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Hypoglycemic effect of Pedada (Sonneratia caseolaris) Fruit Flour (PFF) in alloxan-induced diabetic rats

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Abstract: Our study provided evidence for the hypoglycemic effect of dietary fiber from Pedada Fruit Flour (PFF) in alloxan-induced diabetic rats. PFF is formulated to feed standard AIN-93M as a replacement of Carboxyl Methyl Cellulase (CMC) diet composition. Meal Tolerance Test (MTT) consisted of three groups with six rats each, i.e 3%, 6% and 9% PFF. Blood glucose levels were monitored for 120 min after feeding intervals 30 minutes. The hypoglycemic effects of PFF in alloxan diabetic rats were studied for 4 weeks. The diabetic rats were divided into 5 groups and each was administrated with the same treatment in MTT with compared group of fed: glibenclamide, hyperglycemic and one group of normal rats as control. Blood glucose and body weight levels was weekly monitored. At the end of feeding treatment we determined the Short Chain Fatty Acids (SCFAs) profile from caecum digesta. The MTT showed that all concentration of PFF affected the absorption of glucose in the blood and the lowest blood glucose improvement was 23.89%, indicated the highest ability on glucose absorption. The hypoglycemic effect of PFF was significantly reducing glucose blood in diabetic rats ($P<0.05$), i.e. 31.29%. In the other hand, the effect of PFF increase body weight in diabetic rats ($P<0.05$) with magnitude of 5.25% (glibenclamide), 0.85% (3% PFF), 0.49% (6% PFF), and 4.19% (9% PFF). The concentration of all SCFAs profile is similar, i.e acetic acid > propionic acid > butyric acid.
Keywords: Hypoglycemic; Meal Tolerance Test (MTT); Pedada Fruit Flour (PFF); SCFA.

1. Introduction

The majority of Indonesian people have less attention on diet and nutritional balance lead to negative impact of increase in degenerative diseases. including diabetes mellitus[1]. Diabetes mellitus (DM) is common disorder associated with markedly increased morbidity and mortality rate. DM, which affects a large number of people around the globe, can be defined as a group of metabolic diseases characterized by chronic hyperglycaemia resulting from defects in insulin secretion, insulin action, or both, resulting impaired function in carbohydrate, lipid and protein metabolism[2]. The prevalence for all age-groups was estimated to be 2.8% in 2000; at least 171 million people worldwide suffered from diabetes, or 2.8% of the population and projected to be 4.4% in 2030[3]. It caused by deficiency or ineffective production of insulin by pancreas which results in increase or decrease in concentrations of glucose in the blood[4,5], and the other hand such as lowest the physical activity and consumption of dietary fiber in food[6].

Plant and foods of medicinal value have been proven to be very effective in the treatment and management of diabetes mellitus[7], such as dietary fiber. Dietary fiber has been defined previously as the plant polysaccharides and lignin, which are resistant to hydrolysis by digestive enzymes of man[8]. Hypoglicemic effect of some dietary fiber decreased blood glucose[9], psyllium[11,12], guar gum[13] polysaccharides[14], black glutinous corn[15], and pectin will affect the metabolism and digestion, especially on the adsorption of glucose and cholesterol[16,17,18]. One of the physiological effects of dietary fiber is the ability to form a gel matrix[19], and

depending on the physicochemical properties, the consequences is including viscosity in the upper gastrointestinal tract, fermentation in the colon, and prebiotic effects. These effects improve laxation and increase stool bulking in the gastrointestinal tract and also have metabolic consequences as improvements in serum lipids and postprandial glycemia and promotion of satiety[20]. Mechanism of dietary fiber to recover diabetes is its efficiency to reduce the absorption of carbohydrates, thus reduce insulin response, consequence the pancreas activity to be lighter so it can improve the function of the pancreas to produce insulin[1]. Soluble dietary fiber can form a viscous gel thus inhibiting the absorption of glucose and improves insulin sensitivity[21].

The potential plants to be developed related with a decrease in glucose blood is mangrove plants species of Pedada (*Sonneratia caseolaris*), the fruit is edible and non-toxic[22]. Pedada Indonesian local name i.e. Bogem is mangrove species with a wide distribution range from Sri Langka to Malay Peninsula as well as the Philippines, Timor, New Guinea, Solomon Islands and Indonesia[23,24]. The ripened fruits of *S. caseolaris* have an appealing flavor and taste, enriched with vitamins[10]. The Pedada fruit have many bioactive component such as flavonoid, luteolin and luteolin 7-*O*-β-glucoside, terpenoid, steroid[25-28], oleanolic acid, β-sistosterol-β-D-glucopyranoside that indicated anthihyperglycemic activity[29].

Metanol extract of leaves *Sonneratia caseolaris* is effective as anti-hyperglycemic agents[30], and its dried leaf powder is significantly decrease in serum glucose leaves[5]. Properties of anti-diabetic polysaccharide from mangrove plant (*Sonneratia alba*) had reported by Morada et al[31], but from Pedada fruit flour (PFF) had not been researched. Previously known that PFF is rich dietary fiber (63.70%) and has high level of phenolic compounds 30.61 mg/GAE/g of PFF and had reported decreased total plasma cholesterol, LDL-c, trigliceride, but not affecting the HDL-c levels[32]. Therefore, this study focused to evaluate the hypoglycemic effect of PFF in alloxan-induced rats.

2. Materials and Methods

2.1. Materials

Pedada fruit (*Sonneratia caseolaris*) (50-55g; ± 2 months) were obtained from Wonorejo village, Surabaya, East Java, Indonesia. Pedada fruit flour (PFF) was processed using method of Jariyah et al[32.] to succeed dietary fiber (carboxil methyl cellulose) in standard fed AIN-93M[33]. Fifty four male Wistar rats (*Rattus norvegicus*) 2-3 month of age and weighing 219-234 g. Alloxan, glucose, glibenclamide and DiaSys (*Diagnostic Systems*) Glucose GOD were purchased from laboratory of Food Nutrition University of Gadjah Mada, Yogyakarta. PFF dosing calculated base on the research Anderson & Ward[9] and the conversion dose of fed was conducted using method Reagan-Shaw et al. [34], the composition of diet treatment as showed in Table 1.

Table 1. The composition feed of rats

Composition	Group A	Group B	Group C	Group D	Group E	Group F
	Normal control (%)	Hypergl.control (%)	Hypergl. (%)	Hypergl. Treated 3% PFF	6% PFF	9%PFF
Maizena	62.07	62.07	62.07	64.07	61.07	58.07
Casein	14.00	14.00	14.00	14.00	14.00	14.00
Sucrose	10.00	10.00	10.00	10.00	10.00	10.00
Soy oil	4.00	4.00	4.00	4.00	4.00	4.00
CMC	5.00	5.00	5.00	-	-	-
PFF	-	-	-	3.00	6.00	9.00
Mineral mix	3.50	3.50	3.50	3.50	3.50	3.50
Vitamin mix	1.00	1.00	1.00	1.00	1.00	1.00
L-Systin	0.18	0.18	0.18	0.18	0.18	0.18
Colin bitartrat	0.25	0.25	0.25	0.25	0.25	0.25
Alloxan (mg/kg bw)	-	125	125	125	125	125
Glibenclamide (mg/200 g bw)	-	-	0.18	-	-	-

Note : Hypergl. = Hyperglycemic

2.2. Methods

Meal Tolerence Test (MTT)

Eighteen male Wistar rats were divided into 3 groups (6 rats/group) and individually housed in wire screen cages, then adapted for a week and fed on standard feed of AIN-93M, water *ad libitum*. The rats were fasting for 16 hours before feeding treatment, diet composition for MTT were group D, E and F (Table 1) and follow the modified method of Madar et al.[35] to determine change of blood glucose level increase after consuming the feed. Blood sample were taken 1 mL from retro-orbital plexus of rats at 0, 30, 60, 90 and 120 min after feeding. Bloods samples were separated by centrifuge at 4000 rpm for 20 minutes and stored at 20-25°C for further analysis of glucose levels by glucose oxidase-peroxidase method GOD-POD[36] and absorbance values were measured at a wavelength of 500 nm.

Hypoglycemic effect

The hypoglycemic effect was determined following the procedure of Ruzaidi et al.[6]. Thirty six male Wistar rats (*Rattus norvgicus*) were adapted individually and housed in wire screen cages for a week and fed on standard feed of AIN-93M, water *ad libitum*. The rats were divided into 6 groups (6 rats/group), and fasted 16 hours before treatment. Group A as normal control, and five groups were intraperitonial alloxan induced of 125mg/kg body weight. The rats were futher acclimatized for three days and followed by fasting 16 hours before feeding treatment. A retro-orbital plexus blood sample was collected on non-fasting rats. The rats with glucose level above 200 mg/dL were used in the experiment. Group B as hyperglicemic control, group C was given fed AIN-93M with glibenclamide (0.18 mg/200 g bb), while groups D, E, F were given fed mixture of PFF at different dosages (3, 6 and 9% respectively). Each rat was fed *ad libitum* (15g/day) and had free access of water for 4 weeks, the diet composition of rats showed in Table 1. Blood glucose levels and body weight of rats were measured every week, while the residue was weighed daily. Blood glucose were taken from a retro-ortbital plexus after fasting for 16 hours and were measured by the GOD/POD methode.

Determination of Short Chain Fatty Acids (SFCAs)

As many as 6 rats per group were taken and anaesthetized with ether before the caecum digesta was taken, then it removed to vial tubes and then centrifuged in 14000 rpm for 15 minutes. The supernatant was measured to assess the profile of SCFA by a modified method of Henningsson et al. [37] with gas chromatograph (GC Shimadzu Serie GC 8A). Total of 1 µL supernatant was injected into column of GP 10% SP 1200 1% HPP30 on chromosorb with a 2 m length and temperatures of 130^0C, with FID detector, carrier gas N_2 at 1.25 kg/cm2 pressure. The injector and detector temperatures were maintained at 230^0C.

This study protocol had been appoved for ethical clearence No. 107-KEP-UB from Animal Care and Use Committee, Brawijaya University.

Statistical analysis

All results were expressed as means $\pm$ SEM for each group (n=6). Data were analysed by nested design with two factors by one way analysis of variance (ANOVA) using the general linier model procedure of SPSS 16.0 software. The significance of the difference between the means of test and control studies were established by least significance difference (LSD). P values of less than 0.05 (α = 5%).

3. Results And Discussion

3.1. Meal Tolerence Test (MTT)

The results of MTT study (Figure 1) indicated that all groups were fed with PFF affects the absorption of glucose in the blood ranged from 72.63 mg/dL to 117.36 mg/dL. Groups D within 30 min absorption of glucose increased 11.87 mg/dL or 15.68%, followed by group E and group F, it be required 30 min to reach the blood glucose levels back to normal. After 120 min of feeding, the blood glucose level of rats were increase 41.60 mg/dL (from 75.75 mg/dL to 117.46 mg/dL) or an increase 54.95%, this results was higher than groups E and F which is 29.44 mg/dL (40.54%) and 17.44 mg/dL (23.89%) respectively. It indicated that the group F is the most effective to maintain the blood glucose at normal levels. Low level of starch and add's to PFF into diet composition caused the low absorpstion of the blood glucose, it indicated that dietary fiber from PFF was able to inhibit the absorption of glucose.

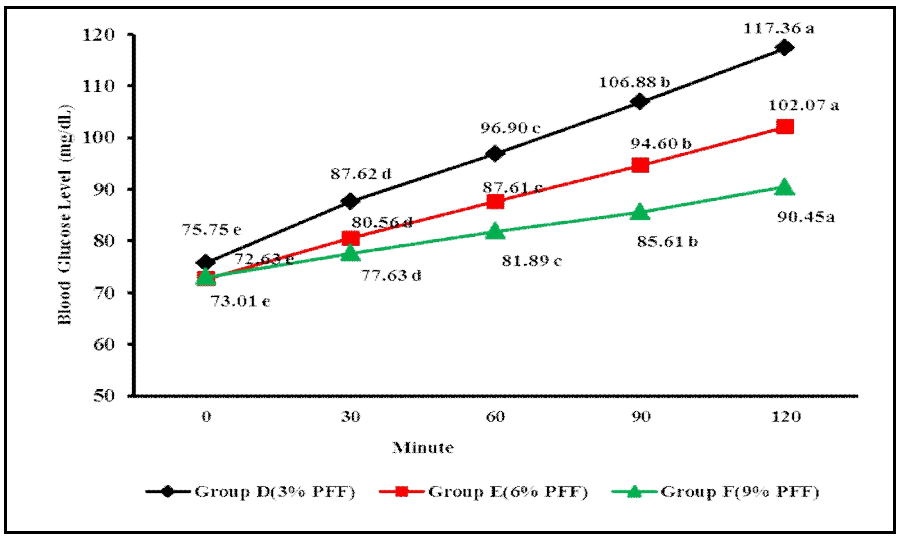

Figure 1. Response on MTT of rats fed formulation with PFF

The inhibition ability of glucose absorption by soluble dietary fiber from PFF is lower than gembili which extracted with papain[38], and alignate on biscuit[39]. This is caused the dietary fiber from PFF had not been purified and higher with insoluble dietary fiber, so forming ability of matrix gel in digestion and absorption of glucose in blood is slow. However, PFF have potential hypoglycemic effects. De Paula et al.[40] explained that soluble fiber can form an unstirred water layer in the gut, which decreases absorption of glucose and can be used to prevent the postprandial increase of glucose.

3.2. Changes of blood glucose

Table 2. Effect of PFF on blood glucose levels (mg/dL) on normal and alloxan-induced hyperglycemic rats

Group of rats	Feed	Blood glucose levels (mg/dL)				
		Week 0	Week 1	Week 2	Week 3	Week 4
Normal (A)	Standart AIN-93M	80.21±1.62^{c}	81.93 ±1.79^{bc}	83.17± 2.31^{b}	86.50 ± 1.89^{a}	88.11 ±1.91^{a}
Hypergl (B)	Standart AIN-93M	223.97±7.69^{a}	227.31±7.45^{a}	224.34±6.62^{a}	230.11±6.15^{a}	232.82±5.93^{a}
Hypergl (C)	Glibenclamide	217.56±10.83^{a}	196.40 ±9.12^{b}	145.70 ±8.49^{c}	98.53 ± 8.34^{d}	95.91±7.40^{d}
Hypergl (D)	3% PFF	211.93±8.26^{a}	198.37±8.73^{b}	167.61±8.80^{c}	142.77± 8.76^{d}	129.35± 3.40^{e}
Hypergl (E)	6% PFF	215.83±11.11^{a}	200.22±6.98^{b}	159.82±7.09^{c}	124.35± 7.00^{d}	109.90±1.67^{e}
Hypergl (F)	9% PFF	214.10±9.09^{a}	198.82±6.21^{b}	154.47±6.72^{c}	114.29±6.23^{d}	100.51±4.67^{e}

*Different code indicated the differences in one column.

The weekly changes of blood glucose levels were presented in Table 2 and the differences treatments shown in Figure 2. The administration of PFF significantly affect the blood glucose levels ($P<0.05$). The first week after alloxan injection showed blood glucose levels increase up to 223.97 mg/dL, exception the normal control group there was a slight result presumably due to an increase in stress by injection, while there were no significant different glucose levels in the hyperglycemic group. Alloxan injection cause damage selective in β - cells islets of Langerhans, and hyperglycemia occurs because glucose output from the liver[15].

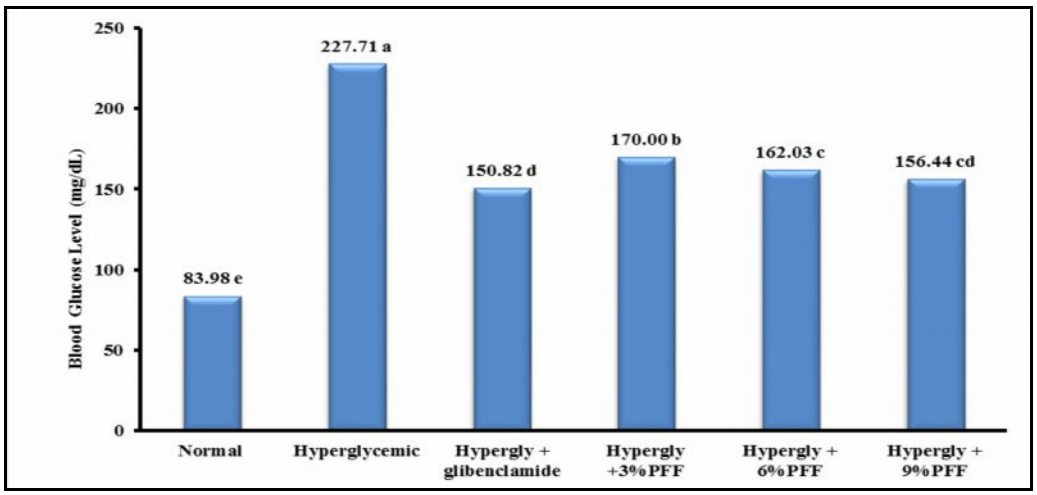

Figure 2. Changes of blood glucose level of rats during 4 weeks feeding PFF in diet compared with glibenclamide

Feed with glibenclamide (group C) and group rats were administrated of 3% PFF (group D), 6% PFF (group E) and 9% PFF (group F) for 4 weeks shows reduction of 55.69%; 38.96%; 49.08% and 53.05% respectively. The highest effect is shown by use of 9% PFF, the same tendency to that found on the MTT, if it compared with glibenclamide the decrease in 2.46% difference. Feed with PFF formulation shows gradual reduction in the glucose blood level depending on PFF added into diet, it indicates that PFF have hypoglycemic effect although the decrease were not as significant as glibenclamide.

The decrease blood glucose levels of groups D for 4 weeks about 211.93 mg/dL - 129.35 mg/dL (38.96%), it is lower than hypoglycemic effect gembili biscuits (135.74 mg/dL) (Harjono et al., 2013), group E and F 49.08% (from 215.83 mg/dL to 109.90 mg/dL) and 53.05% (from 214.10 mg/dL to 100.51 mg/dL) respectively. It indicates that dietary fiber from PFF have ability suppress to absorb glucose in blood and increase of food viscosity. Dikeman & Fahey[41] reported that increase in viscosity will reduce the speed of nutrients transport and inhibit contact between nutrients and surface of mucosa, further agitation peristalsis decrease followed by contact between enzyme and substrate, formation of micelles reduced so that the absorption of nutrients (glucose) be slowed.

Soluble dietary fiber can form water layer which is not moving in the gut so that reduce the absorption of glucose and fat. This effect related to the behaviour of polymer to form immobile water layer, i.e. reduce gastric emptying and withstand effects to remove a substance intestinal contractions and reduce the absorption of glucose by small intestine[15]. The changes of blood glucose in all treatment for 4 weeks were summarized in Table 2. There are two groups of rats to reach normal glucose levels, i.e. group E (109.90 mg/dL) and F (100.51 mg/dL), as well as with treatment glibenclamide (95.91 mg/dL), while group D still above normal, although there is a tendency to decline and near-normal (129.35 mg/dL). Thus feeding groups D have not been effective in lowering blood glucose levels during hyperglycemic rats observation. The differences of profile blood glucose among of all gropus for 4 weeks were summarized in Fig.2. The best treatment dietary fiber were group F (25.34%), which shown decrease in blood glucose level lower than group D (28.84%) and E (31.29%) respectively. It was also lower compared to group C (33.76%). Deruiter[42] explained that glibenclamide drug is sulfonylurea derivative which has a potential decrease in blood glucose levels higher than another.

Reduction of blood glucose in all PFF treatments is still lower than as reported by Morada et al.[31] which observed hypoglycemic effect from leaf extract of *Sonneratia alba* for 6 hours, decreased blood glucose level 66.90%. Whereas Moharib & El-Batran [8] investigated dietary fiber 50-150 mg/kg for 8 weeks reduced blood glucose levels 16-61%, because dietary fiber delayed gastric emptying, diffusion of glucose in the intestine.

3.3. Changes of body weight

The results of changes body weight were presented in Table 3. Dietary fiber from PFF which formulation in diet was significantly affect the body weight of hyperglycemic rats for 4 weeks ($P<0.05$). The hyperglycemic of group B body weight were lower than the control group and it decrease up to 6.17%, caused by alloxan induction which can inhibit secretion of insulin. So that absorption of glucose into tissue will be

slower and gluconeogenesis happen on liver to obtain the energy, and affected degradation of protein in the long time, the body weight were reduced. The body weight increase of group D (0.85%) and E (0.42%) were lower than group C (5.39%) and group F (4.19%). The profile differences of body wieght among all gropus for 4 weeks were summarized in Fig.3. It indicated that group F was best treatment that improved the performance of rats pancreas. The dietary fiber of PFF able to lower the absorption of carbohydrates, as Restiani[1] reported that it reduce the insulin action, the pancreas metabolism becomes lighter so it can improve the function of the pancreas to produce insulin. Harjono et al.[39] explained that diabetes generally causes glycation of body protein and affected the body weight.

Table 3. Effects of PFF on body weight (g) on normal and alloxan-induced hyperglycemic rats

Group of rats	Feed	Body weight (g)				
		Week 0	Week 1	Week 2	Week 3	Week 4
Normal (A)	Standart AIN-93M	236.17±4.17^{a}	245.50± 4.04^{b}	253.50±3.73^{c}	261.50± 4.04^{d}	271.33± 4.76^{e}
Hypergl (B)	Standart AIN-93M	232.33±4.23^{a}	226.83± 4.07^{b}	223.67±3.44^{bc}	220.83± 4.07^{cd}	218.00± 4.52^{d}
Hypergl (C)	Glibenclamide	233.67±3.77^{b}	229.17± 4.02^{c}	233.33± 4.18^{b}	237.33± 4.13^{b}	247.00± 4.60^{a}
Hypergl (D)	3% PFF	233.50±2.74^{a}	228.83±3.66^{b}	226.33± 4.18^{bc}	225.00± 3.69^{c}	234.83± 3.97^{a}
Hypergl (E)	6% PFF	223.50±6.89^{b}	219.17±6.49^{b}	222.83± 6.82^{b}	225.33± 6.28^{b}	234.67±5.61^{a}
Hypergl (F)	9% PFF	228.17±6.11^{bc}	223.17± 5.34^{c}	226.00± 5.48^{bc}	229.33 ±5.05^{b}	238.17 ±5.31^{a}

*Different code indicated the differences in one column.

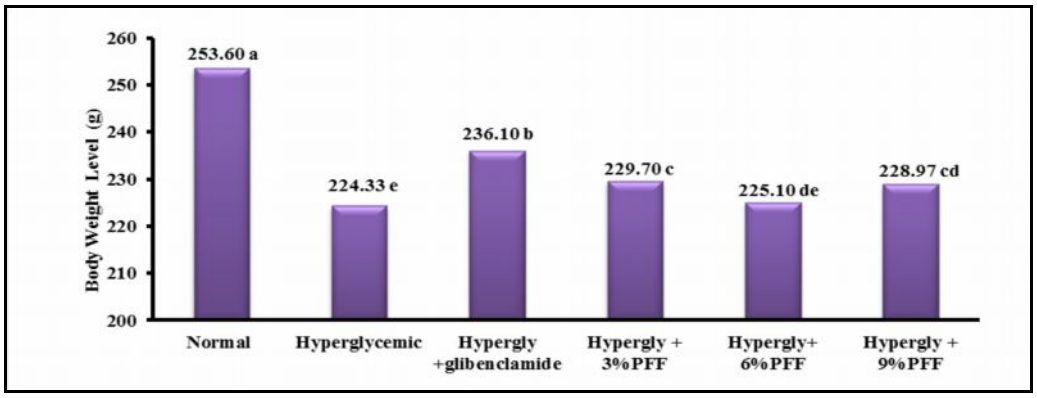

Figure 3. Changes body weight level of rats among all groups during 4 weeks feeding with PFF compared glibenclamide

3.4. SCFAs level of caecum

Dietary fibers pass as unaffected matter through the small intestine, and when reaching the colon, anaerobic bacteria degrade some dietary fibers via fermentation process, yielding short chain fatty acids (SCFA) such as acetic acid, propionic acid, and butyric acid [20,21,43], and forming gases such as H_2, CO_2 and CH_4 [37,44]. SCFA analysis was conducted to prove the alleged mechanism of decreased glucose levels through the utilization of SCFA in process of metabolism in the liver[45]. The decrease in blood glucose levels was not only caused by dietary fiber in the PFF that inhibit the absorption of glucose in small intestine. Another cause is the body's metabolism in mice such as increased insulin response to glucose in the liver due to the formation of short- chain fatty acids (SCFAs).

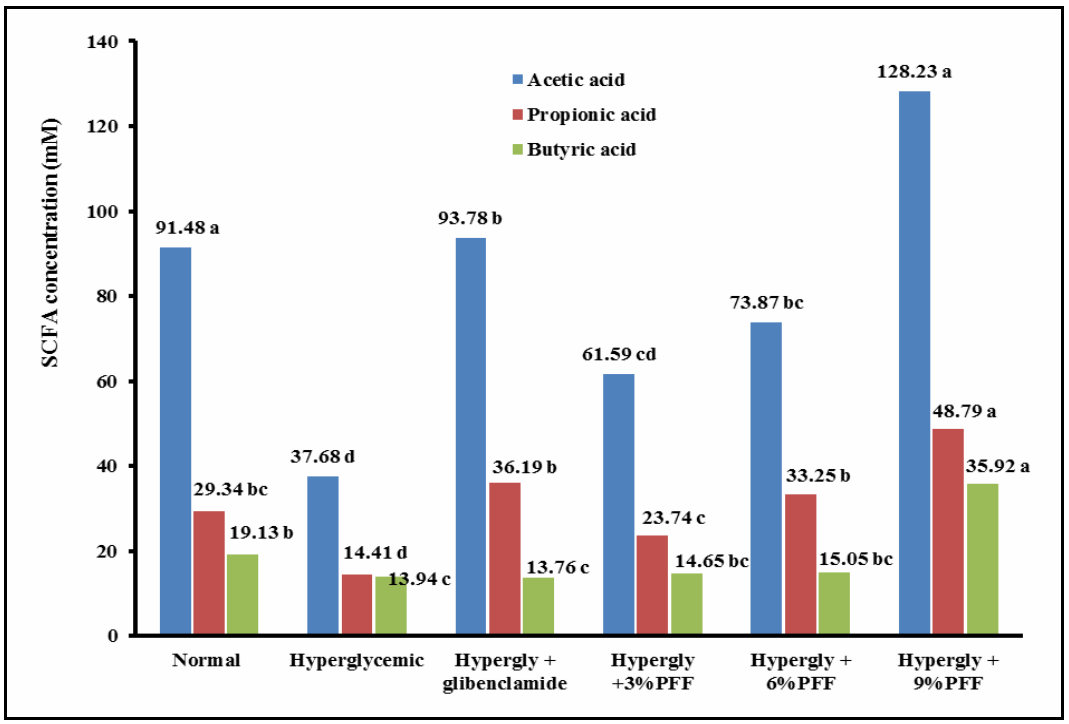

Figure 4. Short Chain Fatty Acids of caecum digesta of rats fed with PFF compared glibenclamide

Tabel 3 show that body weight of rats fed with dietary fiber from the PFF, glibenclamide and the group of normal mice were increased. The increase was much higher in normal AIN-93M fed rat, while the body weight of hyperglycemic groups significantly decreased. It indicates various feed – which formulated in standard fed – have contribute to different metabolism in rats. The results of SCFAs profile from caecum's digesta rats with difference feed for 4 weeks as shown in Figure 4. The similar SCFAs level is on group A (normal) and group C (glibenclamide), whereas hyperglicemic group was lower than any treatment and higher on the group F rats that fed with 9% PFF formula. The SCFAs level is increase along with the concentration of PFF that added to feed. The profile of SCFAs show that the acetic acid were higher, followed by propionic acid and butyric acid. Similar reported by Topping & Clifton[46]. Lunn & Buttriss[47] explained that the SCFAs profile were dominated by acetic acid and followed by propionic acid an butyric acid. Fermentation of food is bacterial performed by anaerobic breakdown and hydrolysed to their monomeric units, glucose, galactose, xylose, arabinose and uranic acids and then fermented via glycolysis to pyruvate and eventually to SCFAs together with some gases[48]. It can impact glucose homeostasis[49]. They were absorbed in the colon and transported to the liver via the enterohepatic circulation, a system that connect the liver and intestine[50].

Caprita et al. [51] explained that effect of dietary fiber to colon depend on the composition and physical properties of fiber. Soluble dietary fiber such as pectin and guar gum are rapid fermented in the colon[37], whereas insoluble dietary fiber such as cellulose, hemicellulose and lignin has less effect on postprandial glucose or insulin[41]. In the other hand it absorbs water in the colon, led to larger stool volume and stimulates the nerves in the rectum, giving rise to a desire for defecation[52]. SFCA also lower the colon pH and thereby inhibit the growth of patogenic organisms and also the formation of toxic breakdown products[53].

4. Conclusion

Dietary fiber from PFF on the diet composition for 4 weeks decrease the blood glucose levels on diabetic alloxan induced rats. The most effective decrease of blood glucose is at the level of 9% PFF that approach value of glibenclamide group, and followed by 6% PFF and 3% PFF. All PFF treatment also increase the body weight of rats. The SCFAs profile in all caecum treatment of the rats have similar concentration order, i.e acetic acid > propionic acid > butyric acid.

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References

1. Restiani, Y. (2010). Regulations related to claims against gastrointestinal function. *Food Review Indonesia*, *5*(3), 56-57.
2. Zbang, J., Huang, Y., Hou, T. & Wang, Y. (2006). Hypoglycaemic effect of *Artemisia sphaerocepbala Krasc* seed polysaccharide in alloxan-induced diabetic rats. *Swiss Med WKLY, 136*, 529-532.
3. Ukwenya, V.O., Ashaoalu, J.O., Adeyemi, D.O., Akinola, O.B. & Carton-Martins, E.A. (2012). Anthihyperglycemic activities of methanolic leaf extract of *Anacardium occidentale* (Linn.) on the pancreas of streptozotocin-induced diabetic rats. *Journal of Cell and Animal Biology, 6*(14), 207-212.
4. Arayne, M.S., Sultana, N., Mirza, A.Z., Zuberi, M.H., & Siddiqui, F.A. (2007). In vitro hypogly cemic activity of methanolic extract of some indigenous plants. *Pak J Pharm Sci, 20*(4), 261-268.
5. Ahmed, L.A., Hassan, D.R., & Hemeda, H.M. (2010). Anti-hyperglycemic effect of Okara, corn hull and their combination in alloxan induced diabetic rats. *World Applied Sciences Journal*, *9*(10),1139-1147.
6. Ruzaidi, A., Maleyki, A., Amin, I., Nawalyah, A.G., Muhajir, H., Pauliena, M.B.S. & Muskinah M.S. (2008). Hypoglycemic properties of Malaysian Cocoa (*Theobroma cacao*). Polyphenols-rich Extract. *International Food Research Journal*, *15*(3), 261-265.
7. Erukainure, O.L., Ebuehi, O.A.T., Adeboyejo, F.O., Okafor, E.N., Hafizur, R.M., Aliyu, M. & Elemo, G.N. (2012). Anti-diabetic and hypoglycemic properties of fiber-enriched cake in alloxan-induced diabetic rats. *Mediterr J Nutr Metab*. doi 10.1007/s12349-012-0116-9.
8. Moharib, S.A. & El-Batran. (2008). Hypoglycemic effect of diatery fibre in diabetic rats. *Research Journal of Agriculture and Biological Sciences, 4*(5), 455-461.
9. Anderson, J.W. & Ward, K.R.D. (1979). High-carbohydrate, high fiber diets for insulin-treated men with diabetes mellitus. *Am J Clin Nutr, 32,* 2312-2321.
10. Abeywickrama, W.S.S. & Jayasooriya, M.C.N. (2010). Formulation and quality evaluation of cordial based on Kirila (*Sonneratia caseolaris*) fruit. *Tropical Agricultural Research & Extension*, *13*(1), 16-18.
11. Sierra, M., Garcia, J.J., Fernandez, N., Diez, M.Z., Calle, A.P. (2002). Farmafibra group, therapeutic effects of psyllium in type 2 diabetic patients. *Eur J Clin Nutr, 56*, 830-842.
12. Clark, C.A., Gardiner, J., Mc Burney, M.I., Anderson, S., Weatherspoon, L.J., Henry, D.N. & Hord, N.G. (2006). Effects of breakfast meal composition on second meal metabolic responses in adults with type 2 diabetes mellitus. *European Journal of Clinical Nutrition*, *60*, 1122–1129.
13. Butt, S.M., Shahzadi, N., Sharif, M.K., & Nasir, M. (2007). A miracle therapy for hypercholesterolemia, hyperglycemia and obesity. *Food Science and Nutrition*, *47*(4), 389-394.
14. Xie, J.T., Wu, J.A., Mehendale, S., Aung, H.H. & Yuan, C.S. (2004). Anti-hyperglycemic effect of polysachharudes fraction from American ginseng berry extract in ob/ob mice. *Phytomedicine, 11* (2/3), 182-185.
15. Zhang, Z., Zhang, W.S. & Feng Du, X. (2010). Hypoglycemic effect of black glutinous corn polysaccharides on alloxan-induced diabetic mice. *Eur Food Res Technol, 230*, 411-415.
16. Gomathy, R., Vijayalekshmi, N.R. & Kurup, P.A. (1990). Hypoglycemic action of the pectin present in the juice of the inflorescence stalk of plantain (*Musa sapientum*)-Mechanism of action. *J Biosci, 1*(4), 297-303.
17. Hamed, W.M.A., Abid, K.Y. & Al-Amin, S.A. (2008). Hypoglycemic and hypolipidemic effects of grapefruit juice in diabetic rats. *Tikrit Journal of Pure Science, 13*(1), 129-131.
18. Sharma, M., Fernandes, J., Ahiwar, D. & Jain, R. (2008). Hypoglycemic and hypolipimic activity of alcoholic extract of citrus aurantium in normal and alloxan-iduced diabetic rats. *Pharmacoloyonline, 3*, 161-171.
19. Bisoi, P.C., Sahoo, G., Mishra, S.K., Das, C., & Das, K.L. (2012). Hypoglycemic effects of Insoluble fiber rich fraction of differnt cereals and millets. *Food Processing and Tecnology*, *3*, 1-11.
20. El Khoury, D., Cuda, C., Luhovyy, B.I. & Anderson, G.H. (2011). Beta glucan: health benefits in obesity and metabolic syndrome. *Review Articel Journal of Nutrition and Metabolism 2012*, 1-28.
21. Anderson, J.W., Baird, P., Davis, R.H., Ferreri, S., Knudtson, M., Koraym, A., Waters, V., & Williams, C.L. (2009). Health benefits of dietary fibers. *Nutrition Reviews*, *67*(40),188-205.
22. Chen, L., Zan, Q., Li, M., Shen, J. & Liao, W. (2009). Litter dynamics and forest structure of introducted *Sonneratia caseolaris* mangrove forest in Shenzhen China. *Estruarine Coastal and Self Science*, *85*(2), 241-246.
23. Mangrove Information Center. (2009). *Sonneratia caesolaris*. Retrieved from *www.mangrovecenter.com*.

24. Varghese, J.K., Belzik, N., Nisha, A.R., Resmi, S. & Silvipriya, K.S. (2010). Pharmacognotical and phytochemical studies of a mangrove (*Sonneratia caseolaris)* from Kochi of Kerala State in India. *Journal Pharmacy Research, 3*(11), 2625-2627.
25. Bandaranayake, W.M. (2002). *Bioactive, bioactive compounds and chemical constituents of mangrove plants*. *Wetlands ecology and management*. Netherlands: Kluwer Academic.
26. Sadhu, S.K., Ahmed, F., Ohtsuki, T., Ishibashi, M. (2006). Flavonoid from *Sonneratia caseolaris*. *Journal Nat Med, 60*, 264-265.
27. Minqing, T.D., Xiaoming, H.L. & Wang, B. (2009). Chemical constituents of marine medical mangrove plant *Sonneratia caseolaris*. *Chinese Journal of Oceanology and Limnology, 27*(2), 288-296.
28. Wu, S.B., Wen, Y., Li, X.W., Zhao, Z., Hu, J.F. (2009). Chemical constituents from the fruits of *Sonneratia caseolaris* and *Sonneratia ovata* (Sonneratiaceae). *Biochenical Systematic and Ecology, 37*(1), 1-5.
29. Tiwari, A.K., Viswanadh, V., Gowri, P.M., Ali, A.Z., Radhakrishnan, S.V.S., Agawane, S.B., Madhusudana, K., & Rao, J.M. (2010). Oleanolic acid - an a-glucosidase inhibitory and antihyperglycemic active compound from the fruits of *Sonneratia caseolaris*. *Journal of Medicinal and Aromatic Plants, 1*(1), 19-23.
30. Rahmatullah, M., Azam, Md.N.K., Pramanik, S., Sania, Rahman, S. & Jahan, R. (2012). Antihyperglycemic activity evaluation of rhizomes of *Curcuma zedoaria* (Christm.) Roscoe and fruits of *Sonneratia caseolaris* (L.) Engl. *International Journal of PharmTech Research, 4*(1):125-129.
31. Morada, N.J., Metillo, E.G., Uy, M.M. & Oclarit, J.M. (2011). Anti-diabetic polysaccharide from mangrove plant, *Sonneratia alba* Sm. *International Conference on Asia Agriculture and Animal, 3*, 197-200.
32. Jariyah, Azkiyah, L., Widjanarko, S.B., Estiasih, T., Yuwono, S.S. & Yunianta. (2013). Hypochole sterolemic effect of Pedada (*Sonneratia caseolaris*) fruit flour in wistar rats. *International Journal of Pharm Tech Research*, *5*(4), 1619-1627.
33. Reeves, P.G., Nielsen, F.H., Fahey, G.C. (1993). AIN-93 purified diets for laboratory rodents: final report of the American Institute of Nutrition ad hoc writing committee on the reformulation of the AIN-76A rodent diet. *The Journal of Nutrition, 123*(11), 1939-1951.
34. Reagan-Shaw, S., Nihal, M. & Nihal, A. (2007). Dose translation from animal to human studies revisited. *The FASEB Journal, 22*, 659-661.
35. Madar, Z., Nir, M., Ttrostler, N. & Norenberg, C. (1988). Effects of cottonseed dietary fiber on metabolic paramaters in diabetic rats and non-insulin-dependent diabetic humans. *Journal Nutr*, *118*, 1143 -1148.
36. Basak, A. (2007). Development of a rapid and inexpensive plasma glucose estimation by two-point kinetic method based on glucose oxidase-peroxidase enzymes. *Indian Journal of Clinical Biochemistry*, *22*(1), 156-160.
37. Henningsson, A.M., Bjork, I.M.E. & Nyman, M.G.L. (2002). Combinations of indigestible carbohydrates affect short-chain fatty acid formation in the hindgut of rat. *Journal of Nutrition*, *132*, 3098-3104.
38. Estiasih, T., Harjono, Suhnarharum, W.B. & Rahmawati, A. (2012). Hypoglycemic activity of water soluble polysaccharides of Yam (*Dioscorea hispida Dents*) prepared by aqueous, papain, and tempeh inoculum assisted extractions. *World Academy of Science Engineering and Technology*, *70,* 323-329.
39. Harjono, Estiasih, T., Sunarharum, W.B. & Hartono, M.D. (2013). Hypoglecemic effect of biscuits containing water-soluble polysaccharides from wild yam (*Dioscorea hispida* Dennts) or lesser yam (*Dioscorea esculanta*) tubers and alginate. *International Food Research Journal*, *20*(5), 2279-2285.
40. De Paula, A.C.C.F.F., Sousa, R.V., Figueriredo-Ribeiro, R.C.L. & Buckeridge, M.S. (2005). Hypoglycemic activity of polysaccharide fractions containing β-glucans from extracts of *Rhynchelytrum repens* (Willd) C.E. Hubb., Poaceace. *Brazillian Journal of Medical and Biological Research*, *38*, 885-893.
41. Dikeman, C.L. & Fahey, G.C. (2006). Viscosity as related to dietary fiber: a review. *Food Science and Nutrition*, *46*(8), 649-660.
42. Deruiter, J. (2003). Overview of the antidiabetic agents (pp 1-33). Endocrine Pharmacotherapy Module.
43. Tensiska. (2008). Fiber food (pp 1-8). Papers Food Industrial Technology Department, Industrial Technology Faculty of Agriculture University of Padjajaran Bandung Indonesia.
44. Tharanathan, R.N. (2002). Food derived carbohydrates-structrural complexity and functional diversity. *Critical Reviews in Biotechnology, 22* (1), 65-84.
45. Lattimer, J.M. & Haub, M.D. (2010). Effects of dietary fiber and its components on metabolic health. *Nutrients, 2*, 1266-1289.

46. Topping, D.L. & Clifton, P.M. (2001). Short-chain fatty acids and human colonic function: roles of resistant starch and nonstarch polysaccharides. *Physiological Reviews, 81*, 1031-1064.
47. Lunn, J. & Buttriss, J.L. (2007). Carbohydrates and dietary fibre. *Nutrition Bulletin*, *32*, 21–64.
48. Khattak, M.M.A.K. (2002). Physiological effect of dietary complex carbohydrates and its metabolites role in certain diseases. *Pakistan Journal of Nutrition, 1*(4), 161-168.
49. Michael, R., Lyon, M.D., Ronald, G. & Reichert, N.D. (2010). The effect of a novel viscous polysaccharide along with lifestyle changes on short-term weight loss and associated risk factors in overweight and obese adults: an observational retrospective clinical program analysis. *Alernative Medical Review, 15*(1), 68-75.
50. Luthana, Y.K. (2009). Asam Lemak Rantai Pendek. Retrieved from *http://www.yongikastanyaluthana.wordpress.com/2009/03/12/asam-lemak-rantai-pendek.*
51. Caprita, A., Caprita, R. & Simulescu, V.O.G. (2010). Dietray fiber: chemical and functional properties. *Journal of Agroalimentary Processes and Technologies*, *16*(4), 406-416.
52. Marsono, Y. & Topping, D.L. (1993). Complex carbohydrates in Australia rice products-influence of microwave cooking and food processing. *Food Science and Technology LWT*, *26*, 364-370.
53. Buttris, J.L. & Stokes, C. (2008). Dietary fibre and health: an overview. *Journal British Nutrition Foundation Nutrition Bulletin, 33*, 186–200.

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