

Nutrient Composition of The Diets of Javan gibbons (*Hylobates moloch*)

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Abstract. Javan gibbons consume different foods to fulfil their nutrient requirement. We analyzed foods eaten by Javan gibbons for their nutrient content in Citalahab area, Gunung Halimun-Salak National Park (GHSNP), Indonesia. The goal was to assess amounts of water content, ash, crude fats, crude protein, crude fibers, carbohydrate and gross energy to determine whether there was nutritional variation between foods eaten by females and males. A total 43 food plant parts representing 33 plant species were collected, processed and analyzed. Females and males in Javan gibbons have similar diets with regard to overall composition. Nutrient analyses revealed high water content, ash and crude protein in young leaves; flowers and ripe fruits contained the most carbohydrate; crude fats content was highest in unripe fruits; ripe fruits were rich in crude fibers and gross energy content was high in all the main plant foods. Individual exhibit higher intake of certain nutrients by increasing feeding intake rate seems to be the key to greater nutrient intake in individual. This data adds our knowledge about nutritional composition of foods eaten by Javan gibbons and provides valuable comparative data for optimizing the diets of Javan gibbons ex situ.

Keywords: javan gibbon, nutrition, ecology, GHSNP

1. Introduction

Diet is an important factor that influences a primate's fitness. Primate diets appear to be complex in structure, diverse in content and variable over time. An individual's ability to safely harvest and process sufficient food to fulfill its requirement to growth, maintenance and reproduction are the key determinants of fitness [1]. In general, differences in food composition and choice can be influenced by energy needs, requirement for specific nutrients, constraints of digestive system, food dispersal and abundance, predation and also intra- and inter-specific competition [2].

Some studies confirm the importance of certain nutrients in a primate's diet. For example, preference of sugar content in the diet of Red Tail and Red Colobus monkeys help them meet heavy metabolic demands [3], and Spider monkeys preferred fruit rich in sugars and lipids because of their short food retention times [4]. Also leaves with relatively high amounts of protein and low amounts of fiber were important components in the foraging strategy of Gorillas [5] and fruits containing high amount of fat was needed by Orangutans because fat provided energy reserves to sustain unpredictable



seasonal food phases in Borneo [6]. However remarkably little is known about what nutrient favored or required in Javan gibbons and how it varies according to sex, especially in the wild (in captivity) [7].

In this study, we examined the nutrient composition of the Javan gibbon's diet and compared nutrient intake of adult females and adult males to explore whether sex differences affect nutrient intake. On the premise that fitness in females is principally limited by access to food, whereas fitness in males is principally limited by access to reproductive females [8], we tested two hypotheses. First, we tested whether energy requirement of females is higher than males since females have different reproduction stages (menstrual cycle, pregnancy, lactation and weaning). We expected that to fulfill the energy requirement, adult females may accomplish this either by spending a greater proportion of their time feeding or by increasing their feeding intake rates.

Second, we tested whether diet of females contain high proportion of certain nutrients than males. Milton [9] suggested that young leaves or flowers have higher protein source than other dietary items. Thus, we predicted either females consume more protein-rich foods than males or females consume more fruits with relatively high water content than males.

Understanding the nutrient composition in primate diet is central to understanding primate ecology because adequate nutrition is a prerequisite for successful reproduction [10]. Additionally, more information about nutrient composition of Javan gibbon' diet is important in gaining a better understanding of their interaction with their habitat and provides valuable comparative data for optimizing the diets of Javan gibbons ex situ.

2. Study sites and methods

2.1. Study sites

This study was conducted in Citalahab area of the 113,357 ha Gunung Halimun Salak National Park (GHSNP), west java-Indonesia. GHSNP (106°48'S 106°29'E) contains the largest remaining of evergreen rainforest in Java. A more detailed description of this study site can be found in Kim et al. (2011; 2012) [11,12]. The study area is covered with primary forest, but is adjacent with villages, rice paddies and tea plantation. Rainfall at Citalahab during study period from February ~ August 2012 was generally high with mean rainfall of 235.1 ± 171.32 mm/month and the average monthly temperature maxima and minima was 28°C and 16°C, respectively.

2.2. Study objects

Javan gibbons (*Hylobates moloch*) are an endemic species that live in undisturbed lowland and lower montane rainforest below 1600 ~ 1800 m above sea level (asl), mostly on the western part of the island of Java but a few are also present in Central Java [13]. This species is strictly arboreal, diurnal and mainly frugivorous. Their mating system is monogamous with inter-birth intervals of typically 3 ~ 3.5 years [14]. Javan gibbons have been protected throughout their range by Indonesian law since 1924 and categorized on the IUCN Red List of Threatened Species as endangered [15].

We selected two groups of Javan gibbons (Group A and Group B) for detailed observation of feeding behaviour and dietary composition. Group A had a 32.3 ha home range and Group B had a 43.3 ha home range [12]. Group A consists of three individuals: adult male, adult female and infant meanwhile Group B consists of four individuals: adult male, adult female, juvenile and infant. Both groups have lactating females and infants with different ages. The ages of infants when the study started for Group A and B was twelve and eight months, respectively.

2.3. Feeding behavioural data collection

We chose adult males and females from Group A and B as focal animals. Continuous focal animal sampling [16] of each individual was done by the researcher and helped by field assistants during their active time with the aim to collecting representative behavioural data for each sex class. Data were collected in 52 days and separated into 26 days for each group with full followed of 3 ~ 4 observation per month started from February until August 2012 amounting to 197 hours for Group A and 224 hours for Group B.

We followed the focal animals on each sampling day and focal samples were balanced among all adult individuals in each study group. Only data from complete dawn to dusk samples were included. During focal animal sampling, we counted food components ingested during time feeding sessions. A feeding session began whenever a focal animal first made contact with a food item that subsequently was consumed and ended when the Javan gibbons stopped feeding. Absolute counts were made of food consumed to establish feeding intake. Sample units included a single plant part (e.g., a leaf or fruit), the approximate dimensions of the food item (for stem), or in the case of small leaves or fruits and flowers, we used the average number of a component consumed.

2.4. Food sample collection

During the 52 days of observation, Javan gibbons in Citalahab used over 54 plant species as food sources and we collected 43 food samples representing 33 plant species that most commonly eaten and accounted for $\geq 1\%$ of feeding time and examined for nutritional analysis.

The food samples were collected either from the ground or by tree climbing. Trees were climbed to obtain fruits or leaves if an appropriate sample could not be found on the ground.

Approximately 150 to 200 grams of each plant part were collected. The samples were processed in manner to ensure that they were similar to the plant sections consumed by Javan gibbons. To determine the mean unit wet weights of food items ingested, 30 representative amounts of plant samples ingested (fruits, leaves, flowers and stems) were weighted using portable digital scale. All items were weighted immediately after collection and stored in the fridge until they were transported to the laboratory for analyses.

We adapted the method from Gould *et al.* [17] to calculated the nutrient intake rate during feeding for each focal animal to statistically examine whether significant variance occurred between females and males as in equation (1)

$$I_f(\text{ng}) = X_{(\text{ng})} * Y * Z \quad (1)$$

Where $I_f(\text{ng})$ represents nutrient intake rate during feeding, $X_{(\text{ng})}$ = proportion of the nutrient content (on a dry matter basis); Y = the average food unit mass of the plant part eaten ; and Z = the number of food units of plant part feed (feeding intake rate) per minute by Javan gibbons.

2.5. Nutritional analyses

The food samples were analyzed at the Nutritional Chemistry Laboratory, Bogor Agricultural University (IPB)-Indonesia. We grouped the food eaten by Javan gibbons by plant part and analyzed the nutrient composition of 43 plant parts that were eaten by two groups of Javan gibbons. It consisted flowers (n=3), mature leaves (n=1), ripe fruits (n=26), stem (n=1), unripe fruits (n=2) and young leaves (n=11).

Because of scarcity of samples, mature leaves and stem were omitted from the statistical analyses. The analyses presented here covered the basic chemical components of nutrition such as water content, ash, crude fibers, crude protein, crude fats, carbohydrate and gross energy.

Following the laboratory procedure, the samples were oven dried to constant mass, and moisture content calculated by subtraction from fresh mass. Water content was determined by drying a subsample at 105°C for 8 hours and hot weighing. Crude fats were determined with the Soxhlet method, extracting the sample for 6 hours in petroleum ether. Total ash was determined by burning the above subsample at 600°C for 2 hours and then weighting. Crude fibers were determined by washed

the samples with acetone to remove fats, followed by dilute acid and ignited in a muffle furnace. The resulting weight loss is equivalent to crude fiber content [18]. Crude protein was determined using the Kjeldahl procedure for total nitrogen and multiplying by 6.25. The remaining carbohydrate percentage was estimated by subtraction with difference method: $[100 - \% \text{ water content} + \% \text{ ash} + \% \text{ crude protein} + \% \text{ crude fats}]$ and gross energy was determined by burning a sample of dry matter in pure oxygen atmosphere in a bomb calorimeter.

The nutrient contents of Javan gibbon's diet are reported on a dry matter basis (DM). The chemical contents for water, ash, crude fibers, crude protein, crude fats, and carbohydrate are expressed as percentages of oven dry mass, while gross energy values as kcal/gram.

2.6. Statistical analyses

Results were summarized using descriptive statistics. Parametric statistical tests were applied as the requirements of parametric methods were fulfilled. The Kolmogorov-Smirnoff test was used to verify the assumption of normality before using parametric statistical tests. We used the t-tests for paired samples to examine differences between females and males in feeding and each nutrient intake, and also compared the coefficient of variation. Throughout the results, means are given with SD.

A univariate general linear model was performed to determine which type of food influenced the difference in nutrient intake. Standard annotation was used for significance levels ($P < 0.05$) in two tailed procedures. All statistical tests were carried out using SPSS version 16.

3. Results

3.1. Dietary composition

There was similar dietary composition between adult females and adult males of Javan gibbons in Citalahab. They spent mostly over half of their observed feeding time consuming ripe fruits followed by young leaves (figure 1). Meanwhile, unripe fruits and flowers were also important in their diet. Small proportions of insects, mature leaves and stem also found in their diet.

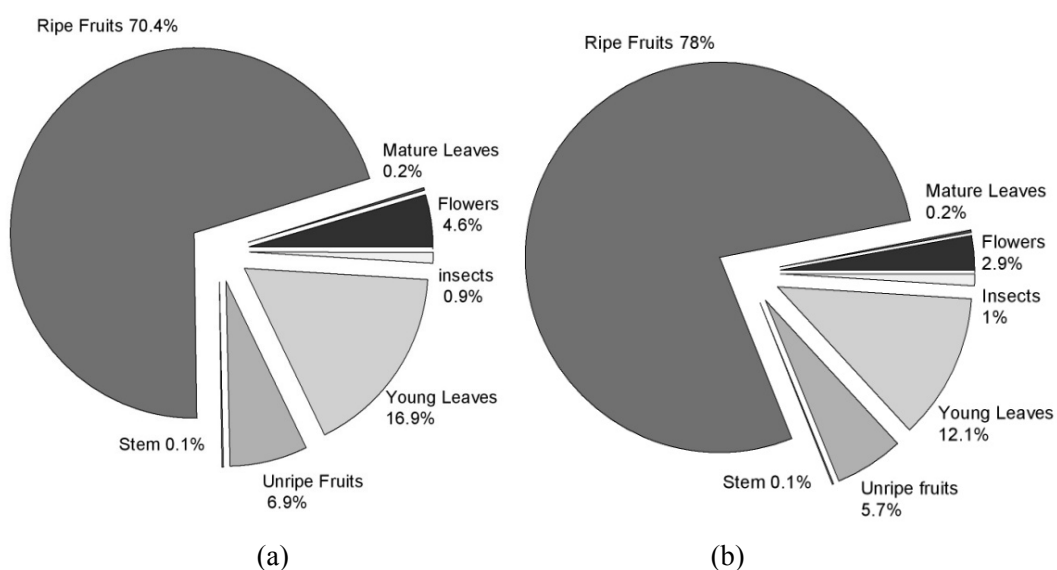


Figure 1. Percentage of foods eaten by (a) females and (b) males Javan gibbons

3.2. Nutrient composition of food items

Nutrient analyses revealed high water contents in young leaves (table 1). Flowers and ripe fruits contained the most carbohydrate, but flowers contained almost 10% more carbohydrate than did ripe fruits. Young leaves were most rich in water, ash and crude protein than other food items. Meanwhile, high crude fats were found in unripe fruit and crude fibers content were highest in ripe fruits, and gross energy content was high in all the main plant foods (figure 2).

Table 1. Composition of the major food plants eaten by Javan gibbons.

| | Flo (n = 3) | RF (n = 25) | YL (n = 11) | UF (n = 2) |
|------------------------|----------------|----------------|----------------|---------------|
| Water content (%) | 78.7 ± 3.83 | 71.1 ± 11.53 | 84.7 ± 3.78 | 77.0 ± 9.60 |
| Ash (%) | 5.9 ± 2.53 | 4.1 ± 2.21 | 8.1 ± 3.49 | 7.1 ± 1.16 |
| Crude Fats (%) | 4.2 ± 3.17 | 5.4 ± 8.20 | 4.3 ± 2.62 | 6.7 ± 2.38 |
| Crude Protein (%) | 13.7 ± 2.69 | 7.1 ± 3.26 | 18.7 ± 5.81 | 10.9 ± 4.26 |
| Crude Fibers (%) | 10.1 ± 2.51 | 24.0 ± 8.58 | 16.2 ± 7.01 | 20.7 ± 3.72 |
| Carbohydrate (%) | 66.1 ± 7.25 | 59.4 ± 13.36 | 52.6 ± 9.85 | 54.5 ± 0.69 |
| Gross Energy (Kcal/gr) | 4.9 ± 0.21 | 4.8 ± 0.62 | 4.7 ± 0.49 | 4.6 ± 0.46 |

*Major food plants are defined as those that collectively comprise 90% of observed feeding time in a particular month. Data presented as mean ± SD. Flo = flowers; RF = ripe fruits; YL = young leaves; UF = unripe fruits.

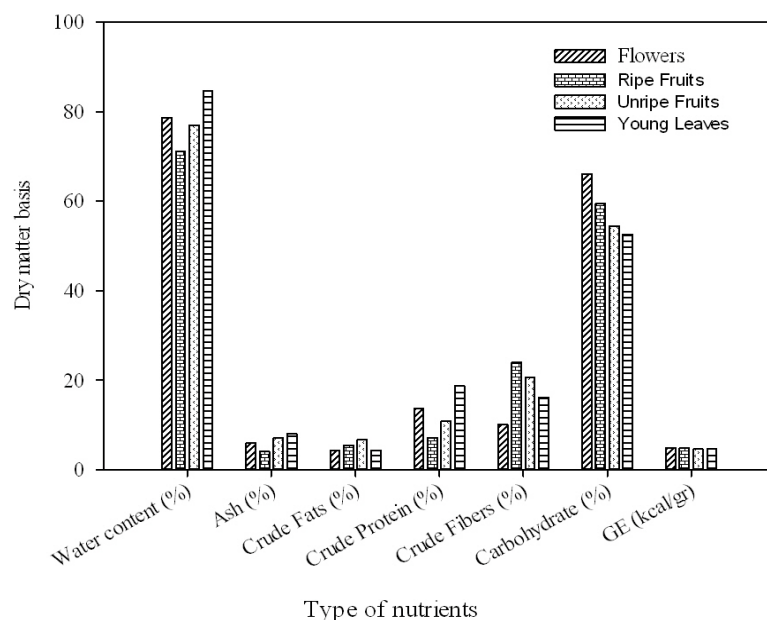


Figure 2. Nutritional composition of food items eaten by Javan gibbons.

3.3. Nutrient intake rate and sex differences

3.3.1. Water content. We found no significant difference in water intake between female and male in Group A (paired t test, $t = -1.557$; $df = 25$; $p = 0.132$). On the contrary, we found a significant difference in water intake between female and male in Group B (paired t test, $t = 2.316$; $df = 25$; $p = 0.029$) where female showed higher water intake rate (467.47 ± 189.06 gr/day) than male (396.37 ± 195.67 gr/day).

3.3.2. *Ash*. We found no sex difference in mean ash intake between female and male in Group A (paired t test, $t = -1.751$; $df = 25$; $p = 0.092$) and also between female and male in Group B (paired t test, $t = 1.730$; $df = 25$; $p = 0.096$).

3.3.3. *Crude fats*. There were no mean sex difference in crude fats intake within Group A (table 2a) (paired t test, $t = -0.490$; $df = 25$; $p = 0.629$), but we found sex difference in Group B (table 2b) (paired t test, $t = 3.096$; $df = 25$; $p = 0.005$) where the female had a higher crude fat intake (48.01 ± 25.38 gr/day) than the male (35.30 ± 18.09 gr/day).

3.3.4. *Crude protein*. Crude protein intake showed a significant difference in both groups of Javan gibbons. In Group A (paired t test, $t = -2.147$; $df = 25$; $p = 0.042$), a higher intake of crude protein was found in the male (56.55 ± 25.12 gr/day) compared to the female (46.29 ± 21.72 gr/day) but in Group B (paired t test, $t = 2.132$; $df = 25$; $p = 0.043$), we found a higher intake of crude protein in the female (59.32 ± 23.83 gr/day) than the male (48.86 ± 25.44 gr/day).

3.3.5. *Crude fibers*. There were no sex difference between female and male of Group A in mean crude fibers intake (paired t test, $t = -1.724$; $df = 25$; $p = 0.097$), but a significant difference occurred in Group B (paired t test, $t = 2.314$; $df = 25$; $p = 0.029$), where a higher crude fibers intake was found in the female (137.32 ± 51.92 gr/day) than the male (117.06 ± 55.68 gr/day).

3.3.6. *Carbohydrate*. We found no significance difference in carbohydrate intake either in Group A (paired t test, $t = -1.296$; $df = 25$; $p = 0.207$) or in Group B (paired t test, $t = 1.947$; $df = 25$; $p = 0.063$).

3.3.7. *Gross energy*. We found no sex difference between female and male in mean gross energy intake within Group A (paired t test, $t = -1.293$; $df = 25$; $p = 0.208$), but a significance difference was found in Group B (paired t test, $t = 2.529$; $df = 25$; $p = 0.018$) where the female had higher gross energy intake (3133.74 ± 1366.86 Kcal/day) than the male (2595.44 ± 1275.69 Kcal/day).

Table 2(a). Paired t-test of differences in nutrient intake rate between female and male in Group A.

| Nutrients | <i>t</i> | <i>df</i> | <i>P</i> _(2-tailed) |
|----------------------|----------|-----------|--------------------------------|
| Water content (gram) | -1.557 | 25 | 0.132 |
| Ash (gram) | -1.751 | 25 | 0.092 |
| Crude fats (gram) | -0.49 | 25 | 0.629 |
| Crude protein (gram) | -2.147 | 25 | 0.042 |
| Crude fibers (gram) | -1.724 | 25 | 0.097 |
| Carbohydrate (gram) | -1.296 | 25 | 0.207 |
| Gross energy (Kcal) | -1.293 | 25 | 0.208 |

Table 2(b). Paired t-test of differences in nutrient intake rate between female and male in Group B.

| Nutrients | <i>t</i> | <i>df</i> | <i>P</i> _(2-tailed) |
|----------------------|----------|-----------|--------------------------------|
| Water content (gram) | 2.316 | 25 | 0.029 |
| Ash (gram) | 1.73 | 25 | 0.096 |
| Crude fats (gram) | 3.096 | 25 | 0.005 |
| Crude protein (gram) | 2.132 | 25 | 0.043 |
| Crude fibers (gram) | 2.314 | 25 | 0.029 |
| Carbohydrate (gram) | 1.947 | 25 | 0.063 |
| Gross energy (Kcal) | 2.529 | 25 | 0.018 |

3.4. Time spent feeding and feeding intake rates

We found no sex difference in overall time spent feeding between females and males either in Group A (paired t test, $t = 1.258$; $df = 25$, $p = 0.220$) or in Group B (paired t test, $t = 1.306$; $df = 25$; $p = 0.203$) (table 3 and figure 3). Although both females and males showed a remarkably similar amount of time to daily feeding time, there was a significant difference in feeding intake rate between female and male in group A (paired t-test, $t = -2.229$; $df = 25$; $p = 0.035$) where the male ate more food per day (659.33 ± 291.27) than the female (546.37 ± 316.92) (figure 4). A significant difference was also found in group B (paired t-test, $t = 3.728$; $df = 25$; $p = 0.001$) where the female had a higher feeding intake rate per day (818.21 ± 374.60) than the male (628.19 ± 306.25).

Table 3. Time spent feeding and feeding intake rate of all food items consumed.

| | <i>t</i> | <i>df</i> | <i>p</i> (2-tailed) |
|--------------------------------------|----------|-----------|---------------------|
| Group A | | | |
| Time spent feeding (minute) | 1.258 | 25 | 0.22 |
| Feeding intake rate (food items/min) | -2.229 | 25 | 0.035 |
| Group B | | | |
| Time spent feeding (minute) | 1.306 | 25 | 0.203 |
| Feeding intake rate (food items/min) | 3.728 | 25 | 0.001 |

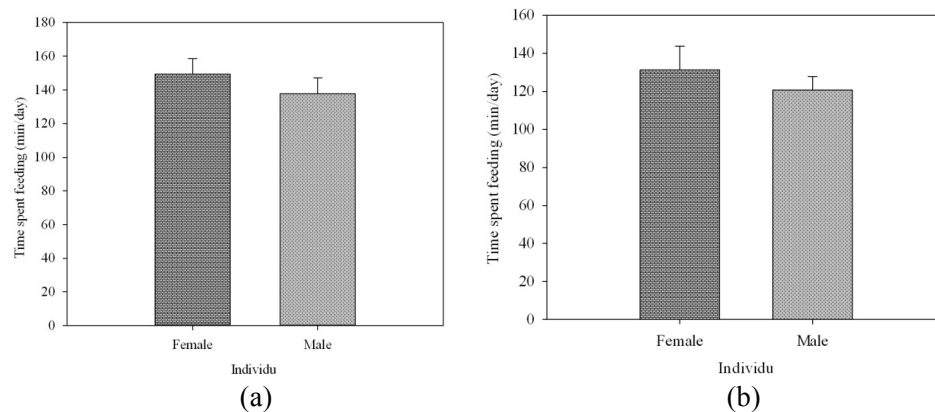


Figure 3. Mean time spent feeding between the sexes in (a) Group A and (b) Group B.

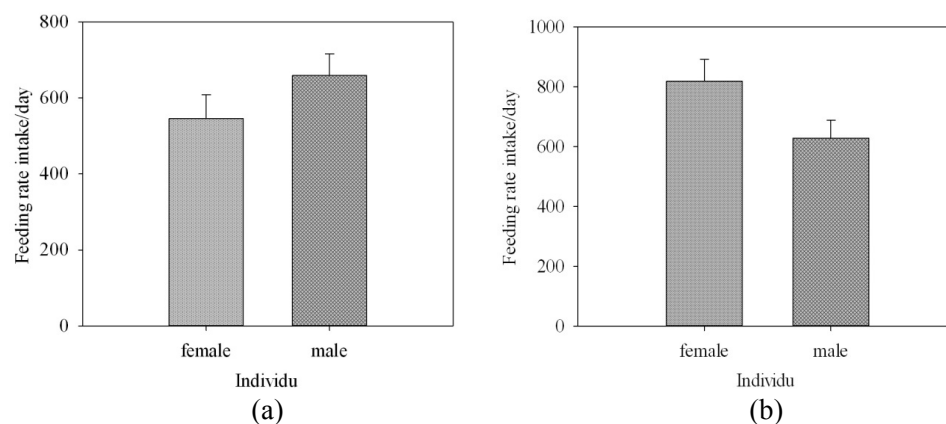


Figure 4. Mean feeding intake rates between the sexes in (a) Group A and (b) Group B.

3.5. Most influential food item related to nutrient intake

We conducted post analyses about which type of food that had the highest influence on nutrient intake in individuals. In Group A, where the male's crude protein intake was the dependent variable, we found that protein intake in the male was influenced by the intake of fruits ($df = 1$; $F = 52.93$; $t = 7.275$; $p = 0.00$) and leaves ($df = 1$; $F = 34.81$; $t = 5.900$; $p = 0.000$). Also in Group B, fruits and leaves were the determining factors for several nutrients intake in female such as water content (leaves: $df = 1$; $F = 22.94$; $t = 4.789$; $p = 0.000$. Fruits: $df = 1$; $F = 156.78$; $t = 12.521$; $p = 0.000$), crude fats (leaves: $df = 1$; $F = 11.872$; $t = 3.446$; $p = 0.002$. Fruits: $df = 1$; $f = 28.783$; $t = 5.365$; $p = 0.00$), crude protein (leaves $df = 1$; $f = 31.156$; $t = 5.582$; $p = 0.000$. Fruits: $df = 1$; $f = 40.539$; $t = 6.367$; $p = 0.000$), crude fibers (leaves: $df = 1$; $f = 10.411$; $t = 3.227$; $p = 0.004$; Fruits $df = 1$; $f = 125.028$; $t = 11.182$; $p = 0.000$) and gross energy (leaves: $df = 1$; $f = 35.743$; $t = 5.979$; $p = 0.000$. Fruits: $df = 1$; $f = 244.935$; $t = 15.650$; $p = 0.000$).

4. Discussion

4.1. Dietary and nutrient composition of food items

Broadly speaking, Bartlett [8] described gibbons as a frugivore-folivore where ripe fruits account for over half of the diet and the remainder is comprised mostly of young leaves. That finding was confirmed by Kim *et al.* [11] where fruits were the most important food of Javan gibbons (63% of feeding time) followed by leaves (24%), and flowers (12%). During our observation period, ripe fruits were also the most important component of the diet and covered over half of feeding time (76.9%), followed by young leaves (16.4%). Besides ripe fruit and young leaves, unripe fruits (6%) and flowers (4.7%) were also important in the diet of Javan gibbons.

The importance of fruits in the diet of primates has been discussed elsewhere primarily as a source of carbohydrates [9, 19] and fruits normally contain a relatively large amount of simple sugars as readily usable sources of energy [20]. Our results showed that food items eaten by Javan gibbons contained high carbohydrate especially from ripe fruits ($59.4\% \pm 13.36\%$) but also from flowers ($66.1\% \pm 7.25\%$). This finding is supported by Lappan and Whittaker [21] where flowers offer important nutritional benefits which other foods lack. Flowers of some species contain high levels of sugars, such as ripe fruits. In addition, Chivers [22] suggested that wild gibbons include a considerable proportion (59% - 87%) of carbohydrate-rich food items in their diets.

Even though Javan gibbons are known to prefer fleshy and ripen fruits [23], we found that Javan gibbons ate both ripe and unripe fruits from several highly preferred species. Based on our results, unripe fruits that were eaten had the highest crude fat composition relative to other food items ($6.7\% \pm 2.38\%$). Other small body size primate species such as the wild Mongoose lemur in northwestern Madagascar also consumed unripe fruits with an average 3% of crude fats in their diet [24]. Unripe fruits may be eaten to gain access to water and crude fats because fats also carry some fat-soluble vitamins and aid in vitamin absorption [25]. So fats should be considered in evaluating the importance of unripe fruits in the diet.

The consumption of young leaves probably satisfied certain nutrient requirement and helped maintain adequate levels of protein in the diet (a nutrient in which ripe fruit is often lacking). According to Struthsaker [26], young leaves contain a high percentage of crude protein. Several investigators have examined the basis for the preference of young over mature leaves in primates. Milton [9] and McKey *et al.* [27] compared young and mature leaves of several species and found that young leaves had higher protein content and lower fiber content. Wild chimpanzees have been found to consume diets containing 15% crude protein [28] and the average crude protein content in leaves consumed by Orangutans was 11.9% [29]. Compared with the other species, my result revealed that Javan gibbons consumed young leaves with high crude protein ($18.7\% \pm 5.81\%$) rather than other food items. Rahman [7] suggested that a food item is have high crude protein content if that component contained more than 18% of crude protein. Moreover, young leaves that were eaten by Javan gibbons

contained levels of crude protein with an average ≥ 2 times as high as those occurring in ripe fruits and therefore constitute an excellent source of protein.

However, food items that are high in water content are typically low in carbohydrate content [30] and our results showed that even though water content of young leaves was highest than the other food items ($84.7\% \pm 3.78\%$) it had the lowest carbohydrate content ($52.6\% \pm 9.85\%$). Thus, Javan gibbons may trade-off the content of water for carbohydrate content from potential food items.

Based on the results, this data lends further evidence that Javan gibbons consume differing nutrients in different types of foods to fulfill their nutrient requirement. Accordingly, flowers, fruits and young leaves are complementary food sources for Javan gibbons and each provide different sources of energy and other nutrients including minerals, though they have been studied in less detail. It seems likely fruits were complimented with young leaves or flowers to provide the most suitable nutrient balance [31] for Javan gibbons and many other primates.

4.2. Nutrient intake between individuals

Given the metabolic requirements in reproduction stages of females such as gestation and lactation [32,33], we expected to find sex differences in feeding behaviour or in nutrient composition between females and males in the two groups of Javan gibbons. However, we found a different result between the two groups. The adult female of Group A did not differ significantly from adult male in nutrient composition except in protein intake where interestingly the female had a lower protein intake than the male. The male of Group A consumed more protein per day (56.55 ± 25.12 gram/day) than the female (46.29 ± 21.72 gram/day).

Meanwhile, the female of Group B did show significant differences ($p \geq 0.005$) in nutrient composition compared with the male, such as in water intake, crude fats intake, crude protein intake, crude fibbers intake and gross energy intake where in all cases the female had higher nutrient intake than the male.

It should be noted that even though both females in the two groups were in the lactation period and carried infants during the full period of data collection, the two females were in relatively different phases of lactation. Approximately, the female of Group A was almost at the end of her lactation phase. Moreover, as the infant grows it gradually improves its ability to provide some forms of care for itself and so does the mother's ability to provide for her. Most maternal care declines after the infant are several months old and begin to move independently to forage and play [34]. This pattern occurs in lactating female Vervet monkeys, in which the mothers' energy intake decreases as their infants age [35].

Meanwhile the female of Group B was in the mid phase of her lactation period. It is likely that the female of Group B was experiencing higher reproductive costs than the female of Group A during the data collection period. Thus, female in Group B may need more nutrition and her requirements could have been elevated by the demands of lactation and transport of younger infants. A study by Gould *et al.* [17] in ring-tailed lemurs showed that females in mid-lactation period spent more time feeding compared with females in late-lactation period related to nutrient transfer for infants. However, in the case of Javan gibbons, more detailed studies are required on reproduction status of females and its effect on diet.

Lactating females must produce nutritious milk for their nursing infant [36]. The difference in water intake between female and male in Group B could be related to the producing of milk by the female. Consuming plant foods high in water content may assist female Javan gibbons to meet infant nutrient and water needs. In addition, gross energy for the female of Group B was also higher than the male, and the female obtained this by consuming more fruits and young leaves.

Intrinsic differences between age-sex classes can also give rise to intra-group differences in activity budgets [8]. In particular, the energetic demands of pregnancy and lactation may be reflected in differences in the activity budgets of males and females. We found that the rates of resting significantly differed between female and male in Group B where the female spent more time resting than the male.

Dufour and Sauther [33] suggested that lactation cost in primates can be met by a number of females' strategies, including increasing nutrient intake, decreasing maintenance costs, using body tissue stores and reducing energy expended in physical activity. It appeared that the female of Group B implemented two strategies (increasing nutrient intake and reducing energy expended through resting behaviour) to meet the energy requirement for lactation cost. Gould *et al.* [17] suggested that females likely benefitted from a reduction in activity during lactation period and conserved energy by spending more time resting (50%) than males (43%). In this regard female Javan gibbons may be viewed as energy maximizers.

During the observation period, the foods eaten by Javan gibbons of different sex were very similar, because the group moves closely and feeds together, usually in the same food trees. When trees are too small for feeding together, individuals may feed in turn or may utilize more than one tree (as when feeding on vine, leaves or fruits spread through two or more trees). Chivers [37] suggested a slight difference in the diets of gibbon's family in different sex or ages because of the high degree of cohesion of the family group. In this study we found that even though both females and males consumed very similar food, the higher difference in some nutrient intakes for female in Group B was not obtained by spending a greater proportion of her time for feeding than the male, but resulted from increased food intake per unit and particularly from young leaves.

Consistent with our result, McCabe and Fedigan [36] also found that greater nutrient intake in lactating females of white-face capuchins was not accomplished via spending more of their waking hours searching for and consuming food, but lactating females ingested food of all types at much higher rates than did other males and other females with different reproductive status. Likewise a study by Sauther and Nash [38] found that lactating Galagos had greater intake rate than females in other states. Indeed, feeding intake rate seem to be the key to greater nutrient intake in individuals.

In conclusion, it is evident from these data that females and males in Javan gibbons have similar diets with regard to overall composition. The difference in nutrient composition is correlated with the intake of food. The nutritional data provided here do not support the prediction that females have longer feeding time than males. These conclusions are based on one reproductive stage of females and therefore must be regarded as preliminary and should be investigated further more comprehensively in the future. Future research on nutrient composition between female and male in different reproductive stages over an annual cycle would expand both our knowledge of Javan gibbons' diet and help determine if behavioural differences related to energy saving strategies are exhibited by females across reproductive and non-reproductive periods.

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