ESTABLISHMENT OF A ZOOLOGICAL BROWSE DATA BASE

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Abstract
Browse, a significant source of nutrition and enrichment for captive animals, is becoming increasingly important and more widely used. Browse includes leaves and twigs from shrubs, trees and herbaceous plants. It is supplemented to a wide range of captive animals including hoofstock, primates, pachyderms, marsupials and even avian species. Despite the importance of browse as a supplemental feed and enrichment tool, little research has investigated its nutritional value or health implications. A browse data base of nutrient content, species preference and health concerns would be advantageous to the zoo community. This need prompted us in the development of such a data base. Initial horticulture surveys have indicated an interest from institutions in several states agreeing to participate in data collection. The data base will use a standardized protocol to evaluate variability in chemical composition of browse by season, location, propagation technique and the target animal species. One year of data (20 species) has been collected at the Denver Zoological Gardens and sampling is continuing. Several institutions have submitted browse samples to be included. Browse information currently in the literature will be incorporated as possible. A working data base will provide a greater understanding of the utilization of browse and enable zoo staff to make more efficient and informed feeding decisions. It is thought that the data base will ultimately serve to improve the health and quality of captive animal lives throughout zoological facilities.

Key words: browse, forage, data base, horticulture

Introduction

Browse, the shoots, twigs and leaves of trees and herbaceous shrubs, has been an integral part of feeding certain captive wild animals (herbivores especially folivores) for years and its use seems to be increasing. Some of the increased use stems from using browse as an enrichment factor in attempts to decrease boredom. While browse is being fed by many zoos throughout North America and around the world, there is limited knowledge on the nutrient composition and/or potential concerns of specific browse species. Many zoological institutions have browse lists that are used to determine browse supplementation to animals. The scientific literature contains some information on browse, in fact, a recent literature search found just under a 100 published articles related to nutrient content, species preference and browse enrichment. Many of these article are found in relatively unknown journals or conference proceedings that are hard to obtain by most zoo personnel. Much of the information found in these articles is inconsistent, empirical and confounded by season and region, thus making it difficult for zoo keepers and horticulturists to utilize. It would be advantageous to the zoo community to standardize the information that is available on browse, in order for zoo personnel to utilize that data for better animal feeding and care. Thus, the objective of this study is to initiate the development of a zoological browse data base.

Methods

Surveys

In 1991, an investigation into the use of browse for captive wild animals was conducted by the Denver Zoological Garden's (DZG) senior staff horticulturist. That investigation resulted in an initial 1992 survey being sent to zoos throughout the United States and Canada, as a collaborative effort between the Association of Zoological Horticulture (AZH) and Colorado State University (CSU). Of those initial surveys sent out in 1992, twelve were returned. The results of that survey indicated inconsistent data on browse, including the nutritional content, specific plant parts fed, seasonal use of browse and management of the browse plants. This resulted in a more comprehensive survey (AZH) being sent out in 1996 to those twelve institutions responding to the first survey. These twelve institutions provided a starting point for the development of the proposed data base.

Denver Zoological Gardens Sample Collection

In 1996, 20 species of plants, and in 1997, 21 species of plants were harvested at the DZG (Table 1). The selection of plants was based on those commonly used as browse plants for the zoo's herbivore collection. The samples were harvested in the spring (May), summer (July) and fall (September) to account for seasonal change.

Harvesting of the browse samples was managed to prevent allelopathic complications. Twenty, 25 cm lengths or branches of each species of browse were collected at each harvest. After harvest, the diameter of each branch was recorded in centimeters. Harvested samples were then refrigerated and transported for processing to CSU .

Processing the 20 branches of each plant species involved separating the plant into leaf and stem fractions, leaving the pedicle with the leaf fraction. Each fraction was then dried in a laboratory oven between 50-60 degrees Centigrade for 48 hours. Upon removal from the oven, the samples were weighed to account for the leaf:stem ratio (dry matter basis) of each plant. Each plant fraction was then ground using a 1 mm screen in a Wiley laboratory mill.

In addition to the 20 branches collected at each harvest, two additional branches were collected from each plant. These samples were also processed by separation into the leaf and stem fractions. Each plant fraction was then dried at 100 degrees Centigrade for 48 hours to determine the harvest dry matter concentration for each plant.

Laboratory Analyses

Samples of each plant fraction were analyzed (Irlbeck, 1997) for dry matter; ash content; crude protein using the combustion method (AOAC, 1990a); detergent fiber analyses including neutral detergent fibers (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL); and mineral content using Inductively Coupled Plasma Emissions Spectroscopy (AOAC, 1990b) using National Institute of Standards and Technology as standard reference material (Ca, K, Mg, Na, P, Cu, Fe, Mn, Zn and Mo). The detergent fiber analyses (NDF, ADF and ADL) were sequentially determined using the ANKOM method (ANKOM$^{200/220}$ Fiber Analyzer; Analytical Instrumentation and Engineering; 140 Turk Hill Park; Fairport, NY 14450), utilizing a heat resistant enzyme (Validase, HT 3401 Alpha-Amylase; Valley Research, Inc.; 1145 Northside Blvd.; South Bend, IN 46615) for the NDF analyses.

Collaborating Zoological Institution Sample Collection

In 1997, the original twelve survey institutions were invited to send browse sample to CSU for inclusion in the data base. The following protocol was developed and sent to each of the institutions. Currently, the North Carolina Zoological Park (Table 2), the Columbus Zoo (Table 3) and the Phoenix Zoo (Table 4) have sent the first harvest of browse samples to CSU. Several other institutions have verbally agreed to send samples and a permit to allow samples from Calgary Zoo in Canada is pending.

The collaborating institutions were asked to contribute at least five, but no more than 20 different browse species. If the institutions were feeding similar browse to what is being analyzed for the DZG, they were encouraged to send those to help account for regional differences in nutrient content among these species. The identical harvesting techniques used in Denver were sent to the collaborating institutions. The 20, 25 cm branches (Sample A) from each browse species (intact with no separation of leaf and stem) were to be enclosed in a paper grocery bag, each species having its own bag. The institutions were not responsible for separation of the plant fractions (leaf and stem). These bags were to be marked with the following information: 1) Sample A; 2) name of institution; 3) name of the browse species; and 4) harvest date. The second sample of 2, 25 cm branches (Sample B) was to be enclosed in a ziploc bag to prevent water loss. The Sample B bags were similarly marked as the Sample A bags. Both samples were to be harvested on the same day and refrigerated until shipping. Samples were to be shipped no later than the morning of the next day by overnight Air Express to CSU. It was requested that samples were harvested and shipped early in the week to prevent deterioration of samples. Upon arrival at CSU, the samples were processed and analyzed in the same manner as the browse samples from the DZG.

The collaborating zoological institutions have already submitted information regarding the use of shipped browse samples in the AZH survey. The information included in the survey includes animal species the browse is fed to, time of year browse cuttings are made, the form browse is fed in and any positive or adverse reactions observed due to the browse.

Development of the Data Base

Currently, a graduate student at CSU is working on preparing and inputting browse data into a computerized data base (Microsoft Access -Version 7, Windows 95). The information that is compiled from nutrient analyses of browse and corresponding surveys will be incorporated into the data base. Compatible data from the literature will incorporated as possible with citations being indicated. The final project will include common plant names, scientific plant name, nutrient content based on harvest time and region, potential concerns (for example secondary compounds) when feeding a browse, animal species that can and cannot be fed a specific browse and the source of literature as it applies. Information from the data base will be accessible by either plant name, region, secondary compounds found in browse species and animal species that browse can be fed or not fed to.

Results

The browse survey sent out in 1996, will be reformatted and sent out again to all AZH-associated institutions within the next two years.

The results of the nutritional analyses of the 1996 browse samples collected from the DZG will be published in a corresponding journal in the near future (Irlbeck, 1997), as will the browse sample from collaborating institutions.

The browse data base itself will be presented at future captive wild animal and AZH conferences, along with submission to a nutrition-related journal.

Discussion

The importance of this browse data base is undeniable. There are several issues being addressed by the data base that will ultimately enable zoo personnel to more safely feed browse to captive wild animals. These issues include: 1) nutritional variation of the browse based on season, location and year; 2) animal preferences; 3) concerns of secondary compounds such as alkaloids, tannins and phenolics; and 4) management concerns for animal and browse species.

The benefits of browse seem obvious as it supplements the animal's diet with additional nutrients and fiber. Therefore, the days of just adding a little browse in an exhibit may be limited. We need to have some idea of what we are feeding these animals. Despite the significant amount of research done on the nutritional content of various browse species, the nutrient content of most browse species is still relatively unknown. It is hoped that the data base can be utilized in some cases to find an acceptable substitute for an animal's natural browse. For example, one study stated that the natural browse of South-East Asian Colobines *(Presbyts rubicunda and melalophos)* contained 43.7-66.7% NDF, 30.5-52.3% ADF and 14.4-28.3% lignin. The fiber analyses of diets fed to these same species in European zoos only analyzed to 32.2% NDF, 17.7% ADF and 3.9% lignin (Nijboer and Dierenfeld, 1995). A subtle change in fiber content like this could potentially compromise the gastrointestinal tract and health of these animals. This is only one example and there are a myriad of other species that this can be applied to. Therefore, the use of the data base could assist in finding a more comparable fiber source for various endangered species.

As indicated in the previous paragraph, when feeding captive wild animals, the natural diet is the first key in determining what the animals should be fed. Browse as a source of fiber alone can be an important integral of the animal's diet, especially if the animal is an herbivore. When feeding an herbivore, complications will arise if inadequate amounts (too much or not enough) of fiber are fed. Complications that could arise are obesity (fiber, thus browse is lower in caloric content and gives a feeling of satiety) and disruption of normal digestive function such as diarrhea, bloat, impaction, torsion, acidosis, pathogenic infections, lumpy jaw and dental concerns (Church, 1988; Barboza and Hume, 1989; Hume and Barboza, 1993). For many species of animals, it is essential that the "right" form of fiber is fed. For example, in 1964, Hill documented that 50% of langur mortality was directly attributed to gastrointestinal problems as a direct result of diet. Also, in 1984, Clemons presented data insinuating that 40% of herbivore deaths were due to acute or chronic gastrointestinal concerns. It is apparent that browse, and particularly what type of browse is fed to an animal will affect its health and well-being.

It has been documented in the domestic animal literature for years that the environment the plant is grown, thus seasonal effects will affect the nutritive quality of a browse sample. Also, the maturity of the plant will affect nutritional quality and its availability to the animals. In general, the hotter the environment (usually later in the season), the amount of lignin and cellulose will increase. Plants grown in more temperate (cool and moist) environments will have less lignin. Therefore, plants harvested in the early or later part of a season, will generally be of higher nutritive value (Baker and Hobbs, 1982; Ha1l-Martin et al., 1982; Hobbs et al., 1981). This can, however, also be changed by the maturity of the plant. In general, the more mature the plant, the lower the nutritive value because of an increase in lignin and cellulose (Church, 1988; Van Soest, 1982). It should also be addressed, that since different areas of the country and world will have different environments, the nutritive value will change with different regions. Likewise, the environment is never the same from year to the next, thus, there is a change in nutrient quality due to year alone. This just provides all the more impetus to add as many years' data from as many regions as possible to increase the validity of the data base values.

While observing animals being fed browse at the Denver Zoological Gardens and reading the results of the horticulture survey, it is obvious that animals have preferences for certain types of browse. Being aware of these preferences and feeding those browse types, if at all possible, can serve to ease the management of these animals. Some of these preferences may be due to secondary compounds found in some browse, some of which are potentially dangerous (Baer, 1989; Gardner et al., 1985). A few of the secondary compounds found in plants include tannins, phenolics and alkaloids. It has been documented that animals select browse components based on the content of secondary compounds. For example, the koala *(Phascolarctos cinerus)* has adapted to Eucalyptus forage which contains volatile oils. These oils can be dangerous and are believed to influence selection of the leaves by the koala (Barboza and Hume, 1989). Other research suggests that the South Indian Leaf-Monkey *(Presbytis johnii)* and other colobines, may be able to detoxify some alkaloids found in some browse species and select their browse components based on low tannin content (Oates et al., 1980). Recently in 1995, two zebra *(Equus grevyi)* were found to be suffering from the symptoms of Red Maple *(Acer rubrum)* Toxicosis (Weber and Miller, 1997). Both animals were treated for hemolytic anemia, however, the older animal still died. The first case of hemolytic anemia from Red Maple leaves in horses was documented in 1981, but this was the first case documented in another equid, the zebra. The irony of this case was that the animals had been held in this enclosure with the trees for over 15 years and this was the first time it had been a concern. Obviously a specific change in the environment resulted in the death of an animal.

Management of browse itself has its own challenges. Some plants when consistently harvested either by insects, animals or by man will produce secondary compounds to deter that behavior. In fact, some plants will produce chemicals to prevent other species of plants from growing in the same area, thus preventing competition from another species. This is called allelopathy (Gardner, 1985). One example of allelopathy occurred in the last few years at the DZG. In this incident, native grasses were planted in from of a hoofstock exhibit. Between the rabbits and the peacocks, the plants were leveled to a height of a few inches for the fIrst year. The next year, the plants grew several feet in height as no animal would graze it, most likely from an allelopathic response (Moore, 1997). This same phenomena may occur if browse samples are collected from the same plant repeatedly in the same season. The plant, with its chemical defenses may prevent animals from consuming the browse, perhaps explaining why animals will eat a browse one time and not another. Thus, the harvesting of browse needs to be done on a rotational basis. Information on the production of these secondary compounds can be of benefits to zoo personnel, both plant and animal staff.

Challenges

There are three major concerns challenging this project. They include: 1) information distribution; 2) funding; and 3) the need for a substantial amount of labor. The decision still needs to be made on how to distribute the information from the data base, so that it can be best used by the captive wild animal community .The two options seem to be: 1) to market the information and use the profits to fund further research; or 2) provide the information as a service, potentially making it available on the Internet. Obviously, this is a decision that will need to be made in the near future. Laboratory analyses of the browse samples is expensive both from a monetary form and in labor. Funding sources are essential to meet the needs of this project. Initial funding for the analyses has been provided by the DZG, but new sources are needed. Also, the amount of labor needed to accumulate this information is tremendous. Browse samples need to be harvested, processed, analyzed and the resulting information entered into the data base. It is hoped that these issues will be resolved soon.

Future Implications

The use of Near Infrared Spectrophotometry (NIR) is used extensively in forage and grain analyses for captive wild and domestic animals alike. It offers a quick and inexpensive way to determine the nutrient analyses of a feed prior to being fed to animals. To date, however, NIR cannot be used for browse nutrient analyses as the equations needed to calibrate the NIR are not available. To adequately develop these equations, thousands of laboratory analyses on browse samples need to be completed. The results of these analyses can be used to develop the equations, the NIR can be calibrated and then used for browse nutrient analyses. From a recent grant, a NIR is available at CSU and the laboratory analyses accumulated thus far are being used in the initial stages of calibrating the machine. It is planned in the future that a NIR can be used for browse analyses anywhere in the world.

It is also planned that the browse data base will take on an International aspect. The permits are being processed to obtain the browse samples from Canada. Plans have been made to bring browse samples back from Australia in the Fall of 1998.

Conclusions

A standardized browse data base would benefit captive wild animals by providing information on: 1) nutrient content of browse species as affected by season, region and plant maturity; 2) protection from concerns of secondary compounds that could elicit toxic responses; and 3) cultivation and harvesting techniques for the browse species to be safely fed.

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Table 1. Plant species collected from the Denver Zoological Gardens in 1996[1] and 1997 for nutrient analyses determination in the development of a browse data base.

Common Name	Scientific Name
American Elm	*Ulmus americana*
Arnold's Red Honeysuckle	*Lonicera tartarica* 'Arnold's Red'
White Ash	*Fraxinus sp.*
Bluestem Willow	*Salix irrorata*
Bud's Yellow Dogwood	*Cornus alba* 'Bud's Yellow'
Burkwood Viburnum	*Viburnum X Burkwoodii*
Common Hackberry	*Celtis occidentalis*
Cottonwood	*Populus sp.*
Crabapple	*Malus sp.*
Dark Lavender Butterfly Bush	*Buddleia davidii* 'Dark Lavender'
French Pink Pussy Willow	*Salix discolor*
Giant Reed Grass[2]	*Arundo donax*
Golden Ninebark	*Physolarpus opulus* 'Luteus'
Honeylocust	*Gleditsia triacanthos var. inermis cvs.*
Linden	*Tilia sp.*
Minnesota Snowflake Mockorange	*Philadelphus X Virginalis* 'Minnesota Snowflake'
Native River Birch	*Betula occidentalis*
Pink Cloud Beauty Bush	*Kolkwitzia amabilis* 'Pink Cloud'
Sunrise Forsythia	*Forsythia ovata* 'Sunrise'
Thin Leaf Alder	*Alnus tenuifolia*
Willowwood Viburnum	*Viburnum X rhytidophylloides* 'Willowwood'

[1]Samples were collected for three harvests in 1996, two harvests in 1997 and one pending seasonal changes.
[2]Sample was not collected in 1996.

Table 2. Plant species collected from North Carolina Zoological Park in 1997[1] for nutrient analyses determination in the development of a browse data base.

Common Name	Scientific Name
Areca Palm	*Chrysalidocarpus luctescens*
Autumn Olive	*Elaeagnus umbrellata*
Black Bamboo	*Phyllostachys nigra*
Black Willow	*Salix nigra*
Bamboo	*Phyllostachys aureosulcata*
Canna	*Canna* X *generalis*
Dwarf Banana	*Musa acuminata*
Giant Reed	*Grass Arundo donax*
Honeylocust	*Gleditsia triacanthos*
Red Maple	*Acer rubrum*
Thorny Elaeagnus	*Elaeagnus pungens*
Wax Myrtle	*Myrica cerifera*
Weeping Fig	*Ficus benjamina*
Winged Elm	*Ulmos alata*

1One harvest has been collected and the second is pending seasonal changes.

Table 3. Plant species collected from the Columbus Zoo in 1997[1] for nutrient analyses determination in the development of a browse data base.

Common Name	Scientific Name
Bailey's Red Twig Dogwood	*Comus sericia 'Baileyi'*
Common Hackberry	*Celtis occidentalis*
Crabapple	*Malus cv.*
Honeylocust	*Gleditsia triacanthos var. inermis cvs.*
Pennsylvania Ash	*Fraxinus Pennsylvanica*
Willowwood Viburnum	*Viburnum X rhytidophylloides 'Willowwood'*
Yellow Twig Dogwood	*Comus serica 'Flaviramea'*

1.One harvest has been collected and the second is pending seasonal changes.

Table 4. Plant species collected from the Phoenix Zoo in 1997[l] for nutrient analyses determination in the development of a browse data base.

Common Name	Scientific Name
Four-winged Saltbrush	*Atriplex canescens*
Honeylocust	*Gleditisa triacanthos* v. *inermis*
Horsetail Tree/She Oak	*Casuarina equisethifolia*
African Sumac	*Rhus lancea*
Sissoo	*Dahlbergia sissoo*
Bottle Tree	*Brachychiton populne.s*
Yellow Trumpet Flower	*Tecoma stan.s. cv. 'Jubilee'*
Carob	Ceratonia siliqua

[l]One harvest has been collected and the second is pending seasonal changes.