HERBIVORE CARBOHYDRATE NUTRIENT ANALYSIS: THE NEXT GENERATION

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Abstract

The proximate analysis system attempted to separate dietary carbohydrates into fiber and non-fiber portions. Under this system, any matter unaccounted for after subtraction of ash, crude protein, ether extract, and crude fiber from total dry matter was assumed to be non-fiber carbohydrates. Due to loss of variable amounts of fiber (cellulose and hemicellulose) and lignin during analysis, the proximate analysis system frequently overestimated non-fiber carbohydrates and underestimated fiber to a degree that could not be determined. The neutral detergent system allowed accurate determination of fiber and lignin, improving the accuracy of non-fiber carbohydrate (NFC) estimation, but with no differentiation between NFC fractions[9]. Non-fiber carbohydrates can be separated into sugars, starch, organic acids, and pectic substances known as neutral detergent-soluble fiber (NDSF), distinct fractions which merit individual consideration in diet formulation.

Emerging evidence suggests that plant materials consumed by wild browsing ruminants may contain variable, but moderate, levels of sugar and very low starch[3,5]. Vegetative material in general typically contains little starch, unlike grain-based concentrate feeds. While grain-based rations are commonly used to maximize production in domestic ruminants, they are frequently associated with digestive disorders such as ruminal acidosis and related health problems[6]. Feeding trials using domestic ruminants have demonstrated beneficial changes in ruminal pH, fermentation patterns, VFA concentrations and diet digestibility associated with partial or total replacement of high sugar and/ or starch feeds with feedstuffs high in NDSF[1,2]. Such changes may have resulted from the differing fermentation characteristics of these NFC and their impact on the rumen environment.

The importance of NDSF in zoo ruminant diets has not been widely investigated, but this NFC displays unique fermentation characteristics with nutritional and health implications. Rapid organic acid production and the strength of the acids produced affect ruminal pH, and reduction of pH <6.0 alters microbial population and nutrient digestion. The moderate fermentation rate of NDSF (digestion/ hour rate of 5 to 50% versus 75 to 400% for sugars and 2 to 14% for fiber)[7] and lack of lactate production[8] may avoid the unfavorable reductions in ruminal pH often associated with starch and sugars. High concentrations of acetate resulting from fermentation of pectin at neutral pH (twice the levels from sugar or starch)[8] further suggest that NDSF may play an important role in meeting energy needs while maintaining ruminal stability and long-term health in zoo ruminants.

The current method of determining NDSF concentrations is: (ethanol insoluble residue (EIR) organic matter – EIR crude protein) – (neutral detergent insoluble fiber (NDF)

organic matter – NDF crude protein)-starch[4]. While this provides the most accurate means of NDSF determination, not all of the necessary analyses are readily available to the zoo community. Samples of alfalfa hay (n=6), a sweet feed (n=5), and a commercial browser pellet (n=5) previously analyzed for NDSF concentration were used for estimation of NDSF by difference. Based on analyses that can be performed at commercial laboratories, NDSF was estimated using two equations: NSDF=DM-(ash+(NDF-NDFCP)+CP+fat)-(sugar+starch) (Method 1) and NDSF=DM-(ash+NDF+CP+fat)-(sugar+starch) (Method 2). Results of each method were compared with analyzed NDSF using single-factor Anova. Values calculated using method 1 did not differ ($p>0.05$) from analyzed NDSF for any of the feeds. When nutrient concentration is estimated by subtraction, missing nutrient values and analytical errors decrease accuracy of the calculated value. Method 2 contains no direct measure of crude protein tied up in cell walls (NDFCP); NDFCP is subtracted twice, as part of both NDF and CP, resulting in overestimation of NDSF. Values calculated using method 2 differed ($p<0.05$) from analyzed NDSF. The practical impact of NDFCP exclusion appears lower in concentrates than forage (Table 1). Values calculated using method 1 appear similar enough to analyzed values to be biologically useful until NDSF analysis becomes more readily available on a commercial scale (Table 1). Laboratory analyses of 5 concentrates and 5 hays fed to zoo ruminants reveal wide variation in sugar, starch, and estimated NDSF concentrations (Table 2). Further consideration should be given to concentrations of these distinct NFC fractions and their impact on zoo ruminant nutrition.

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Table 1. Neutral detergent-soluble fiber (NDSF) concentrations as determined by analysis and calculated difference*

	Omelene 200[d] (n=5)	Mazuri Browser Breeder (n=5)	Alfalfa Hay (n=6)
Analyzed[a]	6.93 ($\pm$ 0.35)$^{+}$	10.63 ($\pm$ 0.33)$^{+}$	15.20 ($\pm$ 0.33)$^{+}$
Calculated[b]	7.62 ($\pm$ 0.28)$^{+}$	9.71 ($\pm$ 0.28)$^{+}$	17.25 ($\pm$ 0.94)$^{+}$
Calculated[c]	9.50 ($\pm$ 0.28)$^{++}$	12.67 ($\pm$ 0.28)$^{++}$	19.44 ($\pm$ 0.82)$^{++}$

*Means $\pm$ standard errors. All values reported as a percent of sample dry matter.

*Fat values estimated using manufacturer specifications and NRC values.

$^{+}$Means with different superscripts in columns differ (p<0.05)

[a](Ethanol insoluble residue (EIR) organic matter-EIR crude protein)-(NDFOM-NDFCP)-starch

[b]100-(ash+(NDF-NDFCP)+CP+fat)-(sugar+starch)

[c]100-(ash+NDF+CP+fat)-(sugar+starch)

[d]Purina Mills, Saint Louis, MO

Table 2. Sugar, starch and calculated neutral detergent-soluble fiber (NDSF) concentrations (as % of dry matter) in ten zoo browser feedstuffs*

Feed	Sugar	Starch	NDSF[a]	NDSF[b]
Pellets				
Mazuri ADF 16	9.20	22.10	7.63	
Mazuri Browser Maintenance	11.70	5.30	11.30	
HMS ADF 16	5.50	26.50	6.04	
HMS ADF 25	9.00	11.60	5.50	
HMS Browsing Rhino	6.20	21.70	7.27	
Purina Equine Senior	7.90	16.00	7.35	
Forages				
Alfalfa Hay	9.30	2.40	15.90	17.50
Timothy Hay	14.60	5.50	1.43	2.23
TNT Chops[c]	11.90	3.70	14.23	19.33
Orchardgrass/ Alfalfa Hay	9.00	2.50	8.16	13.46
Brome Hay	9.10	1.80	7.49	10.29

*Calculated from analysis of single samples of each feed.

[a]100-(ash+(NDF-NDFCP)+CP+fat)-(sugar+starch)

[b]100-(ash+NDF+CP+fat)-(sugar+starch)

[c]Blend of chopped alfalfa hay and molasses. TNT Forage Inc., Archie, MO.