Effect of Jicama (Pachyrhizus erosus) Fiber on Energy Intake and Adipose Tissue Profiles in Mice Fed with High-Fat Diet

P Santoso1*, R Maliza2, S J Insani1, and Q Fadhilah1

1Animal Physiology Laboratory, Biology Department Faculty of Mathematics and Natural Sciences Andalas University, Padang West Sumatra Indonesia 25163
2Biology Department, Faculty of Sciences and Applied Technology Ahmad Dahlan University, Yogyakarta Indonesia 55191

*putrasantoso@sci.unand.ac.id

Abstract. Jicama (Pachyrhizus erosus, Fabaceae) has been reported to elicit various medicinal benefits against metabolic disturbances. We also have previously demonstrated that extracted jicama fiber (JF) could sustain normoglycemic state in high-sugar diet fed mice. In this present study, we investigate the effectiveness of jicama fiber in preventing the dysregulation of energy metabolism as well as adiposity in adult male BALB/c mice fed with a high-fat diet (HFD). Three groups of animals were treated with normal diet (ND), HFD, and HFD in combination with 25% JF (w/w), respectively for 8 weeks ad libitum. Furthermore, food intake, energy intake, water intake, white adipose (WAT) and brown adipose (BAT) tissue mass, kidney and liver weight as well as organ index were determined. Our investigation revealed that JF 25% could preclude the perturbation of circadian feeding and energy intake rhythms caused by HFD but significantly reduced total water intake. JF also effectively counteracted the marked increase of WAT and decrease of BAT weight and its index in HFD fed mice. Furthermore, JF did not significantly alter the weight and index of both kidney and liver in HFD fed mice. This finding suggests that JF could be used as a potent supplement to minimize the disruption of energy homeostasis and obesity caused by HFD.

1. Introduction
A sustained balance of energy intake is profoundly attributed to the normal physiological processes in the body while the disturbances could lead to detrimental consequences including the development of metabolic diseases and subsequent health issues [1]. Previous investigations using animal models as well as human beings have revealed an inevitable relationship between dysregulated energy intake and the development of obesity, diabetes mellitus, cancer and cardiovascular diseases [1-5]. Regardless of its sources, a high-fat diet (HFD) is a salient factor disrupting energy homeostasis thereby implicates in peripheral systems and brain particularly in the hypothalamus as an energy regulation center [4]. However, both traditional and modern cuisines with high-fat content are undeniably palatable thus being excessively consumed by people worldwide. Consequently, the prevalence of metabolic diseases including obesity and associated metabolic disorders is becoming a serious global health issue.

It has been demonstrated that daily consumption of dietary fiber is strongly associated with various benefits on body health including lower risk of having obesity, diabetes mellitus and cardiovascular problems [8-12]. Our previous study also revealed that dietary fiber extracted from the tuber of jicama...
*(Pachyrhizus erosus*, Fabaceae) exerted a preventive effect against obesity development and diabetes in mice treated with high-sucrose diet (HSD) \(^{[13]}\). Although some previous studies have unraveled the beneficial effects of consuming jicama tuber including antidiabetic, anti-cardiovascular diseases and potent immunomodulator \(^{[14-18]}\), particular investigation revealing the effectiveness of its isolated dietary fiber against metabolic disease development including those caused by HFD remains limited. Studies on isolated fibers from sugarcane and bamboo shoot \(^{[8,9]}\) suggest an ameliorative effect of high-calorie intake in rodent models. However, to our knowledge, it remains unclear whether jicama fiber is also effective in preventing HFD-induced dysregulated energy intake and feeding and drinking behavior.

In this recent study, we performed an investigation to clarify whether supplementation of jicama fiber could effectively counteract HFD-induced imbalance in energy intake and its further implication in obesity development. We deployed some diet paradigms with mice as animal models. Our data suggest that jicama fiber is a potent candidate to be used as a dietary supplement to hamper the detrimental effects of HFD on homeostasis energy metabolism and feeding behavior.

2. Materials and Methods

2.1. Animal Model

As many as 30 individuals of adult male mice (2 months old, BALB/c strain from UD Wistar Rats Yogyakarta) were used in this study. All animals were kept in an individual cage (one mouse per cage) and acclimated for 7 days in a well-aerated room designated for animal maintenance (temperature set at 25-27°C and 12-h light-dark cycle). Food (BP-2, normal diet for rodents) and tap water were provided *ad libitum*.

2.2. Preparation of jicama fiber

The jicama tubers were freshly collected from a farmer in Kuranji, Padang city. The tubers were subsequently proceeded for fiber extraction following the procedures as previously described \(^{[13]}\). Briefly, after being peeled, jicama tubers were grated then soaked into cold distilled water overnight. Furthermore, the supernatant containing fiber was collected, steamed and dried out in the oven at 69°C for 16 h. The dried powder was kept in an isolated jar before being used in the experiment.

2.3. Animal Treatments

After the acclimatization period, animals were divided into three different groups (n = 10 per group) namely normal diet group (ND), high-fat diet group (HFD) and HFD supplemented with 25% of jicama fiber (HFD + JF 25%). Animals were fed with diets for 8 consecutive weeks. ND consisted of 9.6% fat, 61.1% carbohydrate, 27.1% protein and 2.1% cellulose and vitamin mix while HFD consisted of 45.9% fat, 38.1% carbohydrate, 13.1% protein and 2.6% cellulose and vitamin mix. The supplementation of jicama fiber was performed by mixed 250 grams of fiber with HFD in each kg of diet. All of the diet types were isocaloric containing an equal amount of energy (4000 kcal/kg).

2.4. Measurement of food and water intake

At the 7th week of treatment, food and water intakes were measured twice a day including light phase (LP, daytime) at 07:00 dark phase (DP, nighttime) at 19:00. The amount of food intake was determined by weighting food in the case using a sensitive balance. The volume of water intake was determined by recording the water level in the water bottle. The ratio of food intake or water intake was calculated by comparing food or water intake at the dark phase against the light phase (DP/LP). Daytime feeding or drinking was determined by calculating the proportion of food or water intake during LP against total food or water intake.

2.5. Calculation of Energy Intake

A calculation of energy intake was conducted based on the food intake data. We considered that a gram of fat is equal to 9 kcal of energy and a gram of protein and carbohydrates is equal to 4.1 kcal,
respectively and the proportion of such nutrients in each diet type was known, therefore the energy intake could be calculated accordingly. The ratio of energy intake was calculated by comparing energy intake at DP against LP and daytime energy intake was determined from the proportion of energy intake during LP against total energy intake.

2.6. Measurement of tissue and organ mass
The white adipose tissue located in the epididymis (eWAT) and brown adipose tissue located in the interscapular (iBAT) were isolated and weighted at the end of treatment. Moreover, the kidney and liver were also collected and weighted. The tissue or organ index was determined by calculating the proportion of its weight against total body weight.

2.7. Statistical Analysis
All data are presented as mean ± SD. The normality of data was firstly tested by the Kolmogorov-Smirnov test. Then the ANOVA followed by Duncan’s new multiple range test were performed to determine the significant difference among experimental groups with P value was set at < 0.05. The IBM SPSS statistics 26 was used in statistical analysis.

3. Results and Discussion
The rhythm of food intake in the ND-fed group exhibited a normal pattern which was consistently higher during the night (DP) and lower during the day (LP) (Fig 1A). Reversely, in the HFD-fed group, the pattern of food intake rhythm was irregular, suggesting perturbed circadian rhythm. Furthermore, the perturbation of feeding rhythm caused by HFD was hampered in the JF 25%-fed group, being comparable with the ND-fed group. Total food intake data (Fig 1B) showed that mice fed with HFD slightly consumed food than other groups, however, it was statistically insignificant. Data of feeding ratio, representing the proportion of food intake during a resting period (LP) of mice, showed a significant reduction in HFD group as compared with the ND-fed group, while it was comparable between HFD + JF 25%-fed group and ND-fed group (Fig 1C). Moreover, daytime food intake in HFD-fed group was significantly higher than ND-fed group and HFD + JF 25%-fed group (Fig 1D). Similarly, the data of energy intake including its daily rhythm (Fig 2A), total energy intake (Fig 2B), energy intake ratio (Fig 2C) and daytime energy intake (Fig 2D) exhibited a nearly identical pattern as food intake.

The data of water intake exhibited inconsistent daily patterns for all groups of treatment (Fig 3A). However, total water intake was significantly reduced in the HFD + JF 25%-fed group compared with others (Fig 3B). Interestingly, the ratio of water intake and daytime water intake remained comparable for all groups of treatment (Fig 3C and 3D, respectively).

Measurement on adipose tissue mass showed that the eWAT weight and its index was significantly increased in HFD-fed group while it was lower in ND-fed group and HFD + JF 25%-fed group (Fig 4A and B). Moreover, the iBAT weight slightly decreased in the HFD-fed group but statistically insignificant as compared with other groups (Fig 4C). However, the iBAT index depicted a significant reduction in HFD-fed group but not in other groups (Fig 4D). Furthermore, the kidney weight and its index were the same among all groups (Fig 5A and B) while the liver weight of the HFD + JF 25%-fed group and liver index of the HFD and HFD + JF 25%-fed groups tended to be lower as compared with the ND-fed group but statistically insignificant (Fig 5C and D).

In this current study, we revealed that jicama fiber at the dose of 25% was effective in hampering the disturbances in feeding behavior and energy intake as well as its subsequent effect on adiposity caused by HFD. It has been well documented that excessive intake of HFD is strongly associated with an alteration in feeding behavior thereby pattern of energy intake both in rodent models and humans [19]. A perturbation in the circadian rhythm of energy metabolism could be indicated by an apparent increase in daytime hyperphagia in nocturnal animals including mice and rats or nighttime hyperphagia in diurnal human beings. The excessive intake of energy during the resting period in which the rate of energy expenditure is markedly lower could lead to obesity and related disorders
including non-alcoholic fatty liver disease and diabetes mellitus \[20\]. Our previous investigation found that supplementation of jicama at the dose 25\% was also effective to prevent the hyperglycemia and obesity with a lesser effect on daily feeding rhythm in HSD-fed mice \[13\]. Interestingly, we also observed that HSD alone did not significantly perturb the rhythm of food intake thereby energy intake. Taken together, such findings suggest that HFD exerts a greater effect on feeding behavior than HSD.

We also observed that the daily rhythm of water intake was markedly altered in the HFD + JF 25\%-fed mice and total water intake was significantly decreased. We speculate that the disruption on the rhythm of daily water intake might be associated with an alteration in locomotor activity’s rhythm. A previous study has suggested an implication of HFD on locomotor activity \[21\]. Unlikely, our previous study in HSD-fed mice suggests that total water intake was increased and the magnitude of perturbation on the rhythm of water intake was lower \[13\]. This discrepancy, as observed in HFD-treated mice, may suggest a distinctive implication of HFD compared with HSD on locomotor activity and thirst state. However, it requires further mechanistic investigation to clarify such speculations.

Disruption in feeding rhythm and energy intake during the inactive phase (daytime in nocturnal rodents or nighttime in humans) has been related to adiposity indicated by elevated white adipose tissue mass \[22\]. Accordingly, in our present study, we also observed that WAT weight was significantly increased in the HFD-fed mice while it was sustained to be comparable with the ND-fed group in the jicama fiber-treated group. This finding suggests that jicama fiber supplementation acts as anti-adiposity in HFD-fed mice. It also has been reported that HFD decreases BAT mass \[23\] while

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**Figure 1. Effect of jicama fiber on food intake.** A daily rhythm of food intake as depicted in A was determined based on daily food intake measured during the dark phase (DP, nighttime) and light phase (LP, daytime) at the latest week of treatment. ND: normal diet; HFD: high-fat diet; JF: jicama fiber. *) indicates a significant difference at P < 0.05.
in this study we revealed that jicama fiber could prevent the HFD-induced BAT reduction. The reduction of WAT and sustained BAT mass in jicama fiber-treated mice could be due to an increase in energy expenditure and a decrease in energy intake. The process of fiber digestion in the gastrointestinal tract requires high energy that could plausibly contribute to increased energy expenditure involving BAT [8,9,11].

Our study found that jicama fiber caused a reduction in the liver mass but not kidney mass. An alteration in organ mass including liver might reflect the structural change either atrophy or hypertrophy due to metabolic dysregulation. Our study in the HSD-fed mice showed that jicama fiber at the dose of 25% was effective to counteract liver damages lead to NAFLD [24]. However, in this present study, we did not perform a histopathological examination on the liver that precludes us to clarify whether a decrease in the liver mass of the jicama fiber-treated group is also related to reduced fat deposition in the hepatocytes. A further study involving microscopic observation on the liver structure is warranted to reveal it.

Our present study could not provide a mechanistic explanation concerning the effects of jicama fiber against the HFD-induced metabolic dysregulation associated with feeding behavior and daily energy intake’s rhythm. Proper consumption of dietary fibers has been reported to decrease the rate of fat digestion and fatty acid absorption in the gastrointestinal tract [11]. It will subsequently implicate in an apparent reduction of fatty acid loading into the circulatory system and depot tissues including adipose tissue. Moreover, an elevation in energy expenditure induced by products of fiber fermentation namely short-chain fatty acids (SCFA) could significantly reduce excessive fat deposition in the tissues [9,10]. Hence, we suggest that further study should be addressed to clarify the implication of jicama fiber supplementation on SCFA production and its subsequent physiological outcomes against diet-induced metabolic diseases.

Figure 2. Effect of jicama fiber on energy intake. A daily rhythm of energy intake depicted in A was calculated based on daily energy intake measured during the dark phase (DP, nighttime) and light phase (LP, daytime) at the latest week of treatment. *) indicates a significant difference at P < 0.05.
Figure 3. Effect of jicama fiber on water intake. A daily rhythm of water intake depicted in A was determined based on daily water intake measurement during the dark phase (DP, nighttime) and light phase (LP, daytime) at the latest week of treatment. #) significantly different at P < 0.01.

Figure 4. Effect of jicama fiber on adipose tissue mass. The weight and index of adipose tissues (WAT and BAT) were determined after 8 weeks of treatment. **) significant different at P < 0.01, and *) at P < 0.05.
Figure 5. Effect of jicama fiber on weight and index of kidney and liver. The weight and index of organs (kidney and liver) were determined after 8 weeks of treatment.

4. Conclusion
Supplementation of 25% of jicama fiber is effective in hampering the perturbation of food and energy intake promoted by consumption of HFD. Moreover, jicama fiber also could effectively preclude an increase in the mass of WAT and decrease of BAT without significantly affecting weight and index of liver and kidney. However, jicama fiber significantly decreased total water intake. Regardless of its effect on water intake, jicama fiber is considerably effective in overcoming the detrimental effects of HFD on metabolic profiles thereby could be suggested as a potent supplement against obesity and associated health problems.

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