Nutrient Composition Of Selected Tropical Browse Species Fed To Zoo Animals In Hawaii

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The objective of this project was to determine the nutrient composition of selected browse species available and fed at the Honolulu Zoo in Hawaii, and to facilitate their use in more balanced zoo rations there and at other tropically located zoos. Samples of 26 different materials including; apple banana, areca palm, hula bamboo, golden bamboo, cape honeysuckle, coral hibiscus, dwarf elephant grass, ohai ali'i, edible hibiscus, elephant grass, hau, ivy gourd, loulu, black mulberry, opiuma, papyrus, pink hibiscus, pothos, sugarcane, thornless kiawe, and viu were obtained and various portions analyzed for nutrient composition and energy density. Feedstuffs were grouped and categorized based on crude protein content: < 9.0%, > 9.0% <14.0%, or > 14.0%. Nutrient compositions varied significantly ($P < 0.05$) between plant species and plant portion/component sampled.

Key words: chemical composition; fresh forages; zoo foods; tropical browse plants

INTRODUCTION

Zoos have the potential to utilize a wide variety of locally grown browses as supplemental feeds for their captive animals. These browse items are beneficial in that they offer occupational value through stimulating naturalistic feeding behaviors [Gould and Bres, 1986]. Occupied versus bored animals also increase the appearance of animal well being to exhibit viewers. Numerous papers have been published on nutrient compositions of browse items as possible livestock feed alternatives, as well as for their use with zoo animals [Carpenter and Niino-DuPonte, 1981; Dierenfeld et al., 1995; Graffam et al., 1997]. In some cases these results have been incorporated into national databases. Nutrient compositions for tropical browse plants, however, are less abundant in feed databases, thus the need for such tropical browse nutrient analysis is great.

This project was undertaken to determine the nutrient composition of browse species both available and fed to zoo animals in the tropical/sub-tropical climate of Hawaii. Nutrient values determined for this project ranged from 7.5 to 53.9% for DM, 2.3 to 27.9% for CP, 15.2 to 46.3% for ADF, and 4336.3 kcal GE/kg to 4725.7 kcal GE/kg. It is hoped that the data obtained during this project will be beneficial to zoos located in other tropical and subtropical areas that wish to incorporate local materials into their feeding plans too. Because browse items have the potential to provide unidentified growth factors and enrichment to browsers, such as the black rhinoceros, *Diceros bicornis,* animal health can potentially be increased while simultaneously lowering feed costs and thus increasing zoo profit [Graffam, 1997].

MATERIALS AND METHODS

Browse samples were collected from the Honolulu Zoo on three separate occasions, each spaced 4 to 6 wks apart. Browse species were identified and parts to be collected were determined through individual zookeeper assessment of what the animals normally eat. Parts collected for each species are described in Table 1. Plant portions collected between samplings varied only slightly, with the exception of the opiuma, in which great variation between samplings was present. Random sampling periods were intentional, as it was the purpose of this project to assess changes do to variations in normal plant growth, and the variations in keeper harvesting/feeding portions. The opiuma was an extreme example of this variation, since what is collected varies greatly between and within keepers. The samplings for this browse item ranged from 30 cm mature branches, which would be consumed entirely, to 3 m moderately mature branches, for which any stem over 1.2 cm diameter would be rejected by the animal, as it stripped and ate only the bark and leaves. Other variations between samplings within browse species included the inconsistent presence of seeds, fruit, and/or flowers. Browse species were occasionally broken into individual collections when possible, as with dry versus green areca palm leaves, or when deemed necessary because of sheer quantity or what is actually being fed, as was the case with apple banana tree leaves versus stalks.

For two browse species, coral and pink hibiscus, separate collections were made because the amount consumed versus weighback stem varied depending on the animal species. Other distinct collections were made within a browse species when specific ages of the plant material were commonly fed separately, such as was the case with mature and immature *Pothos* spp. leaves.

Representative samples of the various species of browse plants previously identified were collected and dried in a forced-draft oven at 55 to 60° C and then ground through a 1 mm stainless steel screen in a Wiley Mill. Samples were analyzed for dry matter (DM), ether extract (EE), and ash following procedures outlined in the A.O.A.C. [1975]. Gross energy was determined using the formula from Pond et al. [1995] and also by Parr bomb calorimetry, so that comparisons could be made between the two GE methods. Crude protein (CP) was determined using an automated combustion method according to Horneck and Miller [1998]. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined using procedures outlined by Ankom (Ankom Technology Corp. Fairport, New York). The nonfiber carbohydrate (NFC) component, which is an estimate of the starch and soluble sugar content of feedstuffs, was calculated by difference. The nutrient composition of alfalfa and timothy hay is presented for comparison [NRC, 1989]. Significant differences between feeds within nutrient categories were analyzed with ANOVA using the PROC GLM procedures in SAS (SAS Institute Inc., Vol. 8, Cary, NC).

RESULTS

Nutrient compositions varied significantly within each nutrient category between browse species ($P < 0.05$). All species were categorized according to % CP and were ranked according to this variable within categories (Tables 2 to4). Gross energy values are shown in a separate table (Table 5) so comparisons can be made between calculated and bomb calorimetry GE values. Dry matter had the greatest range of values, as would be expected, ranging from 7.5% in apple banana stalks to 53.9% in dry areca palm leaves. Crude protein values ranged from 2.3% in green areca leaves to 27.9% in ivy gourd. Ash values ranged from 5.9% in thornless kiawe to 17.8% in Ivy gourd. Ether extract, which represents the fat content of a feed, among other smaller plant constituents such as fat-soluble vitamins, ranged from 1.3% in golden bamboo to 8.1% in mature *Pothos* spp. leaves. Neutral detergent fiber, which represents the hemicellulose, cellulose, and lignin fractions of a feed, ranged from 26.3% in coral hibiscus sample #1 to 68.3% in hula bamboo. For ADF, which primarily represents the cellulose and lignin fractions of a feed, the range was from 15.2% in coral hibiscus sample #1 to 46.3% in thornless kiawe. Nonfiber carbohydrate values showed a large range, with calculations ranging from 4.1% in hula bamboo to 39.2% in ohai ali`i. Calculated and bomb calorimetry GE values ranged from 3655.0 kcal/kg and 3530.6 kcal/kg, respectively, in apple banana stalk to 4336.3 kcal/kg and 4725.7 kcal/kg, respectively, in ohia ali`i. Although calculated and bomb calorimetry GE values differed (calculated values generally lower), they showed the same general trends (Fig. 1). Analyzed GE values ranged from 3530.6 for apple banana stalk to 4725.7 for ohia ali'i..

Pink hibiscus samples #1 and #2 were not significantly different for any nutrient variable, although CP and EE values were slightly lower in sample #1, with NDF and ADF values being slighter higher for this sample. Hula and Golden bamboo were also not significantly different from one another for any nutrient variable. Coral hibiscus samplings, however, varied significantly for all nutrient variables. Immature and mature *Pothos* spp. leaves were significantly different only in CP, 18.8 and 12.5%, respectively; EE, 4.4 and 8.1%, respectively; and ADF, 26.9 and 31.2%, respectively. Dry versus green areca palm leaves varied significantly in DM, CP, ash, NFC, and calculated GE values, but not in EE, NDF, or ADF. Apple banana leaves and stalks varied significantly in all nutrient variables. Dwarf and regular elephant grass species had no significant difference between DM, CP, ash, EE, NDF, or NFC, but did vary significantly in ADF and GE.

DISCUSSION

Apple banana leaves were expected to be the lowest, and dry areca palm leaves the highest in DM due to the very wet and dry nature of these two materials. Such differences are very important to consider when feeding because they greatly affect intake and because very moist feeds may not keep as well and would need to be fed out rather quickly. Another consideration is the dilution of nutrients by the water contained in very moist feeds, and thus the large amount of them required to supply a given amount of nutrients. The high CP values received for ivy gourd were not expected, but are not surprising given the young growth and lush nature of this vining plant. Likewise, given the dry, leached appearance of the dry areca palm leaves, such a low CP content was no surprise. A thick waxy coating present on the mature *Pothos* spp. leaves probably accounted for this plant material having the highest EE value. The feed with the highest ADF value was no surprise, since this browse material came from a tree with very small pinnate leaves, therefore giving it a very small leaf to stem ratio, and thus a high nonsoluble fiber content.

Significant differences were expected between coral hibiscus samplings because the amount of leaf relative to stem was considerably higher for the first sampling than for the second. Significant differences were not seen or expected between pink hibiscus samplings because the amount of leaf relative to stem was approximately the same between the two collections. The differences seen between the mature and immature *Pothos* spp. leaves were expected because of the difference in maturity between the two, the typical scenario being more mature plant materials having higher cellulose and lower protein concentrations, with younger growth being the opposite. The significant difference between the apple banana stalk and leaf collections can also be explained by different nutrient partitioning between different growth regions. Due to leaching and bleaching, it is no surprise the DM, CP, ash, NFC, and thus GE values were seen between the dry and green areca palm leaves, with no difference in the less water soluble fractions of EE, NDF, and ADF. Calculated GE values tended to underestimate the energy concentration of certain feedstuffs.

CONCLUSIONS

1. Extreme variation was seen in nutrient content, showing the importance of knowing types/proportions of feed items in maintaining balanced diets, as well as knowing which types and amounts of feedstuffs to substitute.
2. Data such as these are important for worldwide reference due to the fact that lots of zoos and wild animal facilities do not have the money to pay for analysis to be done on their own locally grown browse items.

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TABLE 1. Collected browse species and description of plant portions analyzed

Common Name	Scientific Name	Plant Portion
Apple banana	*Musa paradisiaca spp. Sapientum*	Stalk
Apple banana	*Musa paradisiaca spp. Sapientum*	Leaves
Areca palm	*Chrysalidocarpus lutescens*	dry leaves w/sheath
Areca palm	*Chrysalidocarpus lutescens*	green leaves w/o sheath
Black mulberry	*Morus nigra*	leaves and approx 30 cm of stem, some immature fruit
Cape honeysuckle	*Tecoma capensis*	leaves and approx 30 cm of stem, flowers, some seed pods
Coral hibiscus #1	*Hibiscus schizopetalus*	leaves and immature stem tips, some flowers
Coral hibiscus #2	*Hibiscus schizopetalus*	approx 1 m of stem with leaves
Dwarf elephant grass	*Pennisetum purpureum cv. Mott*	all aerial
Edible hibiscus	*Abelmoschus manihot*	approx 30 cm of stem with leaves
Elephant grass, Napier grass	*Pennisetum purpureum*	all aerial
Golden bamboo	*Bambusa vulgaris var. Vittata*	approx 30 cm of stem with leaves
Hau	*Hibiscus tiliaceus*	approx 120 - 180 cm of stem with leaves
Hula bamboo	*Schizostachys Glaucifolium*	approx 30 cm of stem with leaves
Ivy gourd	*Coccinia grandis*	all aerial, flowers and fruit present
Loulu	*Pritchardia sp. (aff. P.ramota)*	Leaves
Ohai Ali`I	*Caesalpinia pulcherrima*	approx 30 - 60 cm of stem with leaves, flowers, and seed pods, branches rinsed of some ants
Opiuma	*Pithecellobium dulce*	leaves and bark from approx 30 cm – 3 m of immature stem, stem > 1.2 cm diameter discarded
Papyrus, Egyptian paper plant	*Cyperus papyrus*	flower head
Pink hibiscus #1	*Hibiscus cameronii*	leaves and immature stem tips < 30 cm, some flowers

TABLE 1 (cont'd). Collected browse species and description of plant portions analyzed

Common Name	Scientific Name	Plant Portion
Pink hibiscus #2	*Hibiscus cameronii*	leaves and immature stem tips < 15 cm, some flowers
Pothos, immature	*Epipremnum pinnatum - aureum*	immature leaves
Pothos, mature	*Epipremnum pinnatum - aureum*	mature leaves
Sugarcane, Ko	*Saccharum officinarum*	all aerial
Thornless Kiawe	*Prosopis pallida*	approx 1 m of stem with leaves
Viu, Masai, Niu Sawa	*Prichardia thurstonii*	Leaves

TABLE 2. Nutrient composition of feeds with crude protein content >14.0% ranked in descending crude protein content (all nutrient analyses except DM are expressed on a dry matter basis)[1]

Common Name	DM, %	CP, %	Ash, %	EE, %	NDF, %	ADF, %	NFC, %
A. Feeds with CP content >14.0%							
Ivy gourd	11.0[e]	27.9[a]	17.8[a]	3.1[b]	31.4[c]	19.5[c]	19.9[d]
Opiuma	34.4[a]	20.1[b]	6.4[c]	2.6[b]	49.8[a]	37.5[a]	21.1[c,d]
Pothos, immature	9.5[e]	18.8[b,c]	16.3[a,b]	4.4[a]	36.1[b]	26.9[b]	24.4[c]
Edible hibiscus	14.3[d,e]	17.9[b,c,d]	15.0[b]	4.3[a]	28.2[c,d]	16.8[c,d]	34.6[a,b]
Black mulberry	27.4[b]	16.2[c,d]	16.6[a,b]	2.4[b]	31.4[c]	19.2[c,d]	33.5[b]
Pink hibiscus #2	25.0[b,c]	15.5[c,d]	17.2[a]	4.4[a]	29.3[c,d]	15.9[c,d]	33.6[b]
Pink hibiscus #1	23.4[b,c]	14.9[d]	17.2[a]	4.1[a]	30.5[c,d]	17.2[c,d]	33.2[b]
Coral hibiscus #1	20.3[c,d]	14.6[d]	16.6[a,b]	4.5[a]	26.3[d]	15.2[d]	38.0[a]

[1]Within each protein category and nutrient variable the feeds with different superscripts [abcde] differ ($P < 0.05$).

TABLE 3. Nutrient composition of feeds with crude protein content >9.0% and <14.0% ranked in descending crude protein content (all nutrient analyses except DM are expressed on a dry matter basis)[1]

Common Name	DM, %	CP, %	Ash, %	EE, %	NDF, %	ADF, %	NFC, %
B. Feeds with CP content 9.0% to 14.0%							
Ohai Ali`i	35.9^{b}	13.9^{a}	6.1^{d}	4.4^{c}	36.4^{e}	25.6^{f}	39.2^{a}
Thornless Kiawe	44.1^{a}	$13.0^{a,b}$	5.9^{d}	$2.0^{e,f}$	59.2^{b}	46.3^{a}	$19.9^{d,e}$
Pothos, mature	12.4^{f}	$12.5^{a,b,c}$	15.6^{a}	8.1^{a}	40.5^{e}	31.2^{e}	23.4^{d}
Golden bamboo	45.2^{a}	$12.0^{a,b,c}$	13.6^{b}	1.3^{f}	67.9^{a}	$35.5^{b,c,d}$	5.2^{g}
Apple banana, leaves	20.4^{e}	$11.9^{a,b,c}$	13.0^{b}	6.4^{b}	$52.0^{c,d}$	30.1^{e}	16.7^{e}
Cape honeysuckle	$29.9^{b,c}$	$11.7^{a,b,c}$	6.6^{d}	$3.5^{c,d}$	$50.6^{c,d}$	$37.5^{b,c}$	$27.6^{b,c}$
Hula bamboo	47.2^{a}	$11.0^{a,b,c}$	$14.7^{a,b}$	$1.9^{e,f}$	68.3^{a}	$36.4^{b,c}$	4.1^{g}
Dwarf elephant grass	$24.1^{d,e}$	$10.3^{b,c}$	$14.3^{a,b}$	3.2^{d}	60.3^{b}	$31.8^{d,e}$	12.0^{f}
Papyrus, Egyptian paper plant	$28.7^{c,d}$	9.5^{c}	10.7^{c}	3.1^{d}	54.0^{c}	25.9^{f}	22.6^{d}
Hau	$32.4^{b,c}$	9.5^{c}	10.9^{c}	$2.8^{d,e}$	53.1^{c}	39.3^{b}	$23.7^{c,d}$
Coral hibiscus #2	$28.1^{c,d}$	9.1^{c}	10.1^{c}	$2.9^{d,e}$	47.7^{d}	$34.0^{c,d,e}$	30.2^{b}

[1]Within each protein category and nutrient variable the feeds with different superscripts ^{abcdefg} differ ($P < 0.05$).

TABLE 4. Nutrient composition of feeds with crude protein content <9.0% ranked in descending crude protein content (all nutrient analyses except DM are expressed on a dry matter basis)[1]

Common Name	DM, %	CP, %	Ash, %	EE, %	NDF, %	ADF, %	NFC, %
C. Feeds with CP < 9.0%							
Elephant grass	18.5^{e}	7.9^{a}	15.3^{a,b}	2.7	63.5^{a}	36.0^{b,c}	10.5^{d}
Areca palm, green	38.7^{b}	6.2^{a,b}	7.6^{d}	2.2	60.4^{a,b,c}	41.0^{a}	23.6^{c}
Loulu	35.4^{b,c}	6.1^{a,b,c}	7.2^{d}	2.4	63.5^{a}	42.8^{a}	20.8^{c}
Viu, Masai, Niu Sawa	31.1^{c,d}	5.5^{a,b,c}	13.7^{b}	2.9	57.5^{b,c}	33.4^{c,d}	20.5^{c}
Apple banana, stalk	7.5^{f}	3.9^{b,c}	16.1^{a}	2.2	42.5^{d}	30.0^{d}	35.3^{a}
Sugarcane	26.7^{d}	3.5^{b,c}	8.0^{d}	2.0	62.0^{a,b}	34.5^{c}	24.5^{b,c}
Areca palm, dry	53.9^{a}	2.3^{c}	10.1^{c}	1.8	57.0^{c}	38.9^{a,b}	28.7^{b}
D. Control comparisons							
Alfalfa hay[7] (IFN 1-00-063)	91.0	18.7	8.5	3.6	46.0	36.9	23.2
Timothy hay[7] (IFN 1-04-883)	88.9	9.7	6.1	2.6	67.0	36.4	14.6

[1]Within each protein category and nutrient variable the feeds with different superscripts ^{abcd} differ ($p<.05$).

TABLE 5. Calculated and bomb calorimetry gross energy values for each feed categorized by crude protein composition (kcal/kg dry matter)[1]

Common Name	Calculated GE		Analyzed GE	
A. Feeds with CP content >14.0%				
Ivy gourd	3990.2	b,c	4048.1	b
Opiuma	4320.4	a	4566.6	a
Pothos, immature	3988.7	b,c	3938.8	b,c
Edible hibiscus	4019.0	b	3898.7	b,c
Black mulberry	3829.7	d	3901.8	b,c
Pink hibiscus 2	3899.3	c,d	3932.6	b,c
Pink hibiscus 1	3878.1	d	3873.5	c
Coral hibiscus 1	3915.9	c,d	3903.7	b,c
B. Feeds with CP content 9.0% to 14.0%				
Ohai Ali'i	4336.3	a	4725.7	a
Thornless Kiawe	4202.4	b,c	4556.7	b
Pothos, mature	4113.1	c,d	4225.7	c,d
Golden bamboo	3832.5	f	4191.4	c,d
Apple banana, leaves	4124.5	c	4349.1	c
Cape honeysuckle	4233.7	b	4617.1	a,b
Hula bamboo	3806.7	f	4145.2	d
Dwarf elephant grass	3878.4	f	3944.7	e
Papyrus, Egyptian paper plant	4013.2	d,e	4320.4	c
Hau	3986.4	e	4269.8	c.d
Coral hibiscus 2	4020.9	d,e	4211.1	c,d
C. Feeds with CP < 9.0%				
Elephant grass	3776.3	b	3846.1	c
Areca palm, green	4040.3	a	4505.6	a
Loulu	4069.0	a	4452.9	a
Viu, Masai, Niu Sawa	3817.1	b	4093.4	b
Apple banana, stalk	3655.0	c	3530.6	d
Sugarcane, Ko	3974.2	a	4180.7	b
Areca palm, dry	3861.9	b	4265.3	b

[1]Within each protein category the feeds with different superscripts [abcdef] differ (*P* < 0.05).

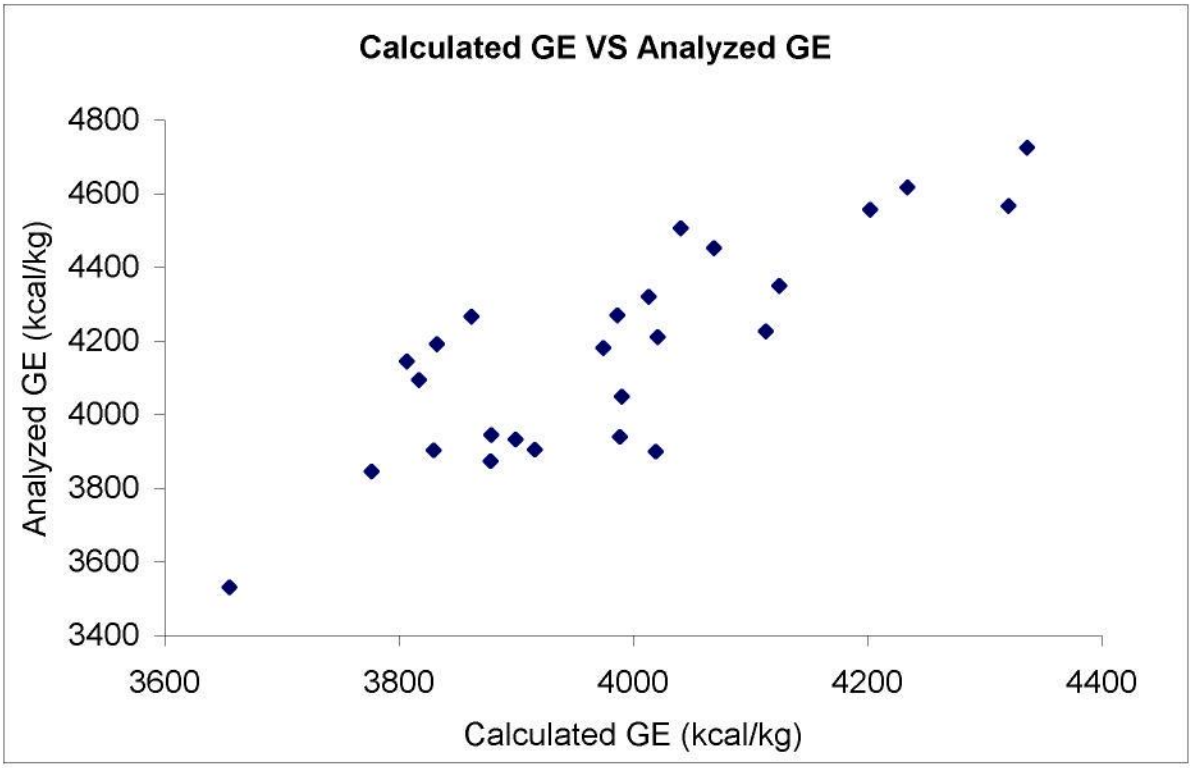

FIG. 1. Scatter plot with correlation between analyzed and calculated GE values (all GE values were taken from Table 5 as kcal/kg).