Non-Structural Carbohydrates in Cool Season Grasses

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SUMMARY

A relatively new (commercially available) analysis used to evaluate grass forage quality is measurement of total nonstructural carbohydrates (TNC). Carbohydrates drive the efficiency of the rumen in the cow and the ensiling process. In the rumen, increasing TNC increases the use of rumen degradable protein, consequently increasing microbial protein production. During the ensiling process, increasing TNC increases the rate of fermentation that increases the preservation of the ensiled nutrients. One recent study looking at forages bred for higher TNC, reported dairy cows had higher dry matter intakes and 8% higher milk production than cows fed typical ryegrasses. They also observed differences in efficiency of use of feed nitrogen, as indicated by changes in nitrogen excretion in the urine. Authors theorized this was primarily due to differences in the microbial capture of rumen degradable nitrogen. This data also suggests that selecting forages with higher TNC not only increases animal performance, but may have the potential to increase nitrogen utilization and reduce nitrogen excretion. The objectives of this study were: 1) To sample TNC and dry matter (DM) yield of cool-season forage grasses throughout the growing season. 2) In year 1, to look specifically at seasonal and diurnal variations in cool season grasses and observe potential variations in the relationship between the level of TNC and DM yield among species and varieties of cool-season forage grasses. 3) In year 2, to plant 10 new varieties potentially high in sugars including varieties studied in grazing trials in the UK and determine total sugar production throughout the season. Non-structural carbohydrates in cool season grasses do significantly vary between varieties, species, from am to pm and seasonally. The variations found appear tremendous and can be difficult to document because of their enormous variation. However, this project was able to demonstrate that certain cultivars and varieties consistently were higher in non-structural carbohydrates than others. In year 2, data collection focused on documenting the total pounds of sugars or nonstructural carbohydrates produced. Amazon ryegrass averaged the highest percent non-structural carbohydrates throughout the season at 20.9% with Impact the lowest at 16.3%. When we determined total dry matter produced and, consequently, total non-structural carbohydrates produced, the ryegrass variety from the UK, Aberavon, was the highest at 2306 lbs/acre. This variety is one in particular that has been bred in Europe to be higher in non-structural carbohydrates than most ryegrasses. This two-year project has been extremely helpful in characterizing non-structural carbohydrates in cool season grasses. We have documented the normal fluctuations seen across environments and, more specifically, variations due to genetic differences. The main conclusions are: 1)

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Percentages of non-structural carbohydrate are highly variable throughout the growing season and between species and varieties of cool-season forage grasses. 2) Growth rate may affect the level of TNC in cool-season forage grasses. 3) Orchard grasses consistently contained lower levels of TNC and higher DM yields than did ryegrasses. 4) Grasses bred in Europe to emphasize non-structural carbohydrates are higher in sugars than the average of the population found in the US, however, not 25% higher as reported in European studies. 5) In the future, the livestock industry will have new criteria for selecting forages.

INTRODUCTION

Forage grass production is a major component of profitable dairying in the Pacific Northwest. Grazing forage grasses with both milk cows and heifers has been a well-established practice. In more recent years, intensive grazing and mechanical harvesting of grasses have also been common. In order to remain profitable, dairies have invested heavily in their own forage systems to provide the feed resources needed for their cowherds.

Grass cultivars are normally selected for yield and resistance to disease and pests. From a milk production standpoint, quality, palatability and intake are very important. Dry matter intake must be at a level where the animal can meet her physiological requirements and other production goals such as milk volume and reproduction. Little is actually known about animal preference, and researchers are just beginning to learn more about cultivar palatability and intake potential. The need to understand performance differences between cultivars is of growing importance.

A relatively new (commercially available) analysis used to evaluate grass forage quality is measurement of total nonstructural carbohydrates (TNC). Carbohydrates drive the efficiency of the rumen in the cow and the ensiling process. In the rumen, increasing TNC increases the use of rumen degradable protein, consequently increasing microbial protein production. During the ensiling process, increasing TNC increases the rate of fermentation, which increases the preservation of the ensiled nutrients (Woolford, 1984).

The overall efficiency of grass nitrogen utilization for milk production tends to be low, due partly to the slow rate of release of energy in the rumen. On fresh forages, up to 40% of the dietary nitrogen may be lost as rumen ammonia because the microbial population in the rumen is unable to incorporate much of the nitrogen released due to lack of available carbohydrate (Scollan et al., 1998). This reduces the efficiency of capture of rapidly degradable plant proteins by the rumen microbial population. When additional sugars are introduced to the rumen, microbial protein is increased (Rooke et al., 1987).

Plants vary diurnally in concentrations of TNC because the export of photosynthate does not keep pace with the rate of carbon fixation during the photoperiod. This is why the highest concentrations of TNC have been observed in late afternoon cut forages (Fisher et al., 1999). Plants accumulate sugars during the day and use them up at night. Cutting forages during the late afternoon (PM) captures much of this extra sugar, resulting in higher feed values than in morning cut (AM) feed (Shewmaker et al., 1999). Researchers at USDA-ARS in Idaho in collaboration with others have conducted several trials measuring animal preference for pm cut forages over forages cut in the morning (Mayland et al., 2000; MacKay et al., 2003).

Very little work has been done on the natural variations between cultivars in sugar content. Tava et al. (1995) reported that three tall fescues varieties having 133g kg^{-1} water soluble carbohydrates were considered more palatable to cattle than three others having only 108 g kg^{-1}. Similar observations were made by Shewmaker et al. (1997) in their study of eight different fescues. In a study examining palatability, researchers reported three tall fescue varieties having 13.3% water-soluble carbohydrates were considered more palatable to cattle than three others having only 10.8%.

Researchers at the Institute of Grassland and Environmental Research (IGER) in the United Kingdom have begun to look at selecting ryegrasses for higher total nonstructural carbohydrates. One study looking at forages bred for higher TNC reported dairy cows had higher dry matter intakes and 8% higher milk production than cows fed typical ryegrasses (Miller et al., 1999). They also observed differences in efficiency of use of feed nitrogen, as indicated by changes in nitrogen excretion in the urine (Miller et al., 2001). Authors theorized this was primarily due to differences in the microbial capture of rumen degradable nitrogen. This data also suggests that selecting forages for higher TNC not only increases animal performance, but may have the potential to increase nitrogen utilization and reduce nitrogen excretion. Studies on other species also indicate that high sugar grasses can significantly improve live weight gain in grazing animals (Lee et al., 1999).

Oregon's livestock industry produces forage on approximately 2 million acres of pasture annually. The combination of sales cattle, calves, sheep and dairy products were estimated to have a combined gross sales of over 780 million dollars in 2001, making this industry the 2nd largest agriculture industry in the state (Oregon Agricultural Statistics Service, 2001-02). The ability of these industries to compete depends primarily on their ability to produce and convert low cost forages into high value agricultural commodities.

Understanding the variation in carbohydrate levels of forage varieties used in Oregon should have significant impacts on livestock profitability. For example, this past year Tillamook County dairymen produced 80 million dollars worth of milk. If forages could be identified that would increase productivity 8%, Tillamook County dairymen productivity would be positively impacted by 6.4 million dollars a year. There are many assumptions in these numbers, but advances being made in improving understanding of the TNC in grasses could potentially have significant economic impacts on the livestock industries of the west coast.

NONSTRUCTURAL CARBOHYDRATE STUDIES AT OREGON STATE UNIVERSITY

This author's interest in nonstructural carbohydrates in grasses began in 2000 after listening to Dr. Hank Mayland speak about his work at the USDA-ARS, in Kimberly, ID. Mayland presented a talk at this nutrition meeting highlighting the diurnal variations he had observed in alfalfa. He also referenced the grass breeding projects that had begun in the UK at IGER. Surprisingly, little data existed on natural variations in cool season grass populations. Therefore, it was decided, the first year, to test a number of cool season grasses that were currently being used in Oregon to determine how much variation existed in the varieties. Several of the varieties tested were developed in New Zealand, some were from Europe and a few were grown locally as an Oregon products.

The objectives of this study were: 1) To sample TNC and DM yield of cool-season forage grasses throughout the growing season. 2) In year 1, to look specifically at seasonal and diurnal variations in a large population of cool season grasses and observe potential variations in the relationship between the level of TNC and DM yield among species and varieties of cool-season forage grasses. 3) In year 2, to plant 10 new varieties potentially high in sugars including varieties studied in grazing trials in the UK and determine total sugar production throughout the season.

Year 1

Eleven perennial ryegrasses, four orchard grasses, one festolium, and one prairie grass were planted in 4 x 25' field plots in Tillamook, Oregon. Three replicates of each variety were planted. Each of the 51 field plots was harvested on six sampling dates in the 2001-growing season. For each of the six dates, DM yield of each field plot was recorded. For three harvest dates, April, June, and October, forage samples were collected for TNC analysis in both the early morning and late afternoon. Immediately after cutting, samples were placed on dry ice to reduce respiration losses and subsequently frozen. Later, samples were dried in an oven at 50^0C. TNC analyses were performed at Dairy One Lab, Ithaca, NY.

Year 2

Ten perennial ryegrasses were identified as being possible high sugar grasses from forage breeders. Surprisingly, very few grass seed companies could even provide varieties they knew were high. I did plant Aberdart and Aberavon from IGER in the UK. Cultivars were planted in 4' x 25' field plots and replicated three times similar to year 1. Each of the 30 field plots was harvested on six sampling dates in the 2002-growing season. Immediately after cutting, samples were placed on dry ice to reduce respiration losses. Samples were dried in an oven at 50^0C. TNC analyses were performed at Dairy One Lab, Ithaca, NY.

RESULTS AND DISCUSSION

Non-structural carbohydrates in cool season grasses do vary significantly between varieties, species, from am to pm and seasonally. The variations found appear tremendous and can be difficult to document because of their enormous variation. However, this project did demonstrate that certain cultivars and varieties consistently were higher in non-structural carbohydrates than others. Table 1 shows the non-structural carbohydrate data for year 1. This table reports the varieties studied and the actual percent non-structural carbohydrate value for the testing period. A few varieties appeared to fluctuate more from am to pm than others. However, all varieties demonstrated some variation. Varieties are listed by average non-structural carbohydrate concentration from the highest to lowest. The value in the far right column labeled "total" is actually an index that rates varieties. The highest varieties are all ryegrasses. Matua, a prairie grass, ended up averaging in the middle of those varieties tested. he festuolium Barfest averaged below all the ryegrasses and just above the orchard grasses. All four varieties on the bottom of the table are orchard grasses. Figure 1 illustrates the relationship observed between nonstructural carbohydrates and dry matter yield.

In year 2, data collection focused on documenting the total pounds of sugars or nonstructural carbohydrates produced. Table 2 illustrates the actual TNC data by cutting. Amazon ryegrass averaged the highest percent non-structural carbohydrates throughout the season at 20.9% with Impact the lowest at 16.3%. When we determined total dry matter produced and, consequently, total non-structural carbohydrates produced, the ryegrass variety from the UK, Aberavon, was the highest at 2306 lbs/acre. This variety is one in particular that has been bred in Europe to be higher in non-structural carbohydrates than most ryegrasses.

CURRENT PROJECTS

This past summer a couple of additional projects have taken place. Data are not yet available yet; however, a brief description of current work follows. The objectives of these projects are: 1) To determine if cows fed green chop with high or lower nonstructural carbohydrates differ in rumen pH, ammonia, volatile fatty acid profiles, feed intake and milk production and 2) To identify differences in pH and profiles of fermentation products between three high nonstructural carbohydrate grasses and one lower TNC ensiled grass.

Experime nt 1 – Green Chopping Forages

Eight cows were assigned to either the high sugar green chop group or the low sugar group. Cows were assigned at random and corrected for lactation number and stage of lactation. Two cows in each treatment were cannulated. Each animal was individually fed for 6 weeks. Forages were cut twice per day, once in the morning and once in the evening and offered *ad libitum*. Cows were supplemented two times per day with a total mixed ration formulated to meet nutrient requirements. Daily milk weights were recorded in addition to intakes. Milk urea N and milk components were evaluated at day 15 to 30. On days 28, 29, and 30 of the treatment period rumen samples were collected and analyzed for pH, ammonia, and acetic, butyric, and proprionic acids.

Experiment 2 – Ensiling Forages

Three varieties of grasses with high nonstructural carbohydrates were chosen as treatments and a variety with lower TNC content was chosen as a control. Forages were ensiled according to standard moisture content, particle size, and compaction rate. Six samples of each variety were ensiled, three per treatment for morning cut forages and three per treatment for late afternoon cut forages. The silage samples will be analyzed for pH, acetic acid, butyric acid, and lactic acid. The green chop and silage projects were conducted and are being summarized by Annette Buyserie, OSU Masters student. Results should be available later this fall.

CONCLUSION

This two-year project has been extremely helpful in characterizing non-structural carbohydrates in cool season grasses. A lot has been learned about the normal fluctuations seen across environments and, more specifically, variations due to genetic differences. The main conclusions are:

1) Percentages of non-structural carbohydrate are highly variable throughout the growing season and between species and varieties of cool-season forage grasses.

2) Growth rate may affect the level of TNC in cool-season forage grasses.

3) Orchard grasses consistently contained lower levels of TNC and higher DM yields than did ryegrasses.

4) Grasses bred in Europe to emphasize non-structural carbohydrates are higher in sugars than the average of the population found in the US; however, not 25% higher as reported in European studies.

5) In the future, the livestock industry will have new criteria for selecting forages.

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Table 1. Non-structural carbohydrate values for am/pm harvested cultivars in 2001

	4-20am	4-20pm	6-28am	6-28pm	10-1am	10-1pm	Total
Elgon	14.3	13.7	18.2	25.3	21.0	23.9	116.4
Tetralite	14.8	14.7	16.3	25.1	19.4	23.9	114.2
Herbie	11.5	13.3	19.2	25.9	19.6	21.7	111.2
BG-34	12.6	16.2	17.2	19.4	17.1	27.3	109.8
Tonga	15.8	21.7	16.0	20.6	15.2	20.0	109.3
Glenn	13.8	17.6	17.0	19.1	19.5	21.8	108.8
Bison	12.1	12.4	18.4	24.5	15.9	22.9	106.2
Matua	12.2	22.6	14.5	21.9	15.5	18.7	105.4
Barfort	14.4	18.0	14.0	23.5	13.8	20.3	104.0
Flanker	12.9	13.6	17.7	21.0	15.2	23.5	103.9
Belramo	12.5	14.1	14.6	19.2	18.3	17.5	96.2
Bronsyn	9.0	15.1	17.6	21.2	13.0	16.5	92.4
Barfest	11.7	15.9	13.5	12.2	13.3	21.8	88.4
Orion	14.3	11.9	17.1	22.4	10.2	11.1	87.0
Pizza	10.0	12.4	12.3	19.6	8.2	12.5	75.0
Cambria	9.7	14.8	9.1	15.6	10.3	12.8	72.3
Baridana	10.8	11.6	8.8	14.0	9.0	16.5	70.7

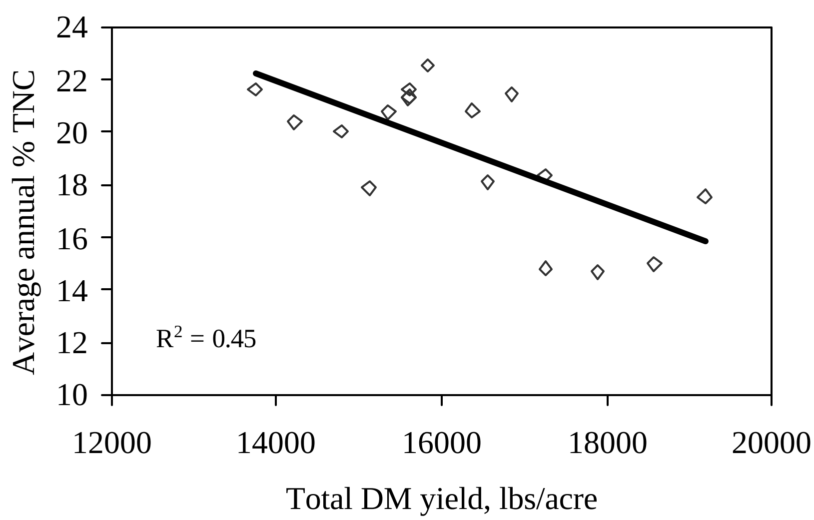

Figure 1. The relationship between nonstructural carbohydrate and dry matter yield throughout all sampling periods.

Table 2. Percent non-structural carbohydrate and total lbs of non-structural carbohydrates for cultivars harvested in 2002.

	3-Apr	26-Apr	13-May	13-Jun	31-Jul	3-Nov	Average
				% NSC			
Amazon	20.8	20.9	20.9	16.1	17.8	28.9	20.9
Aberavon	12.3	20.7	23.5	16.9	24.3	26.3	20.7
Faithful	23.8	20.3	23.3	12.3	15.8	26.5	20.3
Zero Yatsyn	17.6	18.3	20.6	13.5	16.4	23.5	18.3
Polly	18.3	18.2	23.7	15.6	14.9	18.3	18.2
Tivoli	20.8	18.1	20.6	13.1	13.3	22.7	18.1
TPM	18.6	17.1	22.4	13.3	14.4	18.6	17.4
Barmultra	16.2	17.9	24.7	12.1	14.9	18.5	17.4
Aberdart	14.2	17.2	21.2	12.3	12.3	26.4	17.3
Impact	19.4	16.3	19	9.6	13	20.5	16.3
				lbs NSC/acre			
Aberavon	119	444	679	452	256	356	2306
Amazon	229	358	455	462	206	377	2087
Barmultra	207	382	730	368	135	243	2065
Polly	248	407	665	388	132	218	2058
Zero Yatsyn	217	410	516	325	162	386	2016
Faithful	249	337	508	345	156	356	1951
TPM	234	324	565	374	176	271	1944
Tivoli	184	374	428	343	197	363	1889
Aberdart	118	369	513	263	185	431	1879
Impact	212	331	359	190	164	316	1572