The relationship between different dietary protein sources and gut microbioma between Parkinson disease animal models

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Abstract: Certain gut microbiota species of are involved in neural development and functioning (Gut-brain axis) as well as modulation of brain physiology, mood and behaviors; however their role still unclear. Parkinson disease is the second most common neurodegenerative disorder after Alzheimer's disease that approximately affects seven million people worldwide between mainly the elderly. Nutritional therapy is necessary for such patients to improve malnutrition caused by the decrease of food intake, mal-absorption, accelerated nutrient loss and increase of nutritional requirements. The current study established to investigate the effects of dietary protein supplementation interacted with colonic microbiota in PD animal models. Rats supplemented by 10% extra different dietary protein sources; animal and plant sources. Diets A, B and C representing dried skim milk, soy milk and beans respectively. Additionally, negative and positive control groups of rats were included. Bacterial population on gut, glucose, lipid profile, kidney and liver functions were measured. Collected data showed that consuming different dietary protein sources had induced effective impacts on serum glucose levels, lipid profile (cholesterol, triglyceride…*etc.*) in addition to kidney and liver functions. Also, colonic microbiota showed good growth with the colonic probiotic species after additions of the plant dietary protein sources (beans, diet C) comparing to the dietary protein of animal sources. In conclusion, colonic microbiome found to have an interesting role in the disease; however, further more different dietary sources interacted with colonic microbiome composition and activities are needed in addition to different neurodegenerative disorders.

Keywords: Beans, skim milk, soy milk, serum lipid profile, kidney and liver functions.

Introduction

Parkinson disease (PD) is the second most common neurodegenerative disorder after Alzheimer's disease (AD) which affects approximately seven million people worldwide (Cafe-Mendes *et al,*. 2014). PD is a degenerative disorder of the central nervous system resulting from the death of dopamine-generating cells in the substantia nigra in midbrain (De Lau and Breteler, 2006). Also, PD is a widespread condition caused by the loss of midbrain neurons that synthesize the neurotransmitter dopamine (Jong-Hoon *et al.*, 2002 and Abou-Donia *et al.*, 2013). Thus, PD is characterized by depletion of dopaminergic cell bodies in substantia nigra that are subsequently lost in the nigrostriatal system. The pathological hallmark of the disease is accumulation of the protein α-synuclein into inclusions called Lewy bodies in neurons (Aarsland *et al.*, 2009 and Van *et al.*, 2012). The mechanisms of PD may include mitochondrial dysfunction, oxidative stress, inflammation and defective protein handling. Recent studies have established the involvement of CaM kinase II in the mechanisms of PD. Although most cases of PD are idiopathic, a small proportion

of cases can be attributed to known genetic and others to environmental factors (Shulman *et al.*, 2011) such as colonic microbiota. PD is not known to occur naturally in any species other than humans, although animal models which show some features of the disease are used in research. Models based on toxins are most commonly used in primates. Transgenic rodent models that replicate various aspects of PD have been developed (Harvey and Wang, 2008). Using the neurotoxin 6-hydroxydopamine, also known as 6-OHDA to creates a model of PD in rats (Harvey *et al.*, 2008) by targeting and destroying dopaminergic neurons in the nigrostriatal pathway when injected into the substantia nigra (Blum *et al.*, 2001). The intestinal microbiota might be implicated in shaping neuron-developmental and behavioral phenotypes as it influences a variety of complex procedures such as cognition, personality, mood, sleep, and eating behaviors and has also been associated with a variety of psychiatric disorders (Suchowersky *et al.*, 2006).

Gut microbiota is a huge selection of intestinal bacteria which reach about 1,500 species (Young, 2012). Their highest concentration occurs in the colon; 10^{14}/ml and comprise up to 60% of faecal weight. In addition the total species depend on: illness, antibiotics, the immune system, digestive and other secretions, stress and diets (Kolida and Gibson, 2007; Sekirov *et al.*, 2010). Dietary factors affect gut microbiota composition and activity, but different substrates stimulate the growth of specific colonic bacterial species in different ways. The role of the colon in energy metabolism is related to the fermentation of residual dietary components, particularly non-digestible carbohydrates that are not absorbed in the upper GI tract known as prebiotics (Roberfroid *et al.*, 1997; Shen *et al.* 2011). The prebiotic concept was re-defined recently as "a selectively fermented ingredient that results in specific changes in the composition and/or activity of the gastrointestinal microbiota, thus conferring benefit(s) upon host health" (Roberfroid *et al.*, 2010). Additionally, adjusting the colonic bacteria composition could be by raising the levels of bacteria such as *Bifidobacteria* and *Lactobacilli* (Gibson, 1998; Bouhnik *et al.*, 2004) belongs to probiotics. Dietary protein in combination to Levodopa has been in a great advance for PD patients as they use the same transportation system in the intestine and the blood–brain barrier, thereby competing for access and these results in a reduced effectiveness of the drug (Barichella *et al*,. 2009). Low-protein products such as bread or pasta are recommended previously for similar reasons (Barichella *et al.*, 2009). However, the comparisons of the different protien sources are not fully examined. So the current study aims to examine the effects of different dietary protein sources (animal and plant sources) on PD patients using rats. Colonic microbiota is going to be evaluated as an indicator for gut-brain axis interactions.

Materials and Methods

Materials

Different sources of dried skim milk, soy milk and dried beans were purchased from local market (Hyper1, Cairo, Egypt) and were added to the rats' diets by 10% each (Diet A, B and C) of the total meal a day in addition to positive and negative control. Diet A is dried skim milk, diet B is the soy milk and diet C is beans.

Animal Models, rats, of PD

Sprague-Dawley male rats aged 6-weeks old have been purchased from Experimental Animal Care Centre, National training centre, Cairo, Egypt. They have

been divided into 5 groups with 6 rats in each. All rats fed with ordinary laboratory feed; consumed normal diet for up to 3-days as adaptation time and consumed diets were prepared as described previously by the American Institute of Nutrition (AIN, 1993) for 4 weeks. Then, they all were as following:

Group 1 control (-) normal blank control healthy; was given ordinary laboratory feed and drinking water. The experimental induced PD animals groups; received rotenone suspended in 0.5% CMC intraperitoneally at a dose of 3 mg/kg, daily. For 70th days then they have been divided to three subgroups that increased the intake of dietary protein diets in 10% with ordinary laboratory feed as following:

Group 2: Control (+) with PD; fed with ordinary laboratory feed and drinking water.
Group 3: Induced PD and supplemented with dietary protein A, dried skim milk
Group 4: Induced PD and supplemented with dietary protein B, soy milk
Group 5: Induced PD and supplemented with dietary protein C, beans

Biochemical analysis

Serum glucose determined according to of Tinder (1969). Serum cholesterol (CHO) was determined by Thomas (1992). Serum triglycerides (TG) were measured using kits according to Fossati (1982). Low density lipoprotein (LDL), high density lipoprotein (HDL), very low density lipoprotein (VLDL) were established according to method described by Lee and Nieman (1996), Fredewaid (1972) and Lee and Nieman (1996) respectively using the following formula: VLDL (mg/dl) = TG / 5.

LDL (mg/dl) = Total CHO – (HDL + VLDL).

For liver functions; aspartate aminotraferase (AST) and alanine aminotransferase (ALT) evaluated as described previously according to Hafkenscheid, (1979). Urea was carried out with Serum creatinine according to the method described by Henry, (1974).

Gut microbiota compositions

Feacal samples have been collected (0, 2 and 4 weeks) and gut microbiota compositions e.g. *Bifidobacteria, Clostridium histolyticum, and Lactobacillus* were evaluated as described previously by Khalil *et al.*, (2013). All collected feacal samples were diluted using sterilized phosphate-buffered filtered saline (PBS) and then fixed for 4 h at least (4 ºC) in 4% paraformaldehyde (PFA). Additionally, all samples then left at 4 °C for 4 h then centrifuged for 5 mints at 13,000g. Also, they all were washed in 1 ml filtered sterilized PBS twice and were re-suspended in amount of filtered PBS and ethanol (99%) equally. Finally, the samples stored at -20 ºC for at least one hour before further analysis by fluorescence *in situ* hybridization (FISH). Results were expressed in cells/ml of faecal slurries and logarithmic values were used for further statistical analysis.

Statistical analysis

Collected data were presented as mean ± standard deviation (SD) and all the analysis were performed using SPSS package ver.18, one-way analysis of variance (ANOVA). Differences among means were subsequently tested using Duncan's multiple range as post-hoc test. Data were considered statistically significant differences at $P \leq 0.05$ for any significant changes.

Results and discussion

Blood glucose levels affected by different dietary protein sources consumptions in PD rats

Data available on Table (1) illustrated the effects of different dietary protein sources on serum glucose levels between PD animal models. The serum glucose levels were at normal and low amounts within the healthy control rat groups comparing to positive control group that were significantly difference ($p \leq 0.05$) at the highest levels (102.27±1.80 and 248.4±2.59mg/dl, respectively). Also, the serum glucose levels were the biggest animal groups fed different dietary protein sources with Group 3 that presenting rats with PD fed diet A in comparison to levels of rats fed diet B and C at significantly difference ($p \leq 0.05$) of 151.0±2.45 *vs.* 128.27±3.83 and 119.53±0.70 respectively. So the best effective treatment was found to the dietary protein from beans that were different from the healthy rats by 128.87 mg/dl, about 50% reduction of the control rats' positive group. This positive effects of beans as dietary protein sources may be because of the high levels of dietary fibers presented in the beans comparing to the others two protein sources.

Table (1): Effect of different dietary protein sources consumptions on blood glucose levels between PD rats

Groups	Glucose level (mg/dl)	Differences from control (+) (mg/dl)	% Relative change of control (+)
Group 1; Control healthy rats (-)	102.27±1.80 ^{e}	146.13	58.8
Group 2; Control with PD rats (+)	248.4±2.59 ^{a}	0	0
Group 3; Rats with PD fed diet A.	151.0±2.45 ^{b}	97.4	39.21
Group 4; Rats with PD fed diet B.	128.27±3.83 ^{c}	120.13	48.36
Group 5; Rats with PD fed diet C.	119.53±0.70 ^{d}	128.87	51.88

Data represent mean ± SD. Values within the same column not sharing superscript letters are significantly different at $p \leq 0.05$.

Effects of different dietary protein sources consumptions between PD rats on lipid profile

Results in Table (2) demonstrated the effects of different proteins supplemented to rats with PD on serum lipid profile. Total cholesterol (CHO), triglycerides (TG), low density lipoprotein (LDL), high density lipoprotein (HDL), and very low density lipoprotein (VLDL) were measured. It can be observed that CHO amounts were at the biggest significantly difference ($p \leq 0.05$) levels with rats induced PD; control positive group at levels of 181.43±2.3mg/dl. While CHO levels were at the lowest measurable amounts on control healthy group at 97.6±3.17mg/dl. Such data indicated that PD patients are in high levels of hyper-cholesterolimia with much more affordable to heart problems conditions. However, providing such disease models with beans or soy milk showed good reduction with CHO levels comparing to the control PD groups. Additionally, rats supplemented with diets A, B and C was declined significantly ($p \leq 0.05$) with CHO levels at levels of 168.07±4.5, 134.5±3.50 and 113.8±3.36 mg/dl, respectively.

Furthermore, Table (2) presented the TG levels measured with rats induced PD and fed different dietary protein sources. The TG obtained data were at the biggest amounts with the control positive group fed normal diets with 94.17±4.6mg/dl.

However, the lowest results were seen significantly ($p \leq 0.05$) with group induced PD and fed diet C; beans for the month time with levels of 66.63±3.2 and such results were very close with no significantly changes to both of rats induced PD and fed diet B then followed by low levels with control negative group; healthy rats group that were about 70.1±1.83 and 65.17±2.2 respectively. Also, the current TG data indicated a high level after PD induction and that was reduced after supplementing PD rats with either soy milk or beans. On the other hand, the skim milk showed little reduction with TG levels as well as CHO levels. Previous studies shown decrease levels of serum cholesterols after soy protein consumptions. They also recommended that; eating soy protein instead of sources of higher-fat protein diets should be maintaining a healthy status and would be heart (Burke et al., 2012).

Table (2): Effect of different dietary protein sources consumptions on lipid profile between PD rats

Animal groups	CHO (mg/dl)	TG (mg/dl)	LDL (mg/dl)	HDL (mg/dl)	VLDL (mg/dl)
Group 1: Control healthy rats (-)	97.6±3.17 ^{e}	65.17±2.2 ^{c}	36.64±2.78 ^{d}	56.83±3.15 ^{a}	11.37±0.6 ^{a}
Group 2: Control with PD rats (+)	181.43±2.3^{a}	94.17±4.6 ^{a}	153.2±5.04 ^{a}	31.63±1.26 ^{e}	6.33±0.25 ^{e}
Group 3: Rats with PD fed diet A.	168.07±4.5 ^{b}	84.9±3.47 ^{b}	65.31±2.59 ^{b}	40.9±1.80 ^{d}	8.18±0.36 ^{d}
Group 4: Rats with PD fed diet B.	134.5±3.50 ^{c}	70.1±1.83 ^{c}	57.55±5.63 ^{c}	46.47±3.43 ^{c}	9.29±0.68 ^{c}
Group 5: Rats with PD fed diet C.	113.8±3.36 ^{d}	66.63±3.2^{c}	52.30±3.9 ^{c}	52.33±1.30 ^{b}	10.47±0.2^{b}

Data represent mean ± SD. Values within the same column not sharing superscript letters are significantly different at $p \leq 0.05$.

Regarding the LDL levels, the low density lipoprotein presented within the animals serum. Table (2) also presented the data collected for LDL levels and showed that group 1 control healthy rats (-) were at the lowest levels of 36.64±2.78mg/dl. On the other side group 2 as control positive rats (+) has the major significantly ($p \leq 0.05$) levels of 153.2±5.04mg/dl and that were significant different from the others treated groups. Also, group 3 corresponding to rats with PD and consumed diet A (skim milk) are with good decline levels of LDL after soy milk supplementation; around 90mg/dl decline. However, the others two PD groups supplemented with either diet B or C corresponding to soy milk or beans respectively were at similar LDL levels and no significantly changes across protein sources (57.55±5.63 and 52.30±3.9mg/dl). On the other hand, HDL found with the PD animal groups were in the opposite trends with the LDL levels after dietary protein sources. It can be notice that HDL levels were at the smallest amounts with group 2; control (+) rats group at 31.63±1.26 mg/dl. On the other site, the largest significantly ($p \leq 0.05$) results obtained with group 1; control (-) healthy rats at 56.83±3.15 mg/dl. Also, HDL with group 5; rats with PD consumed diet C were the closest HDL levels to the normal healthy group at 52.33±1.30mg/dl. Finally, the VLDL levels were at the highest levels at 11.37±0.6 mg/dl corresponding to group 1; control (-) healthy rats. While the lowest levels were seen with 6.33±0.25 corresponding to group2; control (+) rats.

The effects of different dietary protein sources fed PD rats on liver and kidney functions

Values in Table (3) corresponding to the effects of different dietary protein sources on liver and kidney function on the liver and kidney functions of PD induced rats. For kidney functions, all the rat groups fed soy milk, beans and healthy diets were very close at urea levels of approximately 20mg/dl with no significant changes. Additionally, creatinine levels represented at the lowest levels of 0.46±0.03 mg/dl with group 1; control (-) healthy rats. While it was at the maximum significantly ($p \leq 0.05$) levels at 0.99±0.01 mg/dl with group2; control (+) rats. Rats fed different dietary protein sources were observed as Diet A> Diet B> Diet C. So the highest treatment affected the creatinine amounts by good reduction levels were with Diet C followed by Diet B and finally Diet A.

Table (3): Effect of different dietary protein sources consumptions on liver and kidney functions between PD rats

Groups	Urea (mg/dl)	Creatinine (mg/dl)	ALT (U/L)	AST (U/L)
Group 1: Control healthy rats (-)	19.73±2.37 ^{c}	0.46±0.03 ^{d}	59.43±1.15 ^{c}	31.2±1.20 ^{c}
Group 2: Control with PD rats (+)	39.4±1.05 ^{a}	0.99±0.01 ^{a}	101.4±3.75 ^{a}	70.57±1.45 ^{a}
Group 3: Rats with PD fed diet A.	31.3±1.21 ^{b}	0.79±0.04 ^{b}	80.5±5.08 ^{b}	52.67±2.45 ^{b}
Group 4: Rats with PD fed diet B.	21.43±1.26 ^{c}	0.61±0.02 ^{c}	65.2±4.10 ^{c}	37.23±7.05 ^{c}
Group 5: Rats with PD fed diet C.	20.1±1.30 ^{c}	0.59±0.02 ^{c}	60.06±1.60 ^{c}	34.23±3.29 ^{c}

Data represent mean ± SD. Values within the same column not sharing superscript letters are significantly different at $p \leq 0.05$.

The major relative liver functions are Asprtate Aminotransferase (AST) and Alanine Aminotransferase (ALT) that could be used as an indicator of any relative health problems. So ALT and AST have been evaluated and results recorded in Table (3). It can be notice that ALT was at 101.4±3.75 U/L within group 2 representing control (+) rats group. Such level of ALT was recorded the highest significant ($p \leq 0.05$) among all the groups. However, the lowest significant ($p \leq 0.05$) group was corresponding to the group1 that representing the control negative group at 59.43±1.15 U/L. Additionally, treating the PD rats' animal models with diet A shown little declined significant ($p \leq 0.05$) levels comparing to the others two diets (B and C). however, groups fed diets supplemented with diets B and C were at the lowest levels of ALT (65.2±4.10 and 60.06±1.60 U/L) and were with no significant changes in addition to the control healthy group (group 1; 59.43±1.15 U/L). Furthermore, AST levels with rat groups fed different dietary protein sources was ranked as group2> group3> group4> group5> group 1 representing levels at 70.57±1.45, 52.67±2.45, 37.23±7.05, 34.23±3.29 and 31.2±1.20 U/L respectively. Thus AST levels were similar to the ALT obtained data and both are reflecting the effective liver function on PD rats after consuming different dietary protein sources (Diet C better than B better than A).

Effects of different dietary protein sources consumptions on colonic microbiota profile between PD rats

Table (4) shows the effects of different dietary protein sources supplemented to PD animal models on gut microbiota compositions especially *Bifidobacteria*, *Lactobacillus* and *Clostridium histolyticum group*. The control negative used as untreated healthy group showed the principal accepted levels of colonic species measured at the beginning and at the end of the experimental period. For instant, *Bifidobacteria* was at the start time 6.057±0.03 cells /ml feacal slurry and that was nearly stapled without any significant changes at the end of the experimental time (6.053±0.04 cells /ml feacal slurry). Similarly, *Lactobacillus* levels were with no significant changes at the start and the end of the experimental; 6.15±0.02 and 6.16±0.03 cells /ml feacal slurry). Also, *Clostridium histolyticum group* was with similar population at both of the starting and ending points, around 5.38±0.04 cells /ml feacal slurry with no significant changes. However, both *Bifidobacteria*, *Lactobacillus* species were as probiotics species and were at higher levels than the *Clostridium* group. Such data can be used as an indicator for the health stats of the animal models used for untreated group.

Table (4): Effect of different dietary protein sources consumptions on gut microbiota compositions between PD rats.

Treatments	Time	Bacterial counts (Log ^{10} cells /ml feacal slurry)		
		Bifidobacteria	*Lactobacillus*	*Clostridium histolyticum group*
Group 1: Control healthy rats (-)	Start	6.057±0.03^{a}	6.15±0.02^{a}	5.39±0.03^{f}
	End	6.053±0.04^{a}	6.16±0.03^{a}	5.38±0.04^{f}
Group 2: Control with PD rats (+)	Start	5.03±0.05^{d}	5.73±0.03^{cd}	6.31±0.02^{a}
	End	5.07±0.02^{d}	5.79±0.04^{c}	6.34±0.05^{a}
Group 3: Rats with PD fed diet A.	Start	5.05±0.08^{d}	5.74±0.04^{cd}	6.22±0.03^{b}
	End	5.31±0.02^{c}	5.92±0.03^{b}	5.88±0.01^{d}
Group 4: Rats with PD fed diet B.	Start	5.04±0.04^{d}	5.71±0.02^{d}	6.06±0.02^{c}
	End	5.93±0.03^{b}	5.74±0.04^{cd}	5.64±0.03^{e}
Group 5: Rats with PD fed diet C.	Start	5.01±0.04^{d}	5.21±0.02^{e}	6.01±0.04^{c}
	End	6.03±0.01^{a}	6.11±0.05^{a}	5.43±0.03^{f}

Data represent mean ± SD. Values within the same column not sharing superscript letters are significantly different at $p \leq 0.05$.

On the other hands, the data of PD control group presented in table (4) that fed normal diets showed notable increased levels of *Clostridium histolyticum group* in comparison to the healthy untreated group (6.31±0.02 and 6.31±0.02 cells /ml feacal slurry) at the beginning and the end of the experimental period, respectively. Additionally, values in Table (4) recorded the intestinal microbiota populations at the start and end points of the experimental time with different dietary protein sources. Diet A corresponding to dried skim milk, diet B contains soy milk and diet C contains beans. All the three treated groups had significant changes with the colonic microbiota. An increase levels of *Bifidobacteria* (5.31±0.02 cells /ml feacal slurry) at the end of the experimental period after consuming Diet A. while the highest increase were at the maximum levels after consuming Diet C; 6.03±0.01 cells /ml feacal slurry). Such final levels were interestingly similar to the control negative group

which means such diet is the favorite one between the tasted groups. Also, *Lactobacillus* populations were significantly increased after such effect in order to arrive to similar control negative group's results (6.11±0.05 cells /ml feacal slurry). However, *Clostridium histolyticum group* were on the opposite side, it was declined after the consumptions of Diet C comparing to the control PD group (5.43±0.03 Vs. 6.34±0.05 cells /ml feacal slurry). Finally, PD patients are affordable to malnutrition that resulted from decreases of food intake, mal-absorption, accelerated nutrient loss and increase of nutritional requirements. as it has been demonstrated that different dietary proteins sources have different effects on the PD status. So it's important to eat the right amount and the right kind of protein to get its health benefits such as beans that are loaded with fiber in order to keep you healthy (Burke *et al.,* 2012). Thus the recommended diets could be included either soy or beans protein sources.

Conclusion

The current study has been shown that plant protein sources (beans; diet C) had many different healthy benefits between PD rats including lowering serum glucose levels, CHO and TG in addition to improving kidney and liver function. Beans are at the high levels of dietary fibers and that are associated with many health benefits. Colonic microbiome measured as indicator for gut-brain axis alterations found to have an effective role in the disease causes which provides great therapeutic potential; however, it is still unclear. Thus, nutritional therapy is necessary for improving nutritional states and promoting the reconstruction of mucosa in addition to regulating the immune function in PD rats. But more and more studies of different dietary factors interacted with colonic microbiome composition and activity are needed in different neurodegenerative disorders.

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العلاقة بين مصادر مختلفة للبروتين الغذائي و البكتريا المستوطنة بالقولون باستخدام نماذج للحيوانات المصابة بمرض باركنسون

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قسم التغذية وعلوم الأطعمة، كلية الاقتصاد المنزلى، جامعة المنوفية، شبين الكوم، مصر

الملخص

لقد أثبتت الدراسات العلمية أن هناك أدلة متزايدة على أن البكتريا المستوطنة بالأمعاء لها تأثير على صحة الإنسان مثل التطور العصبي والأداء الوظيفي بالإضافة إلى تعديل فسيولوجيا الدماغ والمزاج والسلوكيات، إلا أن دورها لا يزال غير واضح. ويعد مرض باركنسون (PD) هو ثاني أكثر الاضطرابات العصبية شيوعا بعد مرض الزهايمر (AD) الذي يصيب ما يقرب من سبعة ملايين شخص في جميع أنحاء العالم خاصة وبشكل رئيسي كبار السن. لذلك يعد العلاج الغذائي ضروري لمثل هؤلاء المرضى لتحسين سوء التغذية الناجم عن انخفاض تناول الطعام، وسوء الامتصاص، وفقدان المغذيات السريع مع زيادة الاحتياجات الغذائية. لذا تهدف الدراسة الحالية إلى إستكشاف آثار مكملات البروتين الغذائية من مصادر مختلفة على عدد و نشاط البكتريا المستوطنة بالأمعاء الغليظة بين الفئران المصابة بمرض باركنسون PD. لذلك تم تغذيت الفئران بنسبة 10 ٪ من وجبات غذائية مختلفة في مصادر البروتين: وجبة A و تمثل لبن مجفف منزوع الدسم، وجبة B تمثل لبن فول صوبا يالاضافى إلى وجبة C و التي تتمثل فاصوليا جافة . هذه المجموعات كانت مع المجموعات الضابطة السالبة والموجبة ثم تم قياس نشاط بكتيريا القولون، دهون الدم، بالإضافة إلى وظائف الكلى والكبد حيث أظهرت النتائج أن استهلاك مصادر مختلفة من البروتين الغذائي له تأثيرات فعالة على مستويات الجلوكوز في الدم، ودرجة الدهون بالإضافة إلى وظائف الكلى والكبد. أيضا .. أظهرت بكتيريا القولون ان هناك نمو جيد لأنواع البروبيوتيك بالقولون بعد الاضافات من مصادر البروتين خاصة النباتية المصدر مقارنة مع المصادر الحيوانية. وفي النهاية، وجد أن بكتيريا القولون له دور مهم في هذا المرض، ومع ذلك فإن دورها لا يزال غير واضح. لذلك هناك حاجة إلى مزيد من الدراسات البحثية على المزيد من المصادر الغذائية المختلفة و بكتيريا القولون التي قد توفر بدورها استراتيجيات علاجية جديدة.

الكلمات المفتاحية :، بقوليات، لبن مجفف و فول صويا ، صورة دهون الدم ، وظائف الكلى والكبد.