# NUTRITION

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## EXECUTIVE SUMMARY

Free-ranging orangutans (*Pongo pygmaeus* in Borneo and *P. abelii* in Sumatra) have reported average body weights of 86.3 kg (range 80 – 91 kg) for males and 38.7 kg (range 33 – 45 kg) for females (Markham and Groves, 1990). Knott (1999) estimated energy expenditure for adults during peak fruiting season as approximately 3,400 kcal·day$^{-1}$ for males and 1,900 kcal·day$^{-1}$ for females (without maternal costs). During periods of low fruit availability energy expenditure fell to an estimated 3,100 kcal·day$^{-1}$ for males and 1,800 kcal·day$^{-1}$ for females without maternal costs. Estimated energy demands of 2,300 – 2,400 kcal·day$^{-1}$ remained the same during high and low fruiting periods for females who were pregnant, lactating, and/or carrying an offspring. These requirements are probably lower for captive animals depending on an individual's activity level.

Orangutans are classified as "frugivores" because they typically feed on fruits when available. When fruits are not readily available, orangutans consume leaves, bark, pith, flowers, insects, and honey (Galdikas, 1988; Hamilton and Galdikas, 1994; Knott, 1998a, 1999; Leighton, 1993; MacKinnon, 1974; Rodman, 1977). On average, orangutans can be expected to consume each day 1 – 2 % of their body weight in food (on a dry matter basis).

Recommendations are to offer orangutans 14% of their diet (as fed basis) as nutritionally complete primate biscuits and the remaining 86% as produce (as fed basis), with significantly higher proportions of raw vegetables and leafy green vegetables than fruit. These proportions translate in to 50% biscuits and 50% produce on a dry matter basis. Adjustments should be made based on animal body condition, health, activity level, reproductive status, growth stage, and intake. Do not offer too much food, allowing the orangutan to be satiated on produce alone. See appendices for diet examples.

**Relevant Bibliographic References:**

Knott, C.D. 1999. Reproductive, Physiological and Behavioral Responses of Orangutans in Borneo to Fluctuations in Food Availability. Ph.D. Dissertation. Harvard University, Cambridge, Massachusetts.

National Research Council. 2003. *Nutrient Requirements of Nonhuman Primates,* 2nd Ed. The National Academies Press, Washington, D.C.

## INTRODUCTION

The specific dietary requirements of vitamins, minerals, fat, and protein for orangutans are not known. To determine these requirements the animals would need to undergo long-term, controlled research as is typically done with domestic animals. This type of research, although extremely valuable, is not always practical for endangered/exotic animals. Instead, to form a reasonable estimation of dietary requirements, zoo nutritionists consider the following:

I. research the composition of wild diets,
II. evaluate the anatomy of their gastrointestinal tracts, and
III. extrapolate research information from similar species.

## LITERATURE REVIEW

I. Feeding Ecology

Free-ranging orangutans experience a dramatic flux in food availability due to mast synchronized fruitings of trees in Southeast Asia. Mast fruitings are rare, occurring only once every two to ten years (Ashton et al., 1988). During the lower periods of fruit production, orangutans are forced to rely on other, less energy dense foods. This phenomenon has lead researchers to hypothesize that orangutans evolved to take advantage of mast fruitings by storing the excess calories as fat and to partially then rely on this energy reserve when fruits are not available (MacKinnon, 1974; Wheatley, 1982, 1987; Leighton, 1993; Knott 1998a, 1999). Since orangutans prefer fruits when they are available, they have been given the classification of “frugivore”.

Foods selected by free-ranging orangutans have been identified by various researchers and include fruit, leaves, bark, pith, flowers, insects, and honey (Galdikas, 1988; Hamilton and Galdikas, 1994; Knott, 1998a; Knott, 1999; Leighton, 1993; MacKinnon, 1974; Rodman, 1977). There are even three reports of carnivorous activity by orangutans including the consumption of a gibbon (Sugardjito and Nurhuda, 1981), slow lorises (Utami and van Hooff, 1997), and a rat (Knott, 1998b).

While many researchers have identified the types of foods consumed by free-ranging orangutans, very few have quantified the nutritional composition of those items. Hamilton and Galdikas (1994), Heller (2002), and Knott (1998a, 1999) are the only researchers that have analyzed free-ranging orangutan foods for protein, fat, fiber, and dry matter.

Hamilton and Galdikas (1994) analyzed leaves, fruits, seeds, and flowers selected by free-ranging orangutans at Tanjung Puting Reserve in Indonesia from October through December in 1980. These researchers state that the orangutans' diets during this time were atypical due to the enhanced consumption of seeds and unripe fruits (instead of ripe fruits). The analyses included moisture, crude protein, and neutral detergent fiber (structural fiber including hemicellulose, cellulose, and lignin). On average, the leaves consumed contained 73.8% moisture, 15.2% crude protein (dry matter basis), and 56.4% neutral detergent fiber (dry matter basis), while the fruits contained 76.4% moisture, 48.7% neutral detergent fiber (dry matter basis), and 8.4% crude protein (dry matter basis).

Heller et al. (2002) conducted fat analyses on twelve orangutan foods, including six cambium, four seed, and two fruit pulp samples found in Gunung Palung National Park in Indonesia. Cambium is classified as a "fallback" food item for orangutans because it is consumed during the dry season when other foods are scarce. Heller et al. reported the fat concentrations of the items tested were low; however, the essential fatty acids (fats that the body cannot synthesize and must be obtained from the diet) comprised about 21% of the total fats present.

**Knott's Research** - The most extensive analytical research on orangutan foods was completed, as part of doctoral thesis research, by Knott (1998a, 1999). Her study focused on food availability and its effect on orangutan nutrition, energy balance, and reproduction. She followed Bornean orangutans in Gunung Palung National Park in Indonesia from November 1994 through December 1995, completing an entire year of food documentation. During this time period a mast fruiting event occurred which enabled her to include numerous fruits in her analyses.

She analyzed 93 orangutan food items for structural fiber (neutral detergent fiber, acid detergent fiber, and lignin), crude protein, ash (total mineral composite), and lipids (fat). Overall, there was a wide range in nutrient composition both among and within food categories. The table below is a composite of information of all the food items analyzed by Knott. Note the upper range of neutral detergent fiber concentrations identified for most food items.

**Nutrient Ranges in Orangutan Foods (% on dry matter basis)**

| Item | Neutral Detergent Fiber | Crude Protein | Fat |
|---|---|---|---|
| Seeds (n = 39) | 9 - 84 | 2 - 19 | 0 - 52 |
| Pulp (n = 19) | 9 - 77 | 5 - 13 | 0 - 18 |
| Leave (n = 8) | 21 - 72 | 12 - 19 | 1 - 2 |
| Bar (n = 10) | 53 - 73 | 6 - 17 | 0 - 8 |
| Flowers (n = 3) | 46 - 57 | 10 - 13 | 2 - 3 |
| Whole fruits (n = 4) | 50 - 65 | 4 - 12 | 0 - 4 |
| Pith (n = 4) | 51 - 82 | 3 - 7 | 0 - 2 |

Two food items with dramatically different consumptions between the sexes were *Durio* (or durian) and the seeds from *Neesia*. Durian fruits are described as large in size, averaging 347 grams, and protected by a hard outer husk with long, sharp spines. During the month of January the males spent 44% of their time consuming durian, while females spent only 6.6% of their time feeding on it. Knott suggests that this hard to open, difficult to eat fruit may have a biased consumption by males because males are stronger, can open the fruit easier, and may display territorial dominance over these fruiting trees.

Male orangutans also spent a much longer amount of time feeding on *Neesia* seeds than did females, 74.5% and 1.9%, respectively. Again, this sex biased difference may be attributed to difficulty in manipulating the fruit. *Neesia* seeds are contained in large fruits with a hard, outer casing. Once opened, the seeds then need to be extracted from a layer of irritating hairs in which they are embedded.

Knott approximated individual orangutan consumption using the time an individual spent eating and their average feeding rate. This information, used in conjunction with the food analyses information, was used to estimate intake of specific nutrients.

Based on those intake calculations, neutral detergent fiber comprised 24.1 – 60.8% of the consumed diet. During the non-fruiting period (June – December), the fiber concentrations of the diet were at their highest because orangutans relied on leaves and bark as main food items, both of which are extremely high in structural fiber. While concentrations of fiber changed in the diet, the overall, absolute quantity of fiber consumed did not vary significantly throughout the year. This can occur when an individual increases or decreases their consumption of other dietary components, such as nonstructural carbohydrates, while continuing to consume the same quantity of fiber, thus changing the concentration of fiber consumed.

While the percentage of fiber consumed varied throughout the year, the percentage of protein remained relatively consistent, comprising 5.3 – 16.0% of the diet. The lipid (fat) concentration of the diet ranged between 7.2 – 16.8% with the higher percentages being attributed to the consumption of *Neesia* seeds, which contain 40% fat.

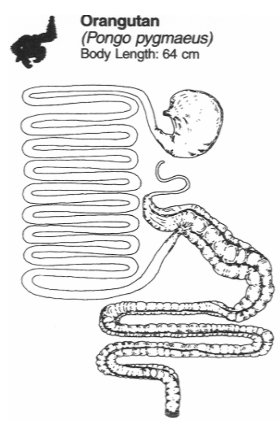
In addition to estimating nutrient consumption, Knott estimated caloric intake and expenditure. During mast fruiting periods, caloric intake was approximated to be 8422 $kcal \cdot day^{-1}$ for males and 7404 $kcal \cdot day^{-1}$ for females, which is greater than during non-mast periods in which males consumed an estimated 3824 $kcal \cdot day^{-1}$ and females consumed 1793 $kcal \cdot day^{-1}$ (Knott, 1998a). Knott estimated energy expenditures for orangutans during fruit-rich periods to be approximately 3,400 $kcal \cdot day^{-1}$ for males, 1,900 $kcal \cdot day^{-1}$ for females (without maternal costs), and 2,400 $kcal \cdot day^{-1}$ for females (with maternal costs) using food consumption rates and caloric content of the foods eaten. In an effort to validate these estimations, she used the American Dietetic Association (ADA) guidelines of 40 $kcal \cdot BW_{kg}^{-1} \cdot day^{-1}$ for a normal, active adult human to determine energy requirements (ADA, 1992). Using orangutan weights of 86.3 for males and 38.7 kg for females (Markham and Groves, 1990) in the ADA equation, estimated energy requirements for free-ranging orangutans were 3,450 $kcal \cdot day^{-1}$ for males and 1,550 $kcal \cdot day^{-1}$ for females (without maternal costs). Knott's calculated caloric intake values were very similar to those estimated using the ADA equation with female energy expenditures expected to rise when taking maternal costs into consideration.

Through her research, Knott tested the hypothesis that orangutans store energy during periods of fruit abundance and utilize those fat stores during periods of low food availability. She accomplished this by monitoring orangutan urine for ketones. Ketones are produced by the body when fat reserves are being used for energy. She did not detect ketones in orangutan urine from November 1994 – February 1995, a period of high fruit availability. She began detecting ketones in orangutan urine in April 1995, one month after the orangutans began relying on leaves and bark, lower energy food items, to supplement their diet.

In summary, Knott reported that male and female orangutan diets were very similar in composition, nutrients, and calories, but varied throughout the year depending on fruit availability. She concluded that orangutans have evolved two nutritional adaptations to cope with the extreme fluctuations in food found in their environment. The first trait is their ability to consume a significant number of calories, which is stored as fat, when fruits are abundant. The second trait is the orangutan's physiological ability to survive on low quality, extremely high-fiber food items during non-fruiting periods. Both adaptations, along with other traits such as their large body size and their decrease in day range during fruit-poor periods, have allowed the orangutan to survive the unusual food dynamics of Southeast Asia.

II. Gastrointestinal Anatomy and Physiology

The second piece of information to consider when formulating diets for animals, especially for those whose dietary needs are not well established, is the anatomy of their gastrointestinal tract. The distinctive feature of an orangutan's digestive tract is the voluminous and lengthy large intestine (Fig 1). Gorillas, also known for their high fiber diets, have a similar digestive tract; however, not all apes share this trait. The large intestine of chimpanzees (Fig 2) and humans (Fig 3), both considered omnivorous species, is smaller in volume and shorter in length than that of the orangutan. The proportionate length and volume of the orangutan's large intestine reflect their ability to ferment significant quantities of fiber from which they are able to acquire energy.



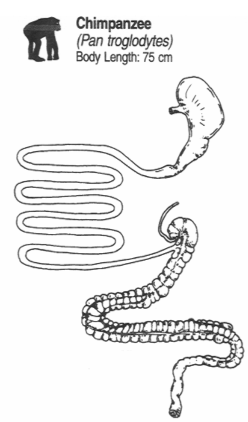




Fig. 1 Fig. 2 Fig. 3

(Stevens and Hume, 1996; reprinted with the permission of Cambridge University Press)

**Fiber Fermentation** - Fiber is a generic term used to describe a broad range of plant compounds, including hemicellulose, cellulose, lignin, gum, and pectin. Mammals do not produce the digestive enzymes necessary to degrade fiber in plants, yet herbivores have evolved to rely on plants as their primary source of food. To overcome this inability, herbivores, and to a lesser degree omnivores and carnivores, have developed a symbiotic relationship with bacteria. In non-ruminant animals, including the orangutan, these bacteria reside mainly in the large intestine. Certain species of bacteria rely specifically on fiber for survival, while other bacterial species survive on undigested protein or starch particles that reach the large intestine. The fiber degrading (fibrolytic) bacteria manufacture and secrete the specific enzymes necessary to break certain types of fiber strands into individual sugar components through a process known as fermentation. Not all types of fiber can be fermented by bacteria. The bacteria use the sugars to meet their own energy needs and excrete an end-product known as volatile fatty acids (VFAs). The herbivore absorbs the VFAs, using them for energy. The research, done by Hamilton and Galdikas (1994) and Knott (1998a,1999), revealed that foods selected by orangutans are relatively high in structural fiber. Through this symbiotic relationship with bacteria, orangutans are able to obtain energy during low fruiting periods by consuming extremely high fiber food items, such as leaves and bark. Combining the knowledge of their high fiber diets with their digestive anatomy would lead one to believe that the orangutans have evolved to metabolically rely on VFAs for a significant proportion of their energy.

## III. Primate Nutrition Research

A considerable amount of research has been completed in the area of nonhuman primate nutrition because primates are often used as models for human nutrition research. The information from these studies has been compiled into *Nutrient Requirements of Nonhuman Primates* (2003) by the National Research Council. This document includes information on feeding ecology, life-stage considerations, the process of dietary formulation, food use in environmental enhancement, and in-depth nutrient discussions on energy, carbohydrates and fiber, protein, fats and fatty acids, minerals, vitamins, and water. One of the tables provided, Composition of Foods and Feed Ingredients, includes energy values, proximate analyses, and fiber concentrations of a variety of food items. For in-depth, comprehensive information on primate nutrition, this book is an invaluable resource.

Even though fiber is not recognized as an "essential nutrient" by classical animal nutritionists, the benefits of its presence to gastrointestinal health and metabolism cannot be ignored. In other species, the presence of fiber in the intestinal tract has been shown to enhance blood flow to the intestines, thereby promoting nutrient absorption and tissue health (Kvietys and Granger, 1981; Howard et al., 1995). The presence of VFAs, by-products of fiber fermentation, helps prevent the overgrowth of pathogenic bacteria, including E. coli and Clostridia (Hidaka et al., 1986; Izat et al., 1990). Volatile fatty acids are also believed to increase the epithelial cell population of the intestines and stop malignant cell growth, decreasing the risk of intestinal cancer (Sakata and von Engelhardt, 1993). In addition to energy, many health benefits are obtained from including fiber in the diet of herbivores. Herbivorous animals, including the orangutan, may be physiologically dependent upon volatile fatty acids to provide a substantial proportion of their daily energy supply.

Schmidt (2002) used high fiber, research gel diets to evaluate the orangutans' capacity for digesting fiber. The fiber concentration in extruded primate biscuits is maximized at 30% due to the manufacturing process (Griffin, Mazuri™, PMI Nutrition International, LLC, 1999, personal communication). To increase the fiber concentration of a nutritionally complete feed ground corncobs (CC) or soybean hulls (SH) were suspended in a fiber-based gel matrix. The resulting neutral detergent fiber concentrations were 47% (CC), 64% (CC), and 53% (SH). These fiber levels were 1.5 -2.0 X greater than that provided by extruded primate biscuits. Results from this study showed that orangutans were able to degrade 58 – 65% of the fiber in the CC gel diets and 75% of the fiber from the SH gel diet. While no other orangutan digestibility trials have been conducted for comparison, the ability of the orangutans in this study to degrade such significant concentrations of fiber was remarkable. Their ability to digest these large quantities of fiber is an indication that they are capable of relying on fiber fermentation and the resulting VFA production to fulfill some of their energy needs.

## NUTRITIONAL STATUS EVALUATION

One way to evaluate the nutritional status of animals is to measure serum concentrations of various circulating nutrients. To know if the obtained values are "normal" or "abnormal", one should know what "reference ranges" are for specific nutrients. This concept is similar to the serum chemistry panel used by veterinarians to assess health status of an animal. In reference to nutrition, these measures would reflect circulating levels of vitamins, minerals, amino acids (protein), fatty acids, and lipoproteins. Crissey et al. (1999) quantified serum concentrations of lipids, vitamins A and E, vitamin D, and carotenoids in nine captive primate species, including orangutans. This is one of the most extensive investigations establishing nutritional reference ranges in captive primates. Establishing these same reference ranges on the free-ranging population would enable nutritionists to determine differences between the captive and free-ranging populations. If dramatic differences are identified, a change in the captive diet formulation may be warranted.

Kilbourn et al. (2003) had the opportunity to conduct health evaluations on free-ranging orangutans (*P. pygmaeus*) in Malaysia. They collected and analyzed serum samples to report average means and ranges for serum chemistries, serum soluble elements, and vitamins A and E. Although serum chemistries are typically used to assess animal health, the values for calcium, phosphorous, cholesterol, and triglycerides can be used as nutritional parameters.

## CAPTIVE DIETS

When feeding any captive animal it is important to consider various factors that may affect an individual's diet. Issues such as animal preference, body condition, health status, and activity level should be considered when determining types and quantity of food to feed an individual. Animals housed in groups should receive enough food to meet their nutritional needs and limit aggressive encounters; however, the quantity should not allow animals to be overly selective in what they eat. For example, allowing them to consume mostly produce while avoiding primate biscuits, a nutritionally complete feed could lead to nutrient imbalances. Animals that are fed as a group should have a small amount of food left over after the feeding period. This ensures that no individual is being deprived of food.

Produce can vary in size and the amount of water it contains. Nutritionally complete feeds also vary in density, even from lot to lot of the same product. For these reasons, it is very important to weigh food in each category rather than preparing the diet by counting items (i.e., weigh out 250 g of apple instead of offering 1 apple).

### I. Commercially Available Produce

The term "produce" refers to the vast array of readily available fruits, vegetables, and leafy greens cultivated for human tastes. Many caretakers want to offer orangutans and other exotic animals more "natural diets" by using produce as the sole source of nutrients. Although orangutans are classified as frugivores, the fruits and other plant items they consume in the wild are dramatically different in composition (Knott, 1999) from the fruits cultivated for human consumption (Schmidt et al., 1999; Schmidt, 2002). Reports on produce composition from the field of human nutrition have analyzed only the "human edible" portions of the produce. Those analyses do not include peels, cores, and seeds, which are often consumed by animals. The inclusion of these items in the analyses can alter the item's nutritional composition. Research by Schmidt et al. (1999) and Schmidt (2002) involved the analyses of many commercially available, whole produce items for concentrations of structural fiber (neutral detergent fiber, acid detergent fiber, and lignin), crude protein, moisture, fat, pectin, fructan and free sugars.

Glucose, fructose, and sucrose concentrations were determined in the free sugar fraction. Vegetables and leafy green vegetables had the highest average concentration of structural fiber at 19%; they also had the lowest level of free sugars at 26% and 18%, respectively. Fruits averaged 13% structural fiber and 41% free sugars. The average structural fiber concentrations for all of the produce items are comparable to the lowest fiber concentrations of foods consumed by free-ranging orangutans. Fruits eaten by free-ranging orangutans are much higher in structural fiber, while fruits cultivated for humans are typically lower in fiber and higher in sugar to satisfy human tastes. It is impossible to meet the average fiber levels consumed by wild orangutans using only commercially available produce. When formulating diets, it is important to remember that animals require specific nutrients, not specific dietary items.

When possible, offer produce items with the peels and cores intact. Removing these items may also remove potential sources of structural fiber. If in doubt concerning what is safe for an animal, consult with your institution's nutritionist and/or veterinarian.

Cooked produce items, especially those high in starch (e.g. yams, white potatoes), contain more readily available sugars than raw produce (Pretorius, 1997). Cooked items should be used sparingly when feeding orangutans or other captive animals to minimize the intake of easily digested sugars. Consistently offering foods high in easily digested sugars and starch may increase an individual's chance of becoming overweight and even obese, conditions that may potentially contribute to secondary health issues later in life (see DIETARY HEALTH ISSUES).

If dried produce items are used, they should not be offered in equivalent weights as fresh fruits. For example, if the diet calls for 100 grams of fresh bananas, you should not offer the animal 100 grams of dried banana chips instead. This would be equivalent to offering the orangutan approximately 5 servings of fresh bananas (based on the average dry matter composition of bananas).

While nuts and seeds (e.g., sunflower seeds) are not typically thought of as "produce" they do originate from plants and are often included in captive primate diets. Nuts and seeds are often scattered in an animal's enclosure to provide the animal with a substance that encourages foraging. Both of these foods should be used in moderation, especially with overweight or obese individuals, due to their extremely high fat content. Gram per gram, fat contains twice as many calories as protein or carbohydrates.

While produce can contribute vitamins, minerals, fats, and protein to an orangutan's diet, it should not be relied upon to supply these nutrients to the animal. In other words, the orangutan's diet should be based on the nutritionally complete feeds (e.g., primate biscuits or canned primate diet) with a variety of produce added to complement the diet. [One exception to this would be adding a supplemental source of vitamin C when canned primate diets are used as the base diet. Many produce items contain significant concentrations of vitamin C, including broccoli, kale, kiwi, citrus, onions and peppers to name a few.] A multitude of produce items are available through vendors and every opportunity should be taken to offer the orangutans an assortment of items. Produce rotation schedules help ensure variety in the diet, make the diet more behaviorally enriching, and ensure that individuals do not repeatedly receive high sugar/starch produce items.

The way food is presented to the animals can also be enriching. Cutting produce into different sized/shaped pieces or leaving it whole allows different modes of presentation. The small pieces can be scattered or hidden in other substrates (e.g., hay, grassy areas), while the whole pieces can be placed in areas that may be more difficult to access and which would not be good for scattered items (e.g., tree forks, behind rocks). If infants are present, consider the size of the foods so they do not create a choking hazard.

II. Nutritionally Complete Feeds

The term "nutritionally complete" means that the product contains the correct proportions of the recommended vitamins, minerals, protein, and fats for the species for which it was formulated. There are currently two different forms of nutritionally complete primate foods: extruded biscuits and canned diets. Primate biscuits, which are manufactured by multiple companies, come in a variety of shapes, sizes, and colors. Many of the biscuits are created using the "extrusion" process. Through this process, starch must be included in the formula at a minimum concentration for the particle to retain its shape. Unfortunately, this requirement for starch limits the amount of fiber that can be included in the biscuit. The maximum amount of structural fiber associated with extruded biscuits is 30% neutral detergent fiber, often referred to simply as "NDF" on the package or feed information sheet. Canned foods, although typically referred to as "nutritionally complete", need to be offered with an additional source of vitamin C. Canned diets do not offer the tooth cleaning abrasion that biscuits provide and are often more costly.

Primate feeds formulated for New World primates should be avoided when feeding orangutans. These formulas contain significantly higher concentrations of vitamin D, which are higher than required by Old World primate species and can be harmful to the orangutan.

When selecting nutritionally complete feeds for orangutans, it is important to select a product that they will reliably consume, just offering it to them is not enough. Trying a variety of biscuits to see which ones they prefer may be warranted if they are not consuming the currently offered biscuits well. Another consideration to keep biscuit consumption optimal may be to rotate the types of biscuits offered throughout the week, helping to keep variety in the diet. It is important to remember products from different manufacturers may contain different proportions of vitamins, minerals, fats, protein, and fiber, even though they may use a similar name such as "leafeater". Proportions offered may need to be adjusted if using different brands of biscuits to ensure nutritional needs are being met.

III. Vitamin & Mineral Supplementation

Nutritionally complete feeds contain the necessary and correct proportions of vitamins and minerals for primates. Adding supplemental vitamins and minerals prophylactically can actually harm an animal if the individual is consuming a nutritionally balanced diet. Certain fat-soluble vitamins (e.g., vitamins A, D, E) and minerals have the ability to be stored by the body and can reach toxic levels. Supplementation of vitamins and minerals should only occur if there is a known nutrient deficiency. However, nursing infants, who do not have access to natural, unfiltered sunlight, may benefit from a supplemental dose of vitamin D to enhance appropriate bone growth and development.

IV. Animal Products

Some institutions use dairy products (e.g., yogurt, milk) as a vehicle for medication or as a food enrichment item. Orangutans do not have a dietary need for dairy products and may experience symptoms associated with lactose intolerance, including bloating and diarrhea. The recommendation is to remove dairy products from the diets of orangutans. However, due to management constraints, this may not be easily accomplished. If dairy products cannot be removed from the diets, it is recommended that no-fat or low-fat products be used and only in moderate quantities.

Free-ranging orangutans are typically thought of as frugivores, but have been seen to eat animal matter (Sugardjito and Nurhuda, 1981; Utami and van Hooff, 1997). If captive orangutans are consuming their nutritionally complete feeds, they will be meeting their dietary requirements for protein. Feeding captive orangutans meat products to fulfill their protein needs is not necessary, nor is it encouraged (Dierenfeld, 1990, 1997).

V. Infant Orangutans

Please refer to the Hand-Rearing section of this husbandry manual for information on hand-rearing infant orangutans. Additional information can be obtained from "Handrearing Great Apes" chapter written by Crissey in The Infant Diet Notebook (1995).

VI. Feeding Guidelines

Giving specific recommendations on the amount of food to offer an individual is not practical due to differences in life stages (e.g., growth, lactation, and pregnancy), body condition, activity levels, and acceptance of the nutritionally complete feeds.

Diet calculations can be confusing when converting from an "as fed" to "dry matter" basis and vice versa. The following guidelines will help calculate the amount of food to offer an individual based on the knowledge that primates will consume 1 – 2% of their body weight in dry matter. Remember that these are ***only guidelines*** and dietary adjustments may be necessary to adapt diets for individuals with specific needs (e.g., weight loss, lactation, 3$^{rd}$ term pregnancy, larger body frame, etc).

Calculating Diet Amounts Based on an Individual's Body Weight

1. Obtain an individual's current weight (kg or lbs).

2. Multiply the individual's current weight by 0.0083 to obtain the amount of **primate biscuits** the individual should receive. The number 0.0083 is derived from an estimated dry matter consumption of 1.5% of body weight. Half of that dry matter amount should be offered as primate biscuits, which is why it is divided by 2. The average dry matter concentration of biscuits is approximately 90%, explaining the division by 0.9. Equation derivation: 0.0083 = [(0.015 / 2) / 0.9]

3. Multiply the individual's current weight by 0.05 to obtain the amount of **produce** the individual should receive. The number 0.05 is derived from an estimated dry matter consumption of 1.5% of body weight. Half of that dry matter amount will be offered as produce, which is why it is divided by 2. For produce, the average dry matter content (erring on the high side) is 15% (Schmidt, 2002), explaining the division by 0.15. Equation derivation: 0.05 = [(0.015 / 2) / 0.15]

4. Using the total amount of produce from #3, proportion it accordingly:
    a. 40 % leafy green vegetables
    b. 40 % vegetables
    c. 20 % fruit

5. Monitor the individual's intake. If too much food is being left or if the animal is able to be selective in what they eat, reduce the diet proportionally across <u>all</u> categories. If the animal is eating all of the offered food (including all of the primate biscuits) and does not have a weight problem, slowly increase the diet proportionally across <u>all</u> categories until a little food is left over. When making changes, it is very important to increase or decrease the diets across all categories to keep nutrient concentrations in the correct proportions.

<u>Example</u>:

1. 80 kg female orangutan
2. 80 kg x 0.0083 = .66 kg of primate biscuits
3. 80 kg x 0.05 = 4 kg of produce
4. 4 kg of produce divided:
    a. 4 kg x 0.40 = 1.6 kg leafy green vegetables
    b. 4 kg x 0.40 = 1.6 kg vegetables
    c. 4 kg x 0.20 = 0.8 kg fruit

Depending on which primate biscuits are fed, the example diet will provide 2.83 - 3.44 kcal ME (Metabolizable Energy)/g on a dry matter basis or 0.64 - 0.73 kcal ME/g on an as fed basis. The energy content of the total diet will be approximately 2,993 - 3,416 kcal ME, again depending on which primate biscuits are offered.

AGAIN, THESE ARE TO BE USED ***ONLY AS GUIDELINES***. INDIVIDUALS, ESPECIALLY THOSE WITH HEALTH CONCERNS SUCH AS OBESITY OR LACTATION, MAY NEED MORE OR LESS FOOD DEPENDING ON INTAKE AND ACTIVITY. IT IS STRONGLY ADVISED FOR EVERY INSTITUTION TO HAVE THEIR DIETS FORMULATED AND REVIEWED BY A PROFESSIONALLY TRAINED NUTRITIONIST.

Examples of currently used orangutan diets and their nutritional analyses are located in Appendices A and B, respectively.

## PHYSIOLOGICAL STATUS

I. Growing Individuals

There has been no specific research done on nutritional needs of reproduction or growth in orangutans. Growing primates have an increased requirement for energy when compared to the requirements of an adult for maintenance (Kerr, 1972; Nicolosi and Hunt, 1979; King, 1978; Ausman, 1995).

During growth it is also important for them to receive vitamin D, calcium, and phosphorus in appropriate concentrations to meet the demands of bone formation and development. Vitamin D is necessary for the absorption of calcium. Of the primates that have been studied, primate milk does not contain sufficient concentrations of vitamin D, which can make the nursing infant susceptible to metabolic bone disease (NRC, 2003). Fortunately, vitamin D can also be synthesized in the skin when individuals are exposed to natural, unfiltered sunlight during the spring, summer, and fall months in the Northern Hemisphere.

II. Reproducing Females

The specific nutritional needs of reproducing female orangutans are not known. Extrapolating from other primate research, including information obtained on humans, no additional energy requirements are needed during the first trimester of pregnancy (NRC, 2003). However, during the second and third trimesters, it is recommended to increase the energy content of the diet by 300-350 $kcal \cdot day^{-1}$ to meet metabolic energy needs for the developing fetal, placental and maternal tissues (FAO/WHO/UNU, 1985; NRC, 1989; Williams, 1997).

Protein requirements of pregnant females have also not been determined. However, when maternal intakes of protein were at least 1 $g \cdot BW_{kg}^{-1} \cdot day^{-1}$ the infants were of normal birth weight (Riopelle et al., 1975; Riopelle and Favret, 1977).

III. Lactating Females

Lactation is the most energy demanding physiological state for an individual. Recommendations for humans by the FAO/WHO/UNU Expert Consultation (1985) are for an additional energy allowance of 500 $kcal \cdot day^{-1}$ of metabolizable energy for the first six months of lactation. These recommendations may not be appropriate for orangutans. Energy needs can be assessed by obtaining frequent weights on individuals to detect changes in weight. If an individual gained excess weight during gestation, it may be best to let that individual use those energy reserves to meet her increased energy needs during lactation. During this time it is also imperative that the lactating females receive adequate concentrations of vitamin D, calcium, and phosphorus for milk production and her body maintenance needs. These needs are typically met through primate biscuits which are formulated in the appropriate vitamin and mineral concentrations.

<u>IV. Geriatric Needs</u>
As animals age, their energy requirements generally decrease (NRC, 2003). Animals also tend to be more sedentary (if that's possible for an orangutan) and thus burn fewer calories. For these reasons it is important to closely monitor the individual's intake to ensure they are consuming a nutritionally balanced diet, yet are not consuming too many calories to become obese.

## DIETARY HEALTH ISSUES

<u>I. Obesity</u>
Excessive weight gain can influence a multitude of health-related problems. These include increased occurrences of mortality, high blood pressure, heart disease, cancer, degenerative arthritis, respiratory problems, diabetes, and liver disease (fatty liver) (Hensrud, 2002). In the wild, on average, male orangutans weighed 86.3 kg while females weighed 38.7 kg (Markham and Groves, 1990). Loomis (2003) reported weight ranges for males as 75-189 kg and 40-81 kg for females; these weights include those of captive individuals. The lower weights from Loomis correspond to the free-ranging orangutan weights reported by Markham and Groves (1990). However, the upper-end weights are double that of the free-ranging weights were most likely obtained from extremely obese, captive animals. In humans, obesity is defined as having reached a weight 20% (males) to 25% (females) above your maximum target weight. Diet and increased activity levels are the two most critical components to maintaining animals at appropriate weights. It is recommended that frequent weights be obtained on individuals to prevent undetected, rapid weight changes.

<u>II.  Diabetes</u>
Many captive, adult orangutans have been classified as overweight and even obese (Jones, 1982). As mentioned above, obesity is often associated with an increased risk of diabetes. There have been numerous, anecdotal claims that captive orangutans are prone to encountering problems with diabetes mellitus. Wells et al. (1990) conducted a medical management survey on orangutans housed in North American zoos. They reported that while endocrine system disorders were rare, the most common endocrine disorder reported was diabetes. Six animals out of 249 individuals on whom responses were received, were diagnosed as diabetic. The full extent to which diabetes is affecting the captive population has not yet been

documented in the literature. According to the international studbook as of March 2004, ten captive individuals, who are now deceased, are on record as having been diagnosed with diabetes (Perkins, Orangutan SSP Coordinator, 2004, personal communication). Out of these ten individuals, two pairs may be potential half-siblings, meaning they may have had a genetic predisposition to developing diabetes. There is only one currently living individual in the adult ($10^+$ years), international population (n = 715) that is known to be diabetic.

Glucose tolerance tests measure how quickly an individual's body can absorb glucose and move it into the cells. This test is used to determine if an individual may be at risk for developing diabetes. Gresl, et al. (2000) conducted glucose tolerance tests on 30 captive orangutans. Their results showed that the captive orangutans tested had a propensity for developing diabetes.

Type II diabetes, also known as non-insulin dependent diabetes mellitus, is the type that typically develops in overweight adults. This form of diabetes is believed to develop from a decreased cellular response to insulin, the hormone necessary for moving glucose from the bloodstream into the cells. With a low glucose transfer rate into the cells and the continued absorption of additional glucose from the recently ingested diet, the body senses an increase in circulating glucose concentrations and tries to compensate by producing more insulin. It is at this stage that the subject is referred to as borderline diabetic, a phase which is impossible to visually diagnose. After repeated episodes, it is only a matter of time before the pancreas can no longer maintain this elevated level of insulin production and begins to shut down. At this stage, without dietary modifications, the individual progresses to the overt stage of diabetes when he begins to experience severe hyperglycemia, weight loss, and ketosis. Walzer (1999) stated that becoming an overt diabetic could be initiated by a stage of glucose toxicity and the death of the insulin-secreting pancreatic cells. Knowing the etiology of this disease makes it imperative that we begin to rethink how we feed captive primates, especially those animals that tend to be sedentary.

## FUTURE RESEARCH NEEDS

There is still much to learn about the nutritional needs of orangutans. Identifying their basic nutrient concentration requirements for vitamins, minerals, fats, and protein will help in the formulation of more appropriate diets for the captive orangutan population. Further research on their ability to utilize fiber as a source of energy, their tendency to become obese, and their propensity for developing diabetes is also meaningful.

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Appendix A Orangutan Zoo Diets

| | San Diego Zoo | San Diego Zoo | Brookfield Zoo | Brookfield Zoo | Brookfield Zoo | Brookfield Zoo | Brookfield Zoo | Brookfield Zoo | Brookfield Zoo | Brookfield Zoo | Saint Louis Zoo | Saint Louis Zoo | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Manufactured Foods | Adult Male (28 yr old) | Adult Female (27 yr old) | Growing Male (2 yr old) | Subadult Male (9 yr old) | Subadult Male (13 yr old) | Adult Male (22 & 26 yr olds) | Growing Female (6 yr old) | Adult, Wt Loss Female (23 yr old) | Adult, Wt Loss Female (24 yr old) | Adult, Wt Loss Female (43 yr old) | Subadult Male (8 yr old) | Adult Male (42 yr old) | Adult Fema (35 yr |
| Marion Leaf Eater (gorilla size) | 400g | 260g | | | | | | | | | 150g | 300g | 150g |
| PMI Labdiet 5038 Monkey Diet | | | | 317g | 191g | 194g | 118g | 54.5g | 197g | 173g | | | |
| PMI Labdiet 5045 High Protein | | | 48.5g | | 191g | 194g | 118g | 54.5g | | | | | |
| HMS Hi-Fiber Primate Diet | | | | | | | | | | | 150g | 300g | 150g |
| **Fruits** | | | | | | | | | | | | | |
| apple | 583g | 690g | | | | | | | | | 200g | 300g | 200g |
| banana (with peel) | 408g | 489g | | | | | | | | | 200g | 300g | 200g |
| grapes | 60g | 60g | | | | | | | | | | | |
| orange (with peel) | 355g | 426g | | | | | | | | | | | |
| citrus | | | | | | | | | | | 100g | 200g | 100g |
| fruit rotation[2] | | | 24g | 160g | 191g | 306g | 118g | 65g | 79g | 69g | | | |
| **Vegetables** | | | | | | | | | | | | | |
| broccoli | 205g | 103g | | | | | | | | | | | |
| cabbage | 182g | 182g | | | | | | | | | | | |
| carrot | 105g | 105g | | | | | | | | | 200g | 300g | 200g |
| kale | 30g | 30g | | | | | | | | | | | |
| lettuce, romaine | 128g | 128g | | | | | | | | | | | |
| sweetpotato/yam | 165g | 165g | | | | | | | | | 200g | 300g | 200g |
| | | | | | | | | | | | 400g | 200g | 400g |
| mixed greens vegetable rotation[3] | | | 59g | 386g | 463g | 346g | 287g | 65g | 79g | 69g | | | |
| starch rotation[4] | | | 24g | 160g | 191g | 184g | 118g | 65g | 79g | 69g | | | |
| leafy green vegetable rotation[5] | | | 191g | 1249g | 1499g | 2855g | 928g | 1849g | 2197g | 1917g | | | |

[1]animal with larger body frame

[2]fruit rotation includes: bananas, grapes, apples, oranges, pears , seasonal fruits

[3]vegetable rotation includes: green beans, cucumbers, steamed and raw carrots, green peppers, tomatoes

[4]starch rotation based on sweet potato

[5]leafy green vegetable rotation includes: escarole, iceberg and romaine lettuces, kale, parsley, celery

Appendix B Orangutan Zoo Diet Analyses

| NUTRIENTS[1] | NRC Requirements | San Diego Zoo Adult Male (28 yr) | San Diego Zoo Adult Female (27 yr) | Brookfield Zoo Growing Male (2 yr) | Brookfield Zoo Subadult Male (9 yr ) | Brookfield Zoo Subadult Male (13 yr) | Brookfield Zoo Adult Male (22 yr) | Brookfield Zoo Growing Female (6 yr) | Brookfield Zoo Adult, Wt Loss Female (23 yr) | Brookfield Zoo Adult, Wt Loss Female (24 yr) | Brookfield Zoo Adult, Wt Loss Female (43 yr) | Saint Louis Zoo Subadult Male (8 yr) | Saint Louis Zoo Adult Male (42 yr ) | Saint Louis Zoo Adult Female (35 yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kcals/g AS FED | | 0.7 | 0.7 | 0.8 | 0.8 | 0.8 | 0.6 | 0.8 | 0.4 | 0.5 | 0.5 | 0.8 | 0.9 | 0.8 |
| Dry Matter (%) | | 28.3 | 24.9 | 20.4 | 20.4 | 20.4 | 15.9 | 20.4 | 12.0 | 13.3 | 13.3 | 30.2 | 32.4 | 30.2 |
| Crude Protein (%) | 15 - 22 | 16.4 | 13.3 | 22.3 | 15.7 | 19.0 | 18.9 | 19.0 | 19.7 | 17.3 | 17.3 | 17.97 | 19.3 | 18.0 |
| Crude Fat (%) | - | 3.7 | 3.2 | 3.9 | 4.5 | 4.2 | 4.1 | 4.2 | 4.0 | 4.4 | 4.4 | 3.7 | 3.9 | 3.7 |
| Crude Fiber (%) | - | 8.3 | 6.5 | 5.1 | 4.4 | 4.7 | 4.9 | 4.7 | 5.5 | 5.1 | 5.1 | 7.9 | 8.5 | 7.9 |
| Vitamin A (IU/g) | 8 | 59 | 63 | 176 | 179 | 177 | 177 | 177 | 195 | 182 | 182 | 155 | 136 | 155 |
| Vitamin $D_3$ (IU/g) | 2.5 | 1.05 | 0.8 | 4.5 | 4.5 | 4.5 | 3.9 | 4.5 | 3.3 | 3.7 | 3.7 | 1.7 | 1.9 | 1.7 |
| Vitamin E (mg/kg) | 100 | 147 | 112 | 51 | 51 | 51 | 53 | 51 | 57 | 57 | 57 | 130 | 141 | 130 |
| Thiamin (mg/kg) | 3 | 5.1 | 4.6 | 15.1 | 9.1 | 12.1 | 11.9 | 12.1 | 12.1 | 10.0 | 10.0 | 4.9 | 5.0 | 4.9 |
| Riboflavin (mg/kg) | 4 | 5.5 | 4.8 | 8.8 | 8.7 | 8.8 | 8.9 | 8.8 | 9.5 | 9.5 | 9.5 | 6.5 | 6.9 | 6.5 |
| Niacin (mg/kg) | 25 | 39 | 34 | 97 | 101 | 99 | 93 | 99 | 90 | 96 | 96 | 43 | 45 | 43 |
| Pyridoxine (mg/kg) | 4 | 8.5 | 9.2 | 12.1 | 12.7 | 12.4 | 12.1 | 12.4 | 11.9 | 12.4 | 12.4 | 7.2 | 6.6 | 7.2 |
| Folacin (mg/kg) | 4 | 1.3 | 1.3 | 9.5 | 7.4 | 8.5 | 9.1 | 8.5 | 10.4 | 9.5 | 9.5 | 1.1 | 1.1 | 1.1 |
| Biotin (mg/kg) | 0.2 | 0.1 | 0.1 | 0.2 | 0.1 | 0.2 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 0.09 | 0.1 | 0.1 |
| Vitamin B12 (mg/kg) | 0.03 | 0.01 | 0.01 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 |
| Pantothenic Acid (mg/kg) | 12 | 18 | 15 | 48 | 55 | 515 | 52 | 51 | 56 | 59 | 59 | 19 | 20 | 19 |
| Choline (mg/kg) | 750 | | | 1238 | 921 | 1079 | 937 | 1079 | 784 | 757 | 757 | 355 | 392 | 355 |
| Vitamin C (mg/kg) | 200 | 1192 | 1192 | 1299 | 1297 | 1298 | 1470 | 1298 | 1682 | 1597 | 1597 | 759 | 755 | 759 |
| Calcium (%) | 0.8 | 0.7 | 0.5 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.7 | 0.8 | 0.7 |
| Phosphorus (%) | 0.6 | 0.5 | 0.4 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Magnesium (%) | 0.08 | 0.2 | 0.1 | 0.2 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.18 | 0.2 | 0.2 |
| Potassium (%) | 0.4 | 1.4 | 1.4 | 1.7 | 1.5 | 1.6 | 2.0 | 1.6 | 2.6 | 2.3 | 2.3 | 1.5 | 1.4 | 1.5 |
| Sodium (%) | 0.2 | 0.2 | 0.1 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.4 | 0.4 | 0.2 | 0.2 | 0.2 |
| Iron (mg/kg) | 100 | 97 | 77 | 298 | 153 | 225 | 212 | 225 | 201 | 154 | 154 | 161 | 175 | 161 |
| Zinc (mg/kg) | 100 | 70 | 53 | 120 | 90 | 105 | 99 | 105 | 96 | 89 | 89 | 77 | 84 | 77 |
| Copper (mg/kg) | 20 | 18 | 14 | 20 | 12 | 16 | 15 | 16 | 15 | 12 | 12 | 15 | 16 | 15 |
| Manganese (mg/kg) | 20 | 40 | 31 | 113 | 85 | 99 | 92 | 99 | 88 | 82 | 82 | 39 | 42 | 39 |
| Iodine (mg/kg) | 0.35 | | | 0.4 | 0.6 | 0.5 | 0.5 | 0.5 | 0.4 | 0.5 | 0.5 | 0.19 | 0.2 | 0.2 |
| Selenium (mg/kg) | 0.3 | 0.2 | 0.2 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.21 | 0.2 | 0.2 |

[1]some dietary components may have missing nutrient data which may be reflected as an untrue dietary deficiency