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Nutrient Intake and Digestibility of Cynomolgus Monkey (*Macaca fascicularis*) Fed with High Soluble Carbohydrate Diet: A Preliminary Study

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High carbohydrate as obese diet is not yet available commercially for monkeys. Therefore, this preliminary study was to carry out nutrient intake and digestibility of cynomolgus monkeys (*Macaca fascicularis*) fed with high soluble carbohydrate diet compared to monkey chow. Five adult female macaques (average body weight 2.67 kg) were made to consume freshly diet. Commercial monkey chows (contains 3500 cal/g energy and 35% starch) were fed to three adult females (average body weight 3.62 kg). Nutrient intakes and digestibility parameters were measured using modified metabolic cages. Result showed that average of protein, fat, starch, and energy intakes in treatment diet were higher than control diet (T-test). Fat intake in the treatment diet was three times higher, while starch and energy intakes were almost two times higher than monkey chow. Digestibility percentage of all nutrients were the same in both diets except for the protein. The study concludes that the freshly prepared high sugar diet was palatable and digestible for the cynomolgus monkeys. Further studies are in progress to develop obese diet high in energy content based on fat and source of starch treatments.

Key words: *Macaca fascicularis*, obese, metabolic cages, intake, digestibility

INTRODUCTION

Obesity is a global problem caused by metabolic syndrome and affecting an estimated of 300 million people worldwide (WHO 2002). Its prevalence is increasing in both developed and developing countries throughout the world. The prevalence of the metabolic syndrome is high among obese children and adolescents and it becomes more severe if not intervened. This disorder can lead to diabetes mellitus which usually followed by phases of obesity.

Bennet *et al*. (1995) reported that diet containing 4.2 Calories/kg of energy and 50-70% of soluble carbohydrate (sucrose and dextrin) can cause rhesus monkeys (*Macaca mulatta*) to become obese. In particular, diabetes mellitus in rhesus monkeys (*Macaca mulatta*) is preceded by phases of obesity and hyperinsulinaemia which is similar to Type 2 (non-insulin-dependent) diabetes mellitus in man (de Koning *et al*. 1993).

Riis (1983) reported that a high plasma concentration of acetate, glucose and insulin will stimulate fatty acid synthesis. Increased concentration of fat in the diet results in higher uptake of fatty acid whereas diet that causes the elevation of concentrations of glucose and insulin favor esterification and tend to increase the lipid balance. A number of obesity studies have been carried out to investigate the effect stress using bonnet monkey (*Macaca radiata*) (Kaufman *et al*. 2007), genetic aspect using baboon (Anthony *et al*. 2003) and to evaluate energy consumption on the nighttime to body weight gain using female rhesus (*Macaca mulatta*) (Sullivan *et al*. 2005). Obesity is caused by two major causes of obesity are genetic factor (50-90%) and environmental factors (e.g. feeding and level of activity) (Chen *et al.* 2000). The aim of this study was to determine nutrient intake and digestibility of high sugar and starch diet as oppose to monkey chow in cynomolgus monkey.

MATERIALS AND METHODS

Preparation of Treatment Diet. Eight adult female cynomolgus monkeys (*Macaca fascicularis*) with age range 6-8 years (estimated by dental examination) and initial body weight 2.67-3.62 kg, obtained from PT. IndoAnilab Bogor, Indonesia. All monkeys were subjected to standard Veterinary Care and Use Committee (ACUC). Animals were held in individual cages positioned to allow them to see and hear each other.

The monkeys were adjusted to the new obese diet for two weeks prior to actual feeding trial of four months. The animals were divided into two groups with unequal replication. The first group consisted of five animals (average body weight 2.67 kg) fed with the high sugar and starch diet whereas the second group consisted three animals (average body weight

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3.62 kg) fed with control diet (monkey chow). Monkeys were fed 120 g (as fed) of diet per head per day. They were fed once a day at 08:00 hours followed by one piece of 100 g *Ambon* banana at 12:00 hours. Water was available *ad libitum*. The treatment diet contained 3570 calories/g, 8.10% fat, and 50.57% starch with ingredient consisting of 15% sugar, 12.5% dextrin, 40% wheat flour, 4% tallow, 6% vegetable oil, 7% fish meal, 5% maizena, 5.5% heated soybean meal, 1.5% minerals, 2% CMC, and 1.5% agar-agar as fiber source. The proximate analysis of treatment diet and monkey chow are as shown in Table 1.

The nutrient intakes and digestibility parameters were measured using modified metabolic cages during the last five days of the study. Nutrient intake was calculated by multiplying dry matter feed intake with nutrient concentration of the diet. Sample of feces (10% of daily total production) were collected from each group and directly frozen until requirement for proximate determination (Table 2). Apparent nutrient digestibility (%) was calculated by the difference in nutrient intake and nutrient in the feces (Mc Donald *et al*. 2002) as described in the following formula:

Table 1. Proximate analysis of high soluble carbohydrate diet and monkey chow

Nutrients (%)	Treatment diet	Monkey chow
Dry matter	71.90	89.00
Protein	10.15	15.00
Crude fat	8.10	5.00
Mineral	2.93	8.08
Crude fiber	0.15	3.49
Starch	50.57	34.95
Gross energy (cal/g)	3570	3500

Laboratory Feed Technology, Department Animal Nutrition, IPB (2006).

Table 2. Proximate analysis of feces

Nutrients (%)	Traetment diet	Monkey chow
Dry matter	31.24	25.80
Protein	24.20	28.60
Crude fat	1.08	1.87
Crude fiber	3.47	4.51
Starch	58.61	50.23
Gross energy (cal/g)	2394	1269
Av.Feces excretion (g/d)	26.60	31

Laboratory Feed Technology, Department Animal Nutrition, IPB (2006).

$$\text{Apparent nutrient digestibility (\%)} = \frac{\text{(Nutrient intake – nutrient in feces)}}{\text{Nutrient intake}} \text{ X } 100\%$$

Analysis of dry matter (DM), crude lipid (CL), crude protein (CP), energy, and starch (NFE = nitrogen-free extractives) were carried out according to standard procedure of AOAC (1995).

Data were analyzed using T-test for comparing means of tratment diet and control (monkey chow) diet. Statistical analysis was carried out using Minitab Release 14 Program (Minitab Inc. 2003). Means of treatment diet and control (monkey chow) diet were tested for significance using T-test.

RESULTS

The average ration eaten by the five female monkeys were 90% of the total portion which was comparable with the monkey chow group. Total dry matter of feed intake for treatment diet was about 4.0% of body mass, while for monkey chow was 3.5% of body mass (Table 3).

The average values of fat, starch and energy intakes in the treatment diet were higher ($P < 0.01$), while protein intake was lower ($P < 0.05$) than control (monkey chow) diet. Percentage of the digestibility of nutrient was the same for both diets (around 96%), however protein digestibility for treatment diet (65%) was lower ($P < 0.05$) than control diet (86%). It seems to be high protein excretion in the treatment diet which almost 2 times compare to control diet (Table 4).

DISCUSSION

Dierenfeld *et al*. (2006) reported that total dry matter feed intake of proboscis monkey was 3% of body mass. The high sugar and starch in diet caused the high dry matter intake. This resulted in fat intake in treatment diet three times higher than in the monkey chow diet (4.73 vs 1.78 g/d), whereas starch and energy intakes were almost two times higher than monkey chow (39.25 vs 25.84 g/d and 242.14 vs 129.33 Cal/d). Monkey fed treatment diet consumed on average 242 Cal/head/day. Under normal condition, the energy intake of these animals has met its requirement. However to develop obesity, it appears more caloric intake (300 Cal/head/day) is required (Bennett *et al*. 1974). Feeding studies using intragastric feeding with 600-1,050 Calories of energy diet was shown to

Table 3. Nutrient consumption of *Macaca fascicularis* fed with different diet

Treatment	DM (g/d)	CP (g/d)	CL (g/d)	Starch (g/d)	Energy (Cal)
High SC diet	103.31 ± 3.12a	10.47 ± 1.01b	4.73 ± 0.61a	39.25 ± 0.67a	242.14 ± 11.10a
Monkey chow	90.04 ± 5.01b	13.50 ± 1.40a	1.78 ± 0.22b	25.84 ± 0.12b	129.33 ± 4.55b

Different letter in the same column was significantly different ($P < 0.05$).

Table 4. Nutrient excretion of *Macaca fascicularis* fed with different diet

Treatment	DM (g/d)	CP (g/d)	CL (g/d)	Starch (g/d)	Energy (Cal)
High SC diet	3.49 ± 0.12	3.59 ± 1.01a	0.04 ± 0.001	2.04 ± 0.07	8.50 ± 1.10a
Monkey chow	3.99 ± 0.01	1.84 ± 0.40b	0.007 ± 0.000	2.00 ± 0.12	5.07 ± 0.55b

Different letter in the same column was significantly different ($P < 0.05$).

Table 5. Digestibility of nutrient of *Macaca fascicularis* fed with different diets

Treatment	DM (%)	CP (%)	CL (%)	Starch (%)	Energy (%)
High SC diet	96.63 ± 2.30	65.78 ± 4.14b	99.18 ± 4.44	94.81 ± 2.27	96.49 ± 2.56
Monkey chow	95.57 ± 3.33	86.40 ± 6.10a	96.08 ± 2.23	92.28 ± 1.12	96.08 ± 2.88

Different letter in the same column was significantly different ($P < 0.05$).

cause increase of 20-67% body weight of rhesus monkey during nine years observation (Bennet *et al*. 1995). It is possible that the duration of the present study was not long enough to enable to develop obesity.

Our studies showed that the use of single monosaccharide carbohydrate which is sugar as energy source should be reconsidered. Storlien *et al*. (1988) reported that high levels of intake of simple sugars in the readily available form of sucrose do not lead obesity through decreased energy expenditure. Insulin action could be impaired at the level of the liver activities, and this can lead to metabolic syndrome. The intake of soluble carbohydrate in treatment diet which was 150 percent higher than monkey chow diet did not result in higher body weight gain. Thus the high sugar content in the diet was not enable for fat and starch deposition, possibly because the total soluble carbohydrate intake of the experimental diet was still lower than those required (50-70%) for obesity. The amount of glucose used for the normal turnover of depot fat in adult animals probably never exceeds 5% of that used by the whole body, and more would be needed for glycerol synthesis in the mammary gland, if the animal is lactating. In fat metabolism, glucose is needed for NADPH formation through the pentose pathway, but this requirement is small since NADPH only phosphate as a reducing agent in the synthesis of long-chain fatty acids (Riis 1983). Thus the use of sugar as main ingredient in the obese diet should be considered rather than using wheat flour or gluten meal.

Wood *et al*. (2003) developed a model of high fat diet-induced obesity in a rat having several features that make it useful for investigating the mechanisms by which dietary composition contributes to body weight regulation. This study reported that fat intake in treatment diet did not increase fat and energy digestibility. The percentage of fat in this experiment diet was still lower than the fat requirement (21-31%) for obese monkey.

Non human primate diet has better digestibility than domesticated animal diet. Studies on the digestion and passage of nutrients in the proboscis monkey (Dierenfeld *et al*. 2006) showed that dry matter and plant cell wall dissapearence may exceed 80%. The marker studies revealed that transit time was 14 hour, with mean passage time and transit time were 49 hours and 52 hour, respectively. Digestion coefficients and retention time were greater than expected based on body size. Mc Donal *et al*. (2002) has reported that factors influenced the digestibility are feed quality, animals and feeding management.

The digestibility of the diet was also depended on nutrient excreted in feces. Soluble carbohydrate (starch) and energy excreted in the feces of treatment diet was higher than those in monkey chow feces (Table 5). Riis (1983) reported it proved that sugar material was not contribute well to the soluble carbohydrate uptake and fat deposition. The low protein digestibility in obese diet was caused by low quality of protein in the treatment ration (heated soybean meal). Heated soybean meal was done to reduce the anti trypsin effect, however, some amino acids would be damage (Table 4).

In summary, we developed a diet high in carbohydrate (sugar source) for monkeys as a preliminary study to establish an obese monkey model. The palatability well received and dry matter feed intake was 4% of BW for treatment group and 3.5% for monkey chow. Dry matter, fat, starch, energy, and protein digestibility of treatment vs control diet were 96.63% vs 95.57%, 99.18% vs 96.08%, 94.81% vs 92.28%, 96.49% vs 96.08% and 65.78% vs 86.40%, respectively. Further studies are required to modify the diet especially in the source of soluble carbohydrate (using gluten and wheat flour for example) and source of protein (casein) to increase its energy content, therefore the consumption energy increase and the development of metabolite syndrome.

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