Banana Foliage and Rejected Banana Fruits as Feed for Livestock in Hawai'i

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Abstract

Different varieties of *Musa spp.* typically exhibit the same relative amounts of nutrient compositions. Banana fruits are known to provide additional amounts of energy from the presence of starch (Ibrahim et al., 2000), but are low in crude fiber, protein and mineral content (Chedly and Lee, 2000). Although low in protein and minerals as well, the leaves, sheaths and pseudo-stems are very high in fiber. Biological compounds, such as tannins, flavonoids and terpenoids found in banana foliage are natural combatants against internal parasites (Marie-Magdeleine et al., 2010). Supplementation for proteins and minerals are generally needed if banana is utilized as feed. Plantations in Hawai'i are usually open in selling rejected fruits and foliage to those willing to buy and transport the materials (Hamakua Springs Country Farms, 2013; Hana Farms, 2013).

Introduction

The state of Hawai'i has a dependence on importing cargo ships full of food and supplies in order to further support the local population. This not only increases the prices of imported goods, but also has an impact on how citizens dispose of waste products. Hence, the implications of self-sustainability and use of waste by-products need to be considered. Livestock production industries in Hawai'i do periodically purchase forages and concentrates from overseas to satisfy the needs of the animals. However, there are possible local alternative crops that have the potential of being utilized as a feed component.

Varieties of banana fruits and foliage are blended into livestock feeds in many tropical regions, especially those in Africa and Central America where other resources are limited. Hawai'i remains one of the most significant commercial producers in the United States with at least 200 banana plantations reported each year (U.S. Department of Agriculture, 2012). Fruits that failed to go to market and leftover organic material have been used to provide starch for energy (Ibrahim et al., 2000) and as a supplemental component in low quality forages.

Nutritional analyses are still being conducted in incorporating banana by-products in various combinations of feedstuffs. Scientific journals have reported observed chemical compositions, digestibility, and influences on feed intake, growth and even actions against parasitic life cycles. Comparing the results from multiple experiments can aid in narrowing down the overall nutritional and economic value of providing banana by-products as a feed to different species of ruminants and non-ruminants.

Source

Multiple varieties of bananas are cultivated within tropical regions of the world such as the Caribbean, Central and South America, South East Asia, and Polynesia. Although commonly referred to as a tree by its appearance, it is actually a giant perennial herb due to the lack of woody structural components (Vezina et al., 2013). Its lifecycle is relatively short compared to most tree or tree-like plants; it ultimately comes to an end after bearing fruit. The leaves and pseudo-stems that remain are commonly composted and eventually returned back into the soil as natural fertilizers.

Availability

The U.S. Department of Agriculture (2012) displayed statistical data regarding banana plantations in the state of Hawai'i. Values were reported in acreage and pounds, which were converted to metric units, hectares, and kilograms, and then rounded for simplicity. During 2011 approximately 240 farms participated in banana production, where an averaged total of 530 hectares were planted with trees. Only 400 hectares were harvested with an average yield of 19,500 kg per hectare, totaling to 7.89 million kg (2% less than 2010). Therefore about 1.58 million kg of waste crop were rejected from going into market (U.S. Department of Agriculture, 2012).

Subsequent to harvesting on banana plantations, the waste products are typically composted and returned back into the soil for natural fertilization. Most of the fruits are shipped to local markets, however, a portion of those rejected are also sold but set at an off-grade quality (Hamakua Springs Country Farms, 2013). Residents or businesses looking into purchasing banana waste products are welcomed to do so. Plantations, such as Hamakua Springs Country Farms and 'Ohana Banana Farm Inc. on the Big Island and Hana Farms on Maui, sell to those willing to buy. The only requirement in purchasing banana waste products is for the customers to provide their own transportation for the by-products, due to the massive weight of the banana trees.

Nutrient Content

Five different scholarly journal articles were used in correlating a relationship between the reported chemical compositions of each particular species of banana. Dung et al. (2002) involved digestive trials using sheaths of *Musa paradisiaca* (plantains) conducted on 18 growing Yorkshire pigs. All animals weighed between 45 and 50 kg live weight (LW) and were dewormed and vaccinated before start of the experiment and individually housed in metabolism cages. The formulated banana sheath diet was given for a 14-day adaptation period and then a 4-day fecal collection period followed. The nutrient compositions are reported in Table 1.

Archimede et al. (2009) held a growth trial and digestion trial on the effects of green *M. paradisiaca* fruits on 40 6month-old Martinik lambs (29.4 kg ± 3.6 kg body weight) and 4 Martinik rams (57.2 kg ± 3.45 kg BW) respectively. All were housed in metabolism crates individually during both trials with ruminal and duodenial cannulae fittings in the digestion trial. Each trial was held a total of 85 days –14 days for adaptation and 71 days of data collection. The chemical compositions are reported in Table 1.

Marie-Magdeleine et al. (2010) studied feeding banana foliage (leaves and pseudo-stems) of *M. paradisiaca* in a blended diet of *Dichantium* hay and commercial pellets at various proportions. Besides analyzing the effects of the foliage on growth and nutrition, there also included research on actions against an internal parasite, *Haemonchus contortus* (Barber Pole Worm). Forty-five-month-old Martinik lambs (17.3 kg ± 4.1 kg BW) were used in both trial 1 and 2. Each trial followed the same standard feeding procedures: a 21-day adaptation period and then 35 days of collection. Within each trial there were a control group and experimental group where the experimental was infected with a fixed number of *H. contortus* eggs after adaptation and the other remained uninfected. The combined nutrient composition of the leaves and pseudo-stems can be found in Table 1.

Table 1
Nutrient composition of *M. paradisiaca* plant parts

Plant part	DM (%)	OM (g kg^{-1} DM)	CP	EE	NDF	ADF	ADL	HC	Ce	Ash
Sheath	NS[b]	836	26	59	567	427	72	140	355	164
Green fruit	18.0	944	53	NS	283	55	22	233	33	NS
Leaf and pseudo-stem	101.0[c]	852	104	NS	680	450	122	NS	NS	NS

[a] DM: dry matter; OM: organic matter; CP: crude protein; EE: ether extract; NDF: neutral detergent fiber; ADF: acid detergent fiber; ADL: acid detergent lignin; HC: hemicellulose; Ce: cellulose.
[b] NS: not stated or not determined in experiment.
[c] Dry matter in terms of g kg^{-1}.

Another species of banana was studied, *M. acuminate*, on 12 4 to 6-month-old goats (15.8 kg ± 2.1 kg BW) using only the leaves and pseudo-stem sheaths (Katongole et al., 2007). All animals were vaccinated for Foot-and-Mouth Disease and intestinal parasites and then housed in metabolism cages. The experiment encompassed 15 days total with 10 days for adaptation and 5 days for data collection. The nutrient composition for this species is shown in Table 2.

Table 2
Nutrient composition of *M. acuminate* plant parts

Plant part	DM[a] (g kg^{-1})	CP (g DM) kg^{-1}	EE	NDF	ADF	Lignin	Ash	Energy[e]
Leaf	216	109	23	613	349	124	108	6.3
Sheath	97	34	NS	659	355	102	128	NS

[a] For abbreviations, refer to Table 1.
[e] Reported as MJ kg-1 DM.

Rejected green fruits of *M. AAA* were given *ad libitum* in addition to pasture grasses (Ibrahim et al., 2000). Thirty-two 10 to 12month-old steers (220-240 kg LW) were subjected to several combinations of pasture grasses, banana fruits, and protein supplements that ran for approximately 5 months. Analysis of the banana fruits was via the *in vitro* dry matter digestibility test (IVDMD). This technique replicates the digestive actions of the rumen. Ground-up feed samples are incubated in fluid that mirrors fluid inside the rumen for 24 to 48 hours. The addition of acid and pepsin follows with a final 24-hour period of incubation to determine the digestibility of the feed. Since the study's main objective was to determine digestibility, all classes except crude protein were excluded from the proximate analysis. Data also shows the values of crude protein on high rainfall and low rainfall levels in a humid tropical climate, in order to see if there was a significant relationship. Crude protein values under high and low rainfalls are shown in Table 3.

Table 3
Nutrient composition of *Musa AAA* fruit

Plant Part	CP (g kg^{-1} DM)[d]	
	HR[f]	LR
Green fruit	47	46

[d] For abbreviations, refer to Table 1.
[f] HR: high rainfall; LR: low rainfall.

Utilization for Livestock

Banana sheaths from *M. paradisiaca* were revealed to contain very low CP levels (26 g kg^{-1} DM) and a high NDF content (567 g kg-1 DM) with a 0.39 ratio of hemicellulose to cellulose (Dung et al., 2002). Regardless of the species of livestock being fed, the banana sheaths alone must be accompanied by an appropriate source of dietary protein. Banana foliage is known to possess secondary biological compounds such as tannins. Tannin compounds can demonstrate negative effects on digestibility by forming large and chemically stable complexes with protein and cellulose. The size of these molecules inhibits microbial fermentation and also prevents absorption of proteins and cellulose through the intestinal mucosa (McLeod, 1974).

Green *Musa paradisiaca* fruits remained proportionally similar to the nutrient composition of banana sheaths. Crude protein content was slightly higher than in sheaths (53 g kg^{-1} DM) and NDF levels were approximately halved (283 g kg^{-1} DM) where hemicellulose is about 7 times more than that of cellulose (Archimede et al., 2009). Digestibility of the starch in the fruit was slightly greater than 90% where the rate of degradation inside the rumen is considered slow. In this study there was no analysis on the starch content. Nonetheless it can be determined that its total tract digestibility will not be affected from negative influences of high fiber concentrations (particularly from *Gliricidia sepium* forage used in this study) (Archimede et al., 2009).

Nutrient composition of *Musa paradisiaca*, Marie-Magdeleine et al. (2010) indicated the presence of biological compounds – polyphenols and condensed tannins. Banana trees primarily contain phenolic compounds where tannins make up a fraction of the polyphenols available. Compared to other studies, the banana foliage comprised of significantly low levels of condensed tannins; most of these tannins typically reside more in the leaves versus the pseudo-stems.

The effects of *H. contortus* confirmation still require further experimentation. The results of trial 1 on the establishment *H. contortus* are still left for debate due to the presence of lurking variables and bias. Low quality forages were used alongside with banana foliage in this trial. Digestibility of crude protein in the forages was significantly lower than in banana, which creates a potential bias, and therefore, trial 1 could not be justified. However the development of immunity to parasitic nematodes can be determined by the amount of dietary protein.

Trial 2 on the other hand did show some promising effects on fully mature *H. contortus.* The observed numbers of eggs found in feces were lower than that of trial 1 with the number of adult female worms remained relatively the same. Consequently, actions of banana foliage could have reduced the fertility rates of adult females. Trial 2 also exhibited a distinct reduction in the development of larvae from eggs. Further chemical analyses on banana foliage discovered more biological compounds – terpenoids and flavonoids, which were determined to play several roles against *H. contortus* (Ademola et al., 2005).

M. acuminate is very similar to its respective plant parts of the *M. paradisiaca*. The leaves, fresh or withered, had a CP content of 109 g kg^{-1} DM, which is within range of *M. paradisiaca*. NDF and lignin components are high in concentration and both have been indicated to decrease dry matter digestibility by limiting microbial digestion in the rumen. Like in any banana foliage tannins were found and of course, have been well known to decrease digestibility of feed. Sheaths possess the same properties as the leaves, but have a significantly higher digestibility due to smaller lignin content. The reason for this observation is from the cellular structure of the sheaths and pseudo-stems where much of the lignin is replaced by water in the cell wall to maintain vertical support of the plant (Katongole et al., 2007).

Ibrahim et al. (2000) involved two different banana fruit combinations tested on steers: pasture with banana and pasture with banana and *Erythrina berteroana* (tropical legume in Central America). LW gains per steer were reported to be highest when green banana fruits were incorporated into the diet. This is due to the high-energy value provided by banana from its starch content. Feedstuffs with high starch levels have a large proportion of bypass energy to the intestines, a possible explanation to the LW gains. However since this particular experiment was carried out in Central America where forages tend to be of lower quality, animals given supplemental energy feeds will gain significantly more weight than the norm.

Economic Value

The average farm price per kilogram of fruit was reported to be \$1.43 kg^{-1}. Hence the crops that failed to be harvested resulted in a lost profit of \$2.26 million (U.S. Department of Agriculture, 2012). Looking at the past ten years from 2011, it can be projected that farm prices will continue to gradually increase (until reaching economic equilibrium) each coming year. Purchasing fresh banana fruits, either retail or directly from the plantation, may or may not be reasonable depending on the profitability of the livestock industry itself. If that is the case, then obtaining those that were rejected would be the better solution. Depending on the farm specifically, most of the rejected fruits are sold off-grade where very little is actually returned to the soil (Hamakua Springs Country Farms, 2013).

Since all the trees and foliage are to be composted after harvesting season, many banana plantations are willing to sell to non-retail customers. The available tannins, flavonoids and terpenoids, provide internal parasitic resistance (Marie-Magdeleine et al., 2010; Ademola et al., 2005) and the high fiber content makes foliage a useful source of roughage that can be ensiled or given as-fed. If provided a hauling vehicle for transportation, utilizing these waste products will benefit livestock health and offer more uses than composting material.

Conclusion

Banana cultivation farms are widely spread throughout tropical and sub-tropical regions. Being that Hawai'i is one of the top banana producers in the United States, over 200 farms produce millions of kilograms of banana fruits alone. Approximately 1.5 million kg of fruits were rejected in 2011 (U.S. Department of Agriculture, 2012) and even more in the weight of foliage left over from harvesting. Any organic material that is not sent to market is converted into compost, making banana a cost-effective ingredient source for livestock feed. Rejected fruits, green, immature or ripe, provide additional energy for animals from the available starch (Ibrahim et al., 2000), but are low in crude fiber, crude protein, and minerals. In conjunction with the fruits, forages such as grasses, and protein and mineral supplements are recommended (Chedly and Lee, 2000). Ensiled or as-fed banana leaves and pseudo-stems can be used as roughage sources due to the high fiber content (Dung et al., 2002; Katongole et al., 2007). Again since they are low in protein and minerals, appropriate supplementation is needed. Presence of tannins, flavonoids and terpenoids enhance resistance to internal parasites (Marie-Magdeleine et al., 2010; Ademola et al., 2005). Incorporation of banana fruits and foliage can greatly benefit livestock and livestock industries in Hawai'i, as well as, simultaneously reducing expenses on purchasing and shipping off-island feedstuffs.

Works Cited

Ademola, I. O., Akanbi, A. I., & Idowu, S. O. (2005). Comparative nematocidal activity of chromatographic fractions of leucaena leucocephala see against gastrointestinal sheep nematodes. *Pharmaceutical Biology*, 43, 599-604.

Archimede, H., Gonzalez-Garcia, E., Despois, P., Etienne, T., & Alexandre, G. (2009). Substitution of corn and soybean with green banana fruits and gliricidia sepium forage in sheep fed hay-based diets: Effects on intake, digestion and growth. *Journal of Animal Physiology and Animal Nutrition*, 118-127.

Chedly, K., & Lee, S. (2000). Paper 6.0: Silage from by-products for smallholders. In L. 't Mannetje (Ed.), *Silage making in the tropics with Particular emphasis on smallholders* (Vol. 161). Rome: Food and Agriculture Organization of the United Nations.

Dung, N. N. X., Manh, L. H., & Uden, P. (2002). Tropical fibre sources for pigs - digestibility, digesta retention and estimation of fibre digestibility in vitro. *Animal Feed Science and Technology*, 102, 111-121.

Hamakua Springs Country Farms. (2013, February 20). Interview by K. Kramer [Personal Interview]. Banana waste utilization and disposal.

Hana Farms. (2013, February 22). Interview by K. Kramer [Personal Interview]. Banana waste utilization and disposal.

Ibrahim, M. A., Holmann, F., Hernandez, M., & Camero, A. (2000). Contribution of erythrina protein banks and rejected bananas for improving cattle production in the humid tropics. *Agroforestry Systems*, 49, 245-254.

Katongole, C. B., Bareeba, F. B., Sabiiti, E. N., & Ledin, I. (2007). Nutritional characterization of some tropical urban market crop wastes. *Animal Feed Science and Technology*, 142, 275-289.

Marie-Magdeleine, C., Boval, M., Philibert, L., Borde, A., & Archimede, H. (2010). Effect of banana foliage (musa x paradisiaca) on nutrition, parasite infection and growth of lambs. *Livestock Science*, 131, 234-238.

McLeod, M. N. (1974). Plant tannins – their role in forage quality. *Nutrition Abstracts and Reviews*, 44, 803-815.

'Ohana Banana Farm Inc. (2013, February 15). Interview by K. Kramer [Personal Interview]. Banana waste utilization and disposal.

U.S. Department of Agriculture, (2012). *Hawaii Farm Facts*. Honolulu: Hawaii Department of Agriculture.

Vezina, A., Van den Bergh, I., & Rouard, M. (2013, February 21). *Morphology of banana plant*. Retrieved from http://www.promusa.org/tiki-index.php?page=Morphology of banana plant.