



Nutrient Compositions of Sugarcane Forages were Influenced by Season and the Time of Harvest

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Abstract

Selection of forty sugarcane crosses from over 7,000 seedlings that appeared to have potential for ruminant feed were made and their respective nutrient values were evaluated. This study showed that season and time of harvest in a day affected the nutrient profiles. The acid detergent fiber (ADF) and neutral detergent fiber (NDF) values were lower for summer harvest vs winter harvest. Summer forages had higher non-fibrous carbohydrates (NFC), starch and water soluble carbohydrates (WSC). These resulted in higher relative feed values. Further examination of the time of harvest within a day showed that influenced the ADF, NDF, NFC, WSC and starch values. They were highest after mid-day suggesting that sunlight influenced the photosynthesis process over the course of the day. The data helped explain the afternoon grazing behavior of animals. It also implied that the best time to harvest forages is in the late afternoon for maximum feed value.

Introduction

Assessing the ability of tropical forages to use solar energy in combination with soil nutrients to produce high quality feed for ruminants is one of the most efficient and sustainable form of agriculture. In Hawaii, a subtropical climate environment, there is a year round growing season with 365 days of sunshine and ample rainfall in many places. Total sunny days may vary by location ranging from 168-276 days [1].

Forages for livestock can be classified into three broad categories:

- legumes- generally high in protein and low in fiber, they constitute forage that is very digestible;
- Cool season grasses - these are grasses with the C3 photosynthetic pathway e.g. Ryegrass, Timothy grass, Kentucky Bluegrass, etc. that generally have high digestibility due to lower fiber content
- warm season grasses - these are the grasses that utilize the C4 photosynthetic pathway, e.g. corn, Guinea grass, California-grass, African Star-grass, Kikuyu-grass, etc. They can yield tremendous biomass but they also contain higher lignin and fiber contents. Some, like guinea grass, have high silica. Hence, they are less digestible than cool-season grasses. Sugarcane crosses, the subject of this study, are C4

grasses. They have the ability to synthesize carbohydrates which adds nutritional values to ruminants.

Animal performance on forages, including meat and milk production is tied closely to forage quality. Intake and digestibility are directly related to fiber content, lignin and indigestible components of a plant. Cooler temperatures result in better quality forages and higher temperatures negatively impact forage quality [2].

Objectives

The objectives of this study were:

- 1) To evaluate the sugarcane crosses as potential forages for ruminants.
- 2) To determine if season (winter-November to March or; summer - June to September.) affects feed quality,
- 3) To determine if time of harvest within a season affects the nutrient composition of C4 forages.

Materials and Methods

Forty sugarcane crosses from over 7,000 seedlings, were selected for field evaluation of their potential for ruminants feed. The selection criteria were published [3]. Each selection was vegetatively propagated in 3.05m (10') x 0.61m (2') rows and irrigated via drip irrigation.

For each season, there was a “cut back” event, where the forages were cut to a height of 33-35cm (13-14”) from the ground. Cut back took place in late October of 2013 for winter harvests and late June of 2014 for summer harvests. The plots were sampled three times per season at six week intervals following the cut back.

At harvest, total yield (kg) was recorded immediately and a sub-sample of 1kg was bagged for drying at 65 °C for 3 days. The forage was ground using a Thomas Wiley mini mill (model 4). The ground sample was then divided into 2 Ziploc plastic bags. One sample was held back in the laboratory for use in future *in vitro* digestibility studies. The other was shipped for analyses (Dairy One, 730 Warren Road, Ithaca, New York 14850; <http://dairyone.com/>).

Forage analyses at Dairy One utilize the Near Infrared (NIR) spectroscopy. While a full analyses was ordered for the samples, this paper will examine only selected nutrients. The nutrients of interest are:

- a. Acid Detergent Fiber (ADF)
- b. Nutrient Detergent Fiber (NDF)
- c. Crude Protein (CP)

- d. Non-Fibrous Carbohydrates (NFC)
- e. Water Soluble Carbohydrates
- f. Starch
- g. Relative Feed Value (RFV).

Statistical Analyses

For the effect of season on forage quality a 2-way analyses of variance (ANOVA) was performed using Prism 6 software (Graphpad, CA, USA). For data reflecting time of harvest, a 3-way analyses of variance (ANOVA) was performed using the same software. Differences in values were depicted with different superscript in the respective table or graphs.

Results and Discussion

Weather data

Figure 1 shows the temperatures (°C, max. average and min.) for the field site where the 40 different selections of sugarcane forages were planted. The data were obtained from the closest weather station adjacent to the test field. In the winter months (October 15, 2013 - March 31, 2014), the average temperature was 22.35+0.10 °C. In the summer months (May 15, 2014 - Aug. 31 2014), the average temperature was 24.94+0.08 °C. Summer temperatures were 2.59 °C higher.

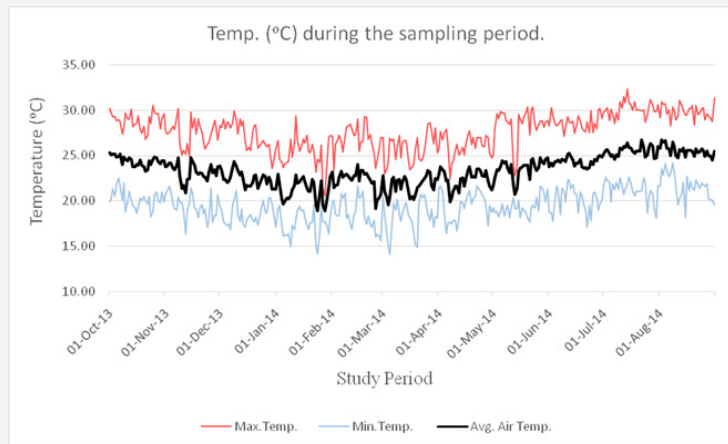


Figure 1: Ambient temperature of the field where the sugarcane forages were planted.

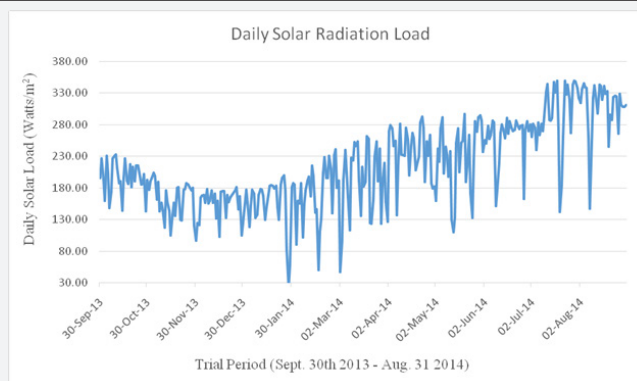


Figure 2: Average daily solar radiation load (24h) for the field where the sugarcane forages were planted. Winter Harvest Summer Harvest

Figure 2 shows the average daily solar load for the field site. This is the 24hour solar load expressed in watts/m². During the winter months from Oct. 15th 2013 - March 31, 2014, the average solar load was 170.8+ 3.21 watts/m². During the summer months from May 15, 2014 - Aug. 31, 2014, the average solar load was 281.26+ 4.68 watts/m². The summer daily solar load was 110.46watts/m² higher than the winter solar load.

Influence of temperature and solar load on nutrient composition of forages

These differences in weather data seem to influence nutrient composition of the sugarcane forages, which are C4 plants. Table 1 shows the influence of season (winter vs summer) on nutrient composition of the forages. The average crude protein (CP) levels were lower in the summer compared to the winter harvests (8.13 vs. 11.42 %). Temperature has been known to reduce leaf to stem ratio in Timothy-grass [4] and Rye-grass [2]. Ohlsson [5] found that 10 °C increased in temperature can lower digestibility for Red Clover and Timothy-grass by 5%. A University of Arkansas article on cool season grasses for hay and silages suggested that for small cereals and ryegrass, early spring harvest yielded the best forage characteristics [6]. In the current study, we observed a 3.2% decrease in CP for the summer months (Table 1). Similarly, Beck et al. [7] reported an 11.4% decrease in CP between November harvest and June harvest for the cool-season annual grasses. However, Buxton & Fales [8] saw little changes in CP levels. They suggested that each 1 °C increase in temperature would result in a 0.3-0.7 % decrease in digestibility.

In the current study, we saw the influence of temperatures on non-fiber carbohydrates (NFC), starch and percent of water soluble carbohydrates (%WSC). The higher temperatures of summer months significantly increase the levels of NFC, starch and WSC.

Table 1: Comparison of nutrients in sugarcane forages by season (winter = Oct. 15-March vs summer (May 15-Sept.); 2013- 2014.

Season	N*	CP	ADF	NDF	NFC	Starch	WSC	RFV
Winter (avg.)	120	11.32	43.34	71.22	8.99	0.52	5.07	72.33
SE		+ 0.12	+0.16	+0.35	+0.25	+0.06	+0.18	+0.46
Summer (avg.)	118	8.13	42.6	69.43	12.11	1.42	7.16	74.23
SE		+0.16	+0.23	+0.23	+0.35	+0.06	+0.16	+0.68
P- value		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

*The lower sample size in summer was due to some forages inability to recover from the harvest schedule and over time decreased in yield to the point it was no longer viable to consider them.

N: Sample Size; CP: Crude Protein; ADF: Acid Detergent Fiber; RFV: Relative Feed Value; NFC: Non-Fibrous Carbohydrates; WSC: Water Soluble Carbohydrates

Influence of time of harvest on nutrient composition of forages

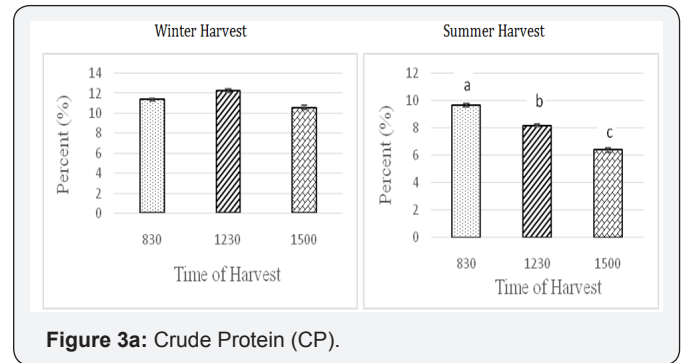


Figure 3a: Crude Protein (CP).

Figure 3 shows the average nutrient composition of the 40 sugarcane grasses in the trial. The times of harvest were: a) 830 h, b) 1230h and c) 1500h. The times were selected due to the following reasons: 1) sufficient day light in the winter months to allow harvesting, sampling, etc. and 2) consideration given to the research field staff who normally end their work day by 3pm. Each harvest and sampling took ~1h 15min. The nutrients presented in Figure 3 are: a) CP, b) ADF, c) NDF, d) NFC, e) Starch, f) %WSC and g) relative feed value (RFV).

In the winter season, CP was lowest at the 1500h harvest and highest at 1230h. In the summer months, CP was also lowest at the 1500h harvest but was highest at the 830h harvest (Figure 3a). Kephart & Buxton [9] found that imposing shade on forage grasses increased CP values but that this was often at the expense of yield and soluble carbohydrates.

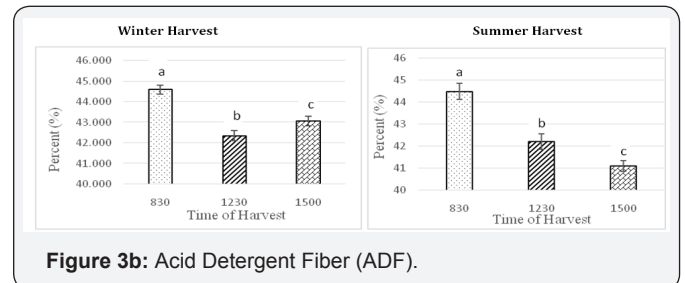


Figure 3b: Acid Detergent Fiber (ADF).

The ADF was highest at 830h harvest for both winter and summer months (Figure 3b). It was lowest in the harvests past noon. The summer ADF at the 1500h harvest was the lowest at 41% compared to >44% at the 830h harvest (p<0.01). The winter months saw the lower NDF at 1230h and 1500h harvest compared to 830h harvest (p<0.01, Figure 3c). However, no significant differences were observed in the levels of NDF in the summer harvest time although the 1230h harvest was the lowest. Two factors probably played a role in these difference: the rapid growth rate due to higher ambient temperature and the intense solar radiation on the plant tissue which may have contributed to the lack of difference in the NDF observed in the summer harvest.

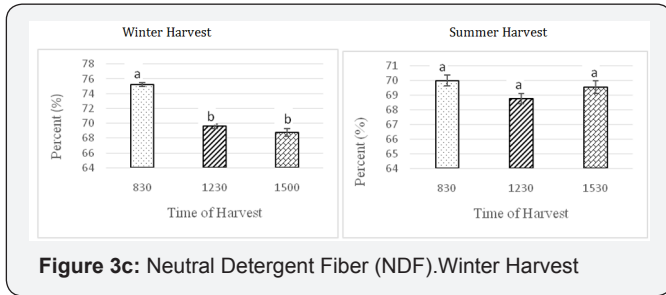


Figure 3c: Neutral Detergent Fiber (NDF). Winter Harvest

High levels of NDF and/or ADF have negative effect on dry matter intake. The high levels of NDF increased retention time in the gut thus contributing the “gut fill” factor [9,10]. Both NDF and ADF contribute to increased chewing time [11-13].

The NFC content for summer (Figure 3d) showed increasing values with respect to harvest time with the 1500h harvest having 2x the NFC values compared to 830h harvest (14.83 vs 7.84%. $P < 0.01$). Similarly this was true for the winter harvest where the 1500h harvest time yielded 2x NFC content compared to 830h harvest (11.83 vs 6.08 %, $P < 0.01$).

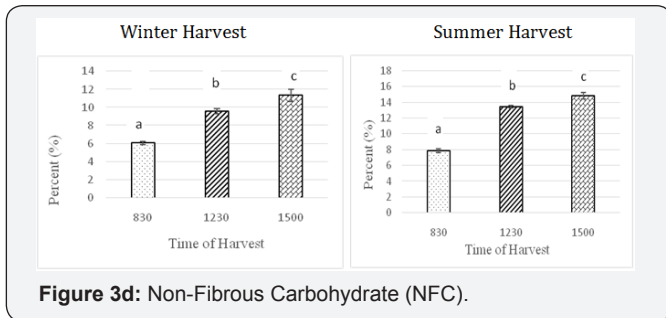


Figure 3d: Non-Fibrous Carbohydrate (NFC).

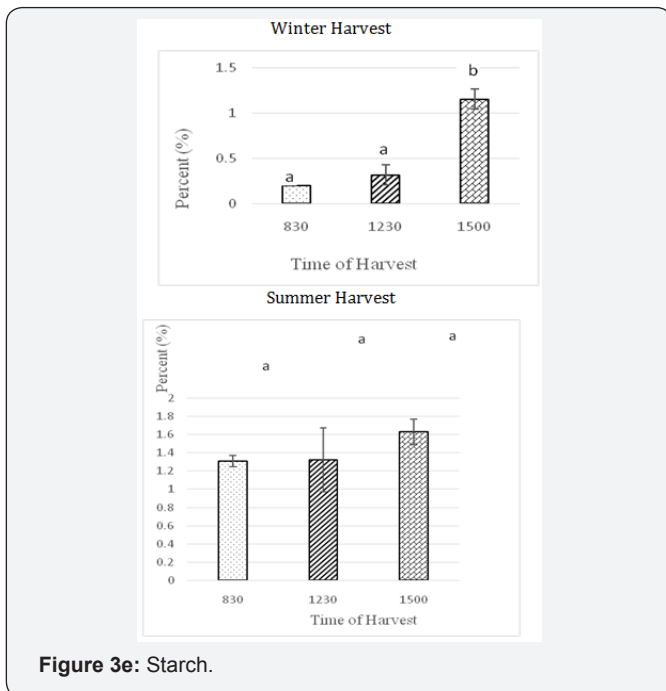


Figure 3e: Starch.

In the winter months, the starch concentrations increased in the plants over the course of the day. The 1500h harvest had 5x the starch level compared to the 830h harvest; (1.16 vs

0.2, $p < 0.01$, Figure 3e). This could be due to the influence of temperature, solar radiation and/or the genetics of the plant. In the summer months the variations in the starch concentrations were not as great although a higher level was observed at the 1500h harvest compared to 830h harvest (1.63 vs 1.31, $P < 0.01$). The level of starch was higher in the summer month’s vs the winter months. Again this can be attributed to the higher temperatures, the higher solar load and the genetic makeup of the forage in this project.

The WSC (%) for winter months reflects that of the starch concentration (Figure 3f). The 1500h harvest yielded 2x more WSC than the 830h harvest (6.7 vs 2.8%, $P < 0.01$). The WSC levels were very similar at all harvests times in summer months.

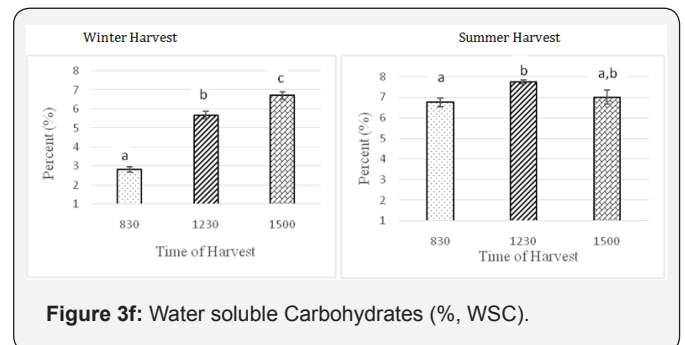


Figure 3f: Water soluble Carbohydrates (% WSC).

Fermentation of starch and carbohydrates in the rumen affects the bacteria population and subsequently the flow of microbial protein to the small intestine [14]. Microbial protein are “by-pass” protein; they provide solid protein for animal growth and milk production. Shenkoru et al. [15] showed that afternoon (PM) harvested alfalfa yielded higher butyrate acid and greater microbial nitrogen flow to the duodenum in ruminants when compared to morning (AM) harvested alfalfa.

Several studies have shown that dry matter intake and milk yield increased when dairy animals were fed afternoon harvested feed [16,17]. Kim et al. [16] reported 8% more dry matter intake and 8% more milk. Berthiaume et al. [17] showed 1.6kg/day more energy corrected milk and lower milk urea nitrogen suggesting better utilization of N by the microbes in the rumen.

The influence of harvest time on carbohydrate composition has been noted in Switch grass (C4 plant), tall fescue and alfalfa harvested in the afternoon (PM) vs the morning (AM) [18]. In the study using steers, sheep and goats, the researchers suggested that the animal showed a preference for afternoon-harvested grass hay. There was an indication that some animals were able to differentiate the PM- vs AM-harvested forages by smell. This preference seems to be associated with the higher concentration of total nonstructural carbohydrates. In another study, Huntington et al. [19] concluded that PM-harvested gama grass hay had 7% greater dry matter intake in goats and 17% greater dry matter intake in steers than AM-harvested gama grass. They attributed this to the higher total non-fibrous carbohydrates in forages in the PM harvest. These observations concurred those

reported with alfalfa harvested at sunrise and sunset 20].

Studies suggest that genetic contribution may enhance starch and carbohydrates by ~13% for alfalfa but time of harvest contributes 46% higher values for these components [21]. Tremblay et al. [22] demonstrated that PM harvest had higher NSC than AM-harvest for spring, summer and fall. The higher concentrations of sugars were not affected during the wilting process.

The above studies may help to explain the earlier observation that the dairy heifers were going out to graze at mid-afternoon. The sun and solar radiation might be high but the forages on the pasture offered the best nutrition due to the photosynthesis. The plants had low fiber and high sugar and starch contents (high energy) at that time of the day. Energy is one of the limiting factor for high milk production or better weight gains. Similar grazing behavior was observed by Gregorini et al. [23] where dusk grazing was observed to be of greater intensity and duration. Griggs et al. [24] confirmed higher soluble carbohydrates in PM vs AM forage. This suggests that cattle are driven to maximize intake based on energy needs.

The relative feed value (RFV) within a season also showed that PM harvested forages had higher RFV, (Figure 3g). In the winter months, early harvest at 0830 yielded the lowest RFV (67.05) compared to the 1500h harvest which had an RFV of 75.05. The RFV for the forages was 72.15 for the 830h harvest and this value was higher than that of winter probably due to higher solar and temperature for the season. The 1500h harvest RFV was 76.25 and this was higher than the 830h harvest ($P < 0.01$).

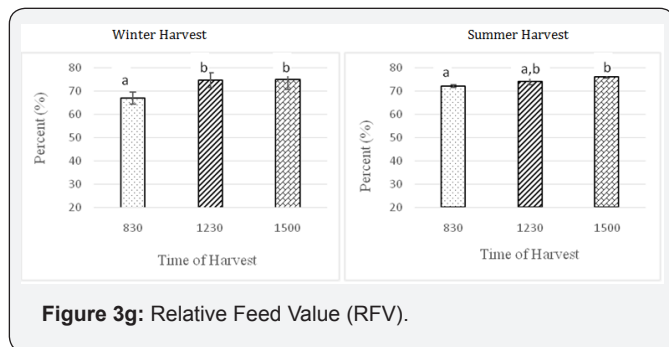


Figure 3g: Relative Feed Value (RFV).

Impact

The cumulative information from this study and others available in the literature explains why cattle grazed with such concentration and vigor in the late afternoon. For several years, it was observed that cattle at the Cloverleaf Dairy in Hawi, Kohahla district, would go out to the pasture to graze in the mid-afternoon (1430h) when the heat was intense and the solar radiation load was high during this time of the day [25]. Yearling dairy heifers in Kohala district compromised their homeostatic status to feed even when the temperature-humidity index was above 84, Figure 4. This THI is considered a severe heat stress condition. The grazing behavior can now be explained by the higher feed value of the forages in the afternoon. The data further suggest

that for those making hay or bio-fuel from forages, PM harvest will yield higher quality product.



Figure 4: Yearling Holsteins heifers grazing on pasture at 1430h in the Kohala district.

Summary

This study demonstrated that season and time of harvest can influence the nutrient composition of the forages. The time of harvest has the greatest influence on the starch, NFC, WSC and ADF values and all these factors will impact animal performance.

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References

1. The National Climate Data Center (2015) Average annual sunshine by state. Days of sunshine per year in Hawaii.
2. Ball D, Collins M, Lacefield G, Martin N, Mertens D, et al. (2001) Understanding forages quality. Published by University of Kentucky, UK, pp. 1-20.
3. Lee CN, Fukumoto GK, Nakahata M, Ogoshi RM (2014) Sugarcane crosses as potential forages for ruminants: Phase 1-Selection Criteria. Pasture and range management, College of Tropical Agriculture and Human Resources (CTAHR), PRM 6, pp. 1-7.
4. Buxton D, Fales SL (1994) Plant environment and quality. In: Fahey GC (Ed.), Forage quality, evaluation, and utilization. American Society of Agronomy, Madison, USA, pp. 155-199.
5. Ohlsson C (1991) Growth development, and composition of temperate forages legumes and grasses in varying environment.
6. Beck P, Jennings J (2013) Using cool-season annual grasses for hay and

- silage. University of Arkansas, USA, pp. 1-6.
7. Beck P, Gadberry S, Jennings J (2013) Using cool-season annual grasses for grazing livestock. University of Arkansas, USA, pp. 1-8.
 8. Buxton D, Fales SL (1994) Plant environment and quality. In Forage quality, evaluation, and utilization. FaheyGC (Ed.), American Society of Agronomy. Madison, WI, USA, pp. 155-199.
 9. Kephart KD, Buxton DR (1993) Forage quality responses of C 3 and C 4 perennial grasses to shade. *Crop Sci* 33(4): 831-837.
 10. Allen M, Oba M (1998) Digestibility of forages fiber-variation, measurement and relationship to animal performance.
 11. Belyea RL, Stevens B, Garner G, Whittier JC, Sewell H (1993) Using NDF and ADF to balance diets.
 12. Firkins JL (2010) Feeding by-products high in concentrations of fiber to ruminants.
 13. Norgaard P, Nadeau E, Randby A, Volden H (2011) Chewing index system for predicting physical structure of the diet. *European Fed of Anim Sci* 30: 127-132.
 14. Ferguson JD (2015) Carbohydrates fraction in dairy ration. In *Penn Vet Medicine: Dairy Nutrition*.
 15. Shenkoru T, Hussein H, Wuliji T (2006) Influence of cutting time and swath type on intake, site and ruminal metabolism of alfalfa hay. *J Anim Sci* 86(Suppl1): 27.
 16. Kim D, Mayland HF, Arambel MJ, Kent B (1995) Morning or Afternoon Harvested Alfalfa Hay Affects Intake, Digestibility, and Milk Production by Dairy Cows. *J Dairy Sci* 78(Suppl): 273.
 17. Berthiaume R, Tremblay GF, Belanger G, Bertrand A, Csatonguay Y, et al. (2013) High quality forages: How sweet should they be? *WCDS Advances in Dairy Technology* 25: 235-254.
 18. Maryland HF, Kimberly E, Shewmaker GE, Fisher DS, Burns JC (2000) Diurnal variation in forage quality affects animal preference and production. University of Wisconsin Extension, Wisconsin Forage Council proceedings.
 19. Huntington GB, Burns JC, Sauve AK (2004) Afternoon harvest increases intake and digestibility of forages for goats and cattle.
 20. Burns JC, Mayland HF, Fisher DS (2005) Dry matter intake and digestion of alfalfa harvested at sunset and sunrise. *J Anim Sc* 83(1): 262-270.
 21. Chouinard-Michaud C, Michaud R, Castonguay Y, Bertrand A, Belanger G, et al. (2010) Time of cutting and genetic selection affect non-structural carbohydrates and some attributes of nutritive value in alfalfa.
 22. Tremblay GF, Morin C, Belanger G, Bertrand A, Castonguay Y, et al. (2011) The effects of cutting time (pm vs am) and swathing on the concentration of non-structural carbohydrates during wilting of alfalfa. *WCDS Advances in Dairy Technology* 23: 388.
 23. Gregorini P, Tamminga S, Gunter SA (2006) Review: Behavior and daily grazing patterns of cattle. *The Professional Anim Scientist* 22: 201-209.
 24. Griggs TC, MacADam JW, Mayland HF, Burns JC (2004) Integrating daily patterns of pasture soluble carbohydrate level and grazing behavior. *Proc Pacific Div Amer Assn Advance Sci* 23: 50.
 25. Lee CN, Hillman PE (2007) Thermal responses of Holstein dairy cows on pastures with high solar loads and high winds. *The 6th Int'l Dairy Housing Conf Proceedings Minneapolis, USA*, pp. 253-259.



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