fenugreek (Trigonella foenum-graecum) also known as Greek hay is a well known leguminous annual herbaceous plant extensively cultivated in Asia, Africa and Europe. The Latin name of fenugreek, Trigonella means triangle shaped pale yellow flower and Foenum greacum means Greek hay. [15-17] Fenugreek grows to an average height of 2 feet its seeds are used in India as a condiment and in Egypt as a supplement to wheat and maize flour for bread making. The medicinal uses of fenugreek have been known for a long time. [18] The mature fenugreek seed has many active components such as amino acids, fatty acids, vitamins and saponins such as diosgenin, gitogenin, neogitogenin, homorientin saponaretin, neogigogenin and tigogenin, fibers, flavonoids, polysaccharides, fixed oils and some identified alkaloids, that is, trigonelline and choline. [19-23] Different active components of fenugreek seeds have been identified and isolated such as polyphenolic flavonoids which exhibit most common properties, that is, hypoglycemic, hypocholesterolemic, hypotriglyceridemic and antiperoxidative, steroid saponins exhibiting anti inflammatory and uterus and lactation-stimulating properties, polysaccharides such as galactomannans contains antidiabetic effects and an amino acid 4-hydroxyisoleucine has been shown to possess insulin-mimetic properties. [24-29] Due to the widespread use and beneficial properties of fenugreek, many studies have been undertaken to investigate its potential application in health and many common disorders. [30,31] However, scientifically, mechanism-based studies on its efficacy in prevention body weight gain and management of obesity-related complications do not exist.

So, because fenugreek seeds are being used as a condiment and are known to have health benefits, *Trigonella Foenum greacum* seed powder was used in this study. To maximize the using of biologically active substances Trigonella foenum-graecum seeds were transferred to highly dispersed state by immobilization on the surface nanosilex that allowed obtaining bionanocomposite.

MATERIALS AND METHODS

Research was conducted in compliance with the standards of the Convention on Bioethics of the Council of Europe's 'Europe Convention for the Protection of Vertebrate Animals' used for experimental and other scientific purposes' (1997), the general ethical principles of animal experiments, approved by the First National Congress on Bioethics Ukraine (September 2001) and other international agreements and national legislation in this field. Animals were kept in a vivarium that was accredited in accordance with the

'standard rules on ordering, equipment and maintenance of experimental biological clinics (vivarium)'. Instruments to be used for research are subject to metrological control.

Seeds of Trigonella foenum graecum L. varieties Ovari 4 were provided by Professor of the University of West Hungary Sándor Makai (Institute of Crop Sciences, Department of Medicinal and Aromatic Plants). Mechanically activation of mixture of nanosilex and powdered seeds of Trigonella foenum graecum carried out in ball mills. It was used fumed silica Fine Asyl-300 (SBET = 340 m2 /g, Kalush, Ukraine). It consists of spherical particles with a diameter of 9-10 nm, which are on the surface silanol groups ≡ Si-OH and adsorbed water molecules. The concentration of free silanol groups (αOH) for the selected sample was 0.8 mmol/g. [32]

Animals and housing conditions:

The study was carried out on 40 rats. The experiments were carried out on white male rats a mass of 155 ± 5 g. All rats were housed in a temperature-controlled facility (23°C) with a 12-hour light/dark cycle and fed a chow diet containing 12.1% fat (C) or high-fat diet containing 38.8% fat (HCD).

Animals and diet:

The animals were divided into groups:

- control rats (C);
- rats which consumed high-caloric diet during 11 weeks of the experimental period (HCD); [33]
- rats of group 3 were fed by a standard chow which containing bionanocomposite (2%) during 11 weeks of the experimental period (C_BNC);
- Rats were fed by a high-caloric diet which containing bionanocomposite (2%) during 11 weeks of the experimental period (HCD_BNC).

Anthropometrical and nutritional determinations:

Food consumption was measured daily at the same time (09:00 to 10:00 h) and body weights were determined once a week. Body length of all animals was measured. The body weight and body length were used to determine the following anthropometrical parameters: body mass index (BMI), [34] specific rate of body mass gain, [34] feed efficiency (FE). [35]

Statistics:

According to Shapiro-Wilks' W test our data were normally distributed. All results are expressed as the M±m of n values. Statistical comparisons between groups were

RESULTS

Figures 1 and 2 shows the dynamics of body weight increase in 4 groups of rats. It was found that after 11 weeks in animals consumed HCD, body weight was significantly higher in comparison with control animals by 16.9% ($p < 0.05$). [36,37] Thus, the body weight of HCD_BNC group rats was lower by 17.4% ($p < 0.05$) compared with HCD group. Weight animals that consume standard feed with the addition of bionanocomposite were 10.8% lower than the mass of the control animals.

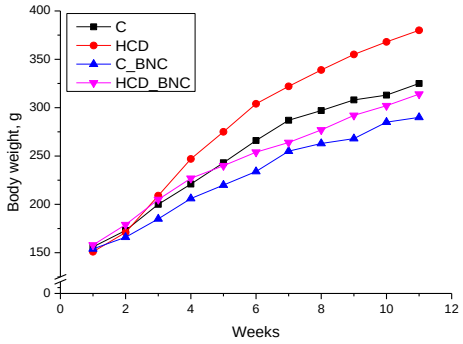

Fig.1. Body weight (g) of control rats (C), rats fed a high-calorie diet (HCD), rats fed a high- calorie diet with bionancomposite (HCD_BNC) and control rats with bionanocomposite (C_BNC) during 11 weeks

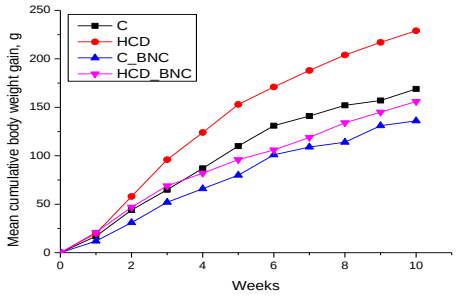

Fig.2. Cumulative body weight gain (g) of control rats (C), rats fed a high-calorie diet (HCD), rats fed a high- calorie diet with bionancomposite (HCD_BNC) and control rats with bionanocomposite (C_BNC) during 11 weeks

Figure 3 shows mean daily food intake in all groups of rats. Group of animals that consumed standard feed with the addition of 2% bionanocomposite consumed more food (by 16.7% ($p < 0.05$)) than the control group of animals during 11 weeks. Other groups were not observed significant differences between the food intake.

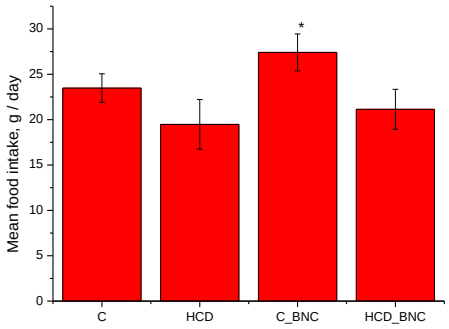

Fig.3. Mean food intake (g) of control rats (C), rats fed a high-calorie diet (HCD), rats fed a high- calorie diet with bionancomposite (HCD_BNC) and control rats with bionanocomposite (C_BNC) during 11 weeks
* - $p < 0.05$ compared to control group, # - $p < 0.05$ compared to HCD-group

Figure 4 shows that HCD rats had significantly higher cumulative feeding efficiency, than C rats by 90% ($p < 0.05$). In the group of animals HCD_BNC decreased efficiency of feeding compared with HCD by 47,4% ($p < 0.05$).

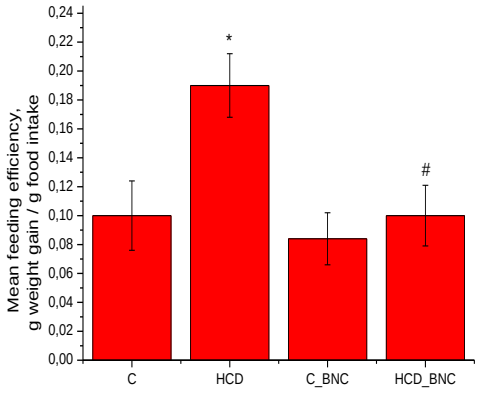

Fig.4. Cumulative feeding efficiency in control rats (C), rats fed a high-calorie diet (HCD), rats fed a high- calorie diet with bionancomposite (HCD_BNC) and control rats with bionanocomposite (C_BNC) during 11 weeks
* - $p < 0.05$ compared to control group, # - $p < 0.05$ compared to HCD-group

The cumulative food intake increased in all groups of rats. Mean cumulative food intake of C, HCD, HCD_BNC and C_BNC during the period of the experiment is shown in Figure 5. In C_BNC group of animals observed increase of cumulative food intake compared to all other groups.

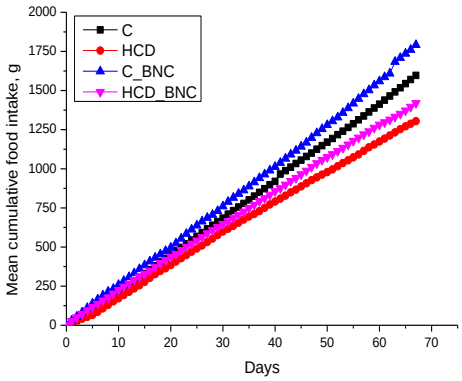

Fig.5. Cumulative food intake in control rats (C), rats fed a high-calorie diet (HCD), rats fed a high- calorie diet with bionancomposite (HCD_BNC) and control rats with bionanocomposite (C_BNC) during 11 weeks

Figure 6 shows specific rate of body mass gain of all experimental groups of animals during 11 weeks. The specific rate of body mass gain in HCD group was significantly decreased with increasing time of experiment. In the C, HCD_BNC and C_BNC groups of animals observed a lower specific rate of weight gain during the experiment.

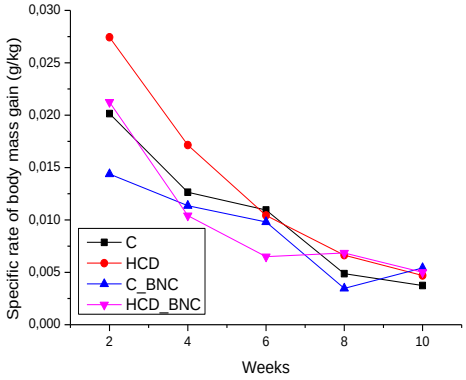

Fig.6. Specific rate of body mass gain (g/kg) in control rats (C), rats fed a high-calorie diet (HCD), rats fed a high- calorie diet with bionancomposite (HCD_BNC) and control rats with bionanocomposite (C_BNC) during 11 weeks

DISCUSSION

In previous studies we have shown the development of obesity in conditions of high consumption of food. [36-38] A high calorie diet-induced obese animal is pathophysiologically very similar to an obese human. [39] Therefore, it is an appropriate animal model for the evaluation of anti-obesity interventions in an in vivo experimental test. [40]

Today the need for effective tools for prevention of weight gain, obesity and complications in the general population. There is also an urgent need to restore weight in people who are overweight.

In theory the solution is simple, but implementation will continue to be difficult and ineffective as long as we maintain the view that just telling people that they should eat less and exercise more does the job. [41] This simplistic strategy assumes that humans have conscious control over appetite and body weight regulation, which is certainly not the case for most people; if it were true, there would be no overweight or obese people. [41] in the words of Astrup A:"I have never met an obese patient who has worked hard to become obese and to maintain an excessive body size. [41] We need to acknowledge that our regulatory systems are geared to prevent depletion of body energy stores and under nutrition effectively, whereas the systems that reduce appetite and increase energy expenditure during periods of excess availability of foods are easily suppressed by palatability and by the social, psychological, and rewarding aspects of foods". [41]

The best method in the fight against obesity is its prevention. Public health and general preventive medicine focuses on promoting health, preventing disease, and managing the health of communities and defined populations. These practitioners combine population-based public health skills with knowledge of primary, secondary, and tertiary prevention-oriented clinical practice in a wide variety of settings.

The application of nanoparticles allowing the combination of therapy and diagnosis, known as theranostic, has received increasing attention in biomedicine.[42] Pharmacological, pharmaceutical and toxicological aspects of the application of nanoparticles in biomedical purposes still remain poorly understood. Nanodisperse state of natural biologically active substances Trigonella foenum graecum seeds in biocomposite ensures their high bioavailability, so they can more effectively influence the metabolic processes in cells.

Medicinal herbal supplements are cost-effective, and exert less to no toxic side-effects in comparison with many chemically synthesized drugs.

In the present study bionanocomposite incorporated into diet at level of 2% showed significant decrease in body weight. The probable mechanism decreasing the total body and adipose tissue weight may be that fenugreek flushes out the carbohydrates from the body before they enter the blood stream resulting in weight loss or fenugreek seeds contain a high proportion of soluble fiber. Fenugreek seeds can also exert hypoglycemic effects by inhibiting the activities of alpha-amylase and sucrase, the two intestinal enzymes that are involved in carbohydrate digestion and absorption. [43] In clinical studies the hypoglycemic action of fenugreek has been attributed to its content of galactomannan, a water soluble fiber, which inhibits glucose absorption and slows gastric emptying. [44-48]

CONCLUSION

As obesity is a component of metabolic syndrome which eventually leads to type 2 diabetes, incorporation of fenugreek in the daily diet may assist with weight management and hence may help prevent or delay the onset of chronic diseases. Further research can be done to measure insulin index in order to learn more about the mechanism of action. In addition novel food products enriched with fenugreek can be developed.

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Abbreviations

HCD: high-carbohydrate diet; BNC: bionanocomposite; Fg: Trigonella foenum-graecum; MAO: monoaminoxidase; FE: feed efficiency; BMI: body mass index.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

GII performed experiments and statistical analysis of obtained data and prepared the article. KVV, TMO performed experiments and analysis of the study, did the literature review in part of the discussion, formulated prospects and performed the final article drafting. OLI did the organization, literature review and analysis of the study. All authors read and approved the final manuscript.

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REFERENCES

1. Nigro E, Scudiero O, Monaco ML, Palmieri A, Mazzarella G, Costagliola C, Bianco A, Daniele A. New insight into adiponectin role in obesity and obesity-related diseases. Biomed Res Int. 2014;2014:658913.
2. Recognition of Obesity as a Disease. Available from: http://www.npr.org/documents/2013/jun/ama-resolution-besity.pdf.
3. Bray GA, Bellanger T. Epidemiology, trends, and morbidities of obesity and the metabolic syndrome. Endocrine. 2006;29:109-117.
4. Shuldiner AR. Obesity genes and gene-environment-behavior interactions: recommendations for a way forward. Obesity (Silver Spring). 2008;16(3):S79-S81.
5. Sesti G, Perego L, Cardellini M, Andreozzi F, Ricasoli C, Vedani P, Guzzi V, Marchi M, Paganelli M, Ferla G, et al. Impact of common polymorphisms in candidate genes for insulin resistance and obesity on weight loss of morbidly obese subjects after laparoscopic adjustable gastric banding and hypocaloric diet. J Clin Endocrinol Metab. 2005;90:5064-5069.
6. WHO. Obesity and overweight. [Internet]. 2015 [updated 2015 Fact sheet N°311]. Available from http://www.who.int/mediacentre/factsheets/fs311/en/
7. Leibel RL, Rosenbaum M, Hirsch J. Changes in energy expenditure resulting from altered body weight. N Engl J Med. 1995;332:621-628.
8. Dishman RK. The measurement conundrum in exercise adherence research. Med Sci Sports Exerc. 1994;26:1382-1390.
9. Hanotin C, Thomas F, Jones SP, et al. Efficacy and tolerability of sibutramine in obese patients: A dose-ranging study. Int J Obes Relat Metab Disord. 1998;22:32-38.
10. McNeely W, Benfield P. Orlistat. Drugs. 1998;56:241-249.
11. McNeely W, Goa KL. Sibutramine. A review of its contribution to the management of obesity. Drugs. 1998;56:1093-1124.
12. Bray GA, Blackburn GL, Ferguson JM, et al. Sibutramine produces dose-related weight loss. Obes Res Relat Metab Disord. 1999;7:189-198.
13. Sjostrom L, Rissanen A, Andersen T, et al, for The European Multicentre Orlistat Study Group. Randomised placebo-controlled trial of orlistat for weight loss and prevention of weight regain in obese patients. Lancet. 1998;352:167-172.
14. Davidson MH, Hauptman J, DiGirolamo M, et al. Weight control and risk factor reduction in obese subjects treated for 2 years with orlistat. JAMA. 1999;281:235-242.
15. Srinivasan K Fenugreek (Trigonella foenum-graecum): A review of health beneficial physiological effects. Food Rev Int. 2006;22:203-24.

16. Hashim H, Kamali EL, Mohammed Y. Antibacterial activity and phytochemical screening of ethanolic extracts obtained from selected Sudanese medicinal plants. Curr Res J Biological Science. 2010;2(2):143-146.
17. Ethan B, Grace K, Michael S. Therapeutic Applications of Fenugreek. Altern Med Rev. 2003;8(1):20-27.
18. Bahmani M, Shirzad H, Mirhosseini M, Mesripour A, Rafieian-Kopaei M A Review on Ethnobotanical and Therapeutic Uses of Fenugreek (Trigonella foenum-graceum L). J Evid Based Complementary Altern Med. 2016;21 (1):53-62.
19. Shabbeer S, Sobolewski M, Anchoori RK, Kachhap S, Hidalgo M, Jimeno A, Davidson N, Carducci MA, Khan SR. Fenugreek: a naturally occurring edible spice as an anticancer agent. Cancer Biol Ther. 2009;8(3):272-8.
20. Fuller S, Stephens JM. Diosgenin, 4-hydroxyisoleucine, and fiber from fenugreek: mechanisms of actions and potential effects on metabolic syndrome. Adv Nutr. 2015;6(2):189-97.
21. Scott Fuller, Jacqueline M Stephens Diosgenin, 4-Hydroxyisoleucine, and Fiber from Fenugreek: Mechanisms of Actions and Potential Effects on Metabolic Syndrome Adv Nut. 2015; 6:189-197.
22. Yoshikawa M, Murakami T, Komatsu H, Murakami N, Yamahara J, and Matsuda H. Medicinal Foodstuffs: IV. Fenugreek seeds (1): structures of trigoneosides Ia, Ib, IIb, IIIa and IIIb new furostanol saponins from the seeds of Indian Trigonella foenum- graecum L. Chem Pharmacol. Bull 1997;45:81-7
23. Tadigoppula Narender, Anju Puri, Shweta, Tanvir, Khaliq, Rashmi, Saxena, Geetika, Bhatiac, and Ramesh Chandrab. 4-Hydroxyisoleucine an unusual amino acid as antidyslipidemic and antihyperglycemic agent. Bioorganic & Medicinal Chemistry Letters. 2006;16:293-296.
24. Prajapati VD, Jani GK, Moradiya NG, Randeria NP, Nagar BJ, Naikwadi NN, Variya BC. Galactomannan: a versatile biodegradable seed polysaccharide. Int J Biol Macromol. 2013;60:83-92.
25. Abha Saxena and Naval Kishore Vikram. The Journal of Alternative and Complementary Medicine. July 2004, 10(2): 369-378.
26. Broca C, Gross R, Petit P, et al. 4-Hydroxyisoleucine: Experimental evidence of its insulinotropic and antidiabetic properties. Am J Physiol. 199;277:617-23.
27. Gupta A, Gupta R, Lal B. Effect of Trigonella foenum-graecum (fenugreek) seeds on glycaemic control and insulin resistance in type 2 diabetes mellitus: a double blind placebo controlled study. J Assoc Phys Ind. 2001;49:1057-61.
28. Petit PR, Sauvaire YD, Hillaire -Buys DM, Leconte OM, Bassiac YG, Ponsin GR and Ribes GR. Steroid saponins from fenugreek seeds: extraction, purification and pharmacological investigation on feeding behavior and plasma chlosterol. Steroids.1995;60:674-680.
29. Rafraf M, Malekiyan M, Asghari-Jafarabadi M, Aliasgarzadeh A. Effect of Fenugreek Seeds on Serum Metabolic Factors and Adiponectin Levels in Type 2 Diabetic Patients. Int J Vitam Nutr Res. 2014;84(3-4):196-205.
30. Yadav UC, Baquer NZ. Pharmacological effects of Trigonella foenum-graecum L. in health and disease. Pharm Biol. 2014;52(2):243-54.
31. Haber SL, Keonavong J. Fenugreek use in patients with diabetes mellitus. Am J Health Syst Pharm. 2013;70(14):1196-1203.
32. Voronin EF, Pakhlov EM, Sydorchuk VV, Chuiko AA. Effect of mechanical activation of highly dispersed silica on some of its properties. Ukrainian Chemical Journal. 1995;61(10):90-92.
33. Hua Shen, Qing-Ya Tang, Juan Huang. Vitamin E regulates adipocytokine expression in a rat model of dietary-induced obesity. Exp Biol Med. 2010;235(1):47-51.
34. Novelli ELB et al. Anthropometrical parameters and markers of obesity in rats. Laboratory Animals Ltd. 2007;41:111-119.
35. Cope MB, Jumbo-Lucioni P, Walton RG, Kesterson RA, Allison DB, Nagy TR. No effect of dietary fat on short-

term weight gain in mice treated with atypical antipsychotic drugs. International Journal of Obesity. 2007;31:1014-1022.
36. Konopelnyuk V, Yurchenko A, Karpovets T, Ostapchenko L. The development of obesity and prediabetes under conditions of longterm consumption of fructose solution in rats. Journal of Applied Pharmaceutical Science. 2015;5(1):001-005.
37. Karpovets TP, Konopelnyuk VV, Galenova TI, Savchuk AN, Ostapchenko LI. High-calorie diet as a factor of prediabetes development in rats. Bulletin of Experimental Biology and Medicine. 2014;156(5):639-641.
38. Konopelnyuk V, Kot L, Makai S, Ostapchenko L. Effect of Powder From Trigonella Foenum- Graecum Seed on Anthropometrical And Nutritional Paramet. J App Pharm Sci. 2015;5(11):095-100.
39. Kim JH, Kim OK, Yoon HG, Park J, et al. Anti-obesity effect of extract from fermented *Curcuma longa* L. through regulation of adipogenesis and lipolysis pathway in high-fat diet-induced obese rats. Food & Nutrition Research. 2016;60:30428.
40. Varga O, Harangi M, Olsson IA, Hansen AK. Contribution of animal models to the understanding of the metabolic syndrome: a systematic overview. Obes Rev. 2010;11:792-807.
41. Astrup A. The satiating power of protein--a key to obesity prevention? Am J Clin Nutr. 2005;82(1):1-2.
42. Chuiko OO, Gorbyk PP, Pogorelyi VK, Pentuk AA, Gerashchenko II, Il′chenko AV, et al. Nanomaterials and Supramolecular Structures. Application. Spriger Science + Busines Media B.V.;2010.
43. Basch E, Ulbricht C, Kuo G, Szapary P, Smith M. Therapeutic applications of fenugreek. Alternative Medicine Review. 2003;8(1):20-27.
44. Hannan JMA, Ali L, Rokeya B, et al. Soluble dietary fibre fraction of Trigonella foenum-graecum (fenugreek) seed improves glucose homeostasis in animal models of type 1 and type 2 diabetes by delaying carbohydrate digestion and absorption, and enhancing insulin action. The British Journal of Nutrition. 2007;97(3):514-521.
45. French SJ, Read NW. Effect of guar gum on hunger and satiety after meals of differing fat content: relationship with gastric emptying. The American Journal of Clinical Nutrition. 1994;59(1):87-91.
46. Groop P-H, Aro A, Stenman S, Groop L. Long-term effects of guar gum in subjects with non-insulin-dependent diabetes mellitus. The American Journal of Clinical Nutrition. 1993;58(4):513-518.
47. Würsch P, Pi-Sunyer FX. The role of viscous soluble fiber in the metabolic control of diabetes: a review with special emphasis on cereals rich in *β*-glucan. Diabetes Care. 1997;20(11):1774-1780.
48. Chandalia M, Garg A, Lutjohann D, von Bergmann K, Grundy SM, Brinkley LJ. Beneficial effects of high dietary fiber intake in patients with type 2 diabetes mellitus. The New England Journal of Medicine. 2000;342(19):1392-1398.

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