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J.S. Heldt

R.C. Cochran

C.P. Mathis

See next page for additional authors

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Effects of various carbohydrate sources on the utilization of low-quality tallgrass-prairie hay in continuous culture

Abstract

We evaluated the effects of supplemental carbohydrate sources on the utilization of low- quality forage in continuous "artificial rumen"? culture. Providing readily digestible carbohydrates (starch, glucose, and fiber) did not improve total diet digestion. In fact, starch and glucose depressed fiber digestion. Response to other simple sugars was variable.

Keywords

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Authors

J.S. Heldt, R.C. Cochran, C.P. Mathis, Evan C. Titgemeyer, and Tiruvoor G. Nagaraja

EFFECTS OF VARIOUS CARBOHYDRATE SOURCES ON THE UTILIZATION OF LOW-QUALITY TALLGRASS-PRAIRIE HAY IN CONTINUOUS CULTURE

J. S. Heldt, R. C. Cochran, C. P. Mathis, E. C. Titgemeyer, and T. G. Nagaraja

Summary

We evaluated the effects of supplemental carbohydrate sources on the utilization of low-quality forage in continuous "artificial rumen" culture. Providing readily digestible carbohydrates (starch, glucose, and fiber) did not improve total diet digestion. In fact, starch and glucose depressed fiber digestion. Response to other simple sugars was variable.

(Key Words: Digestion, Carbohydrate, Forage, Continuous Culture.)

Introduction

Feeding supplements with a large amount of carbohydrate (CHO) can have different effects on forage utilization, depending on the source used. Supplemental starch has decreased utilization of low-quality forages, whereas nonstarch CHO sources such as fiber and glucose have had both positive and negative effects. Similar results were observed in recent research conducted at KSU, although the impact of CHO source tended to be dependent on the amount of supplemental degradable intake protein provided. The present study was designed to provide additional insight into the specific effects of various CHO sources on digestion and fermentation characteristics of low-quality tallgrass-prairie hay.

Experimental Procedures

In experiment 1, eight dual-flow contin- uous-culture flasks were used for two periods in a randomized complete block design. The four dietary treatments were forage only (negative control; NC) and forage plus either starch; glucose (supplied as commercial dextrose); or digestible fiber (FIBER; supplied as alkaline hydrogen peroxide-treated oat hulls). In experiment 2, nine dual-flow continuous-culture flasks were used for three periods in a randomized complete block design. The nine dietary treatments were forage only (NC), and forage plus pentoses (arabinose and xylose); hexoses (glucose, fructose, and galactose); or disaccharides (lactose, maltose, and sucrose). The same prairie hay (5.4% CP and 65.7% NDF) was used in both experiments. The experimental periods consisted of 5 days of adaptation and 3 days of sampling. The continuous-culture fermenters (554 mL) were designed to simulate ruminal fermentation and were each fed 16 g DM/day with a forage-to-CHO ratio of 4:1 (g DM/g DM). The fermenters contained ruminal microorganisms harvested from a ruminally cannulated steer maintained on a low-quality, prairie-hay diet. They were held at rumen temperature, and pH was maintained within levels that allowed for continuous growth and digestion by the microorganisms. A constant amount of nitrogen (urea) was infused into each flask each day as part of the buffer solution.

Results and Discussion

The source of supplemental CHO did not affect ($P \geq .49$) either apparent or true organic matter digestion (Table 1). However, starch and dextrose tended ($P \leq .11$) to decrease neutral detergent fiber (NDF) digestion compared to NC and FIBER. Part of the reason why supplemental

FIBER may not have affected NDF digestion was that the treated oat hulls were very digestible fiber sources. All supplemental CHO sources decreased ($P \leq .10$) flask pH below 6.2, which may have depressed forage digestion (Table 2). Including starch and dextrose both increased ($P \leq .08$) total VFA concentration and decreased ($P \leq .10$) the molar proportion of acetate, indicative of the fermentation of a highly available CHO. Propionate, acetate: propionate ratio, and butyrate were unaffected ($P \geq .10$) by supplemental CHO. The quantity of ammonia detected in the ruminal fluid was less than that for NC when starch was supplemented and was intermediate and similar to that for NC with the dextrose and fiber treatments.

In experiment 2 (Table 2), diet digestion was greater ($P \leq .10$) when sucrose was supplemented compared to NC. Most of the remaining supplemental sugars resulted in digestibilities intermediate between those for NC and sucrose. The only exceptions were arabinose and lactose, which provided values lower than sucrose. No differences ($P \geq .10$) occurred in NDF digestion between the pentoses or among the disaccharides. However, within the hexoses, glucose decreased ($P \leq .10$) NDF digestion compared to NC, whereas galactose and fructose did not. Two of the eight supplemental sugars decreased ($P \leq .10$) flask pH (Table 4) and four increased total VFA concentration compared with NC. Also, all supplemental sugars, except the pentoses, decreased acetate and increased butyrate proportions compared with NC. It is apparent that supplemental sugars differ in their effects on forage utilization. Clarifying those differences is necessary to effectively plan their incorporation into supplementation programs.

Table 1. Effects of Carbohydrate Source on OM and NDF Digestion in Continuous- Culture Fermenters

		Digestion, %			
Item	Control	Dextrose	Starch	Fiber	SEM
Apparent OM[c]	68.8	67.0	66.6	70.2	3.30
True OM	74.7	72.6	73.2	75.8	3.18
NDF[d]	72.4[ab]	64.0[a]	64.0[a]	73.7[b]	3.38

[a,b]Means in a row with uncommon superscripts differ ($P \leq .10$).
[c]OM = organic matter.
[d]NDF = neutral detergent fiber.

Table 2. Effect of Carbohydrate Source on pH, Total VFA Concentrations, and VFA Proportions in Continuous-Culture Fermenters

Item	Control	Carbohydrate: Dextrose	Starch	Fiber	SEM
pH	6.55^{b}	5.91^{a}	5.94^{a}	6.02^{a}	.11
Ammonia N, m*M*	17.6^{b}	14.4^{ab}	10.2^{a}	13.8^{ab}	1.81
Total VFA, m*M*	28.3^{a}	36.5^{b}	34.7^{b}	33.9^{ab}	1.76
	------------------------mol/100 mol---------------------				
Acetate	64.3^{b}	51.0^{a}	51.5^{a}	59.3^{ab}	3.85
Propionate	21.0	21.2	23.8	22.9	3.70
Acetate:Propionate	3.15	2.53	2.43	2.77	.51
Butyrate	13.7	23.5	22.4	16.7	4.24

^{a,b}Means in a row with uncommon superscripts differ (P ≤ .10).

Table 3. Effects of Sugar Source on OM and NDF Digestion in Continuous-Culture Fermenters

Treatment	Digestion, %: Apparent OM^{d}	True OM	NDF^{e}
Control	71.4	76.1^{a}	70.6^{c}
Arabinose	72.0	76.7^{a}	67.0^{abc}
Xylose	71.7	78.7^{ab}	63.4^{ab}
Fructose	72.7	79.4^{ab}	69.2^{abc}
Galactose	74.8	79.6^{ab}	71.4^{c}
Glucose	71.9	78.6^{ab}	62.8^{a}
Lactose	73.6	77.2^{a}	65.7^{abc}
Maltose	73.2	79.2^{ab}	68.4^{abc}
Sucrose	74.7	82.7^{b}	66.0^{abc}
SEM	2.53	1.77	2.90

^{a,b,c}Means in a column with uncommon superscripts differ (P ≤ .10).
^{d}OM = organic matter.
^{e}NDF = neutral detergent fiber.

Table 4. Effect of Sugar Source on pH, Total VFA Concentrations, and VFA Proportions in Continuous Culture Fermenters

Treatment	pH	NH_3-N, mM	Total VFA, mM	Acetate	Propionate	Acetate: Propionate	Butyrate
				- - - - - - - - - - - mol/100 mol - - - - - - - - - -			
Control	6.88^{b}	10.6^{b}	35.7^{a}	68.5^{d}	17.2^{a}	4.15^{b}	12.8^{a}
Arabinose	6.04^{a}	$73.^{a}$	53.5^{b}	63.3^{cd}	19.8^{ab}	3.21^{ab}	15.5^{a}
Xylose	6.09^{a}	6.6^{a}	51.5^{b}	57.4^{bc}	21.4^{b}	2.74^{a}	17.1^{a}
Fructose	6.22^{a}	7.4^{a}	47.7^{b}	48.4^{a}	17.0^{a}	2.99^{a}	32.1^{cd}
Galactose	6.28^{a}	7.4^{a}	46.9^{b}	55.2^{abc}	19.0^{ab}	2.99^{a}	24.6^{b}
Glucose	6.51^{ab}	8.3^{a}	43.2^{ab}	52.9^{ab}	16.9^{a}	3.32^{ab}	29.1^{bc}
Lactose	6.33^{a}	7.5^{a}	45.8^{ab}	48.0^{a}	16.8^{a}	3.04^{a}	30.4^{cd}
Maltose	6.37^{ab}	8.1^{a}	45.0^{ab}	50.7^{ab}	18.5^{ab}	2.88^{a}	29.1^{bc}
Sucrose	6.20^{a}	6.9^{a}	45.9^{ab}	47.1^{a}	16.6^{a}	3.05^{a}	34.6^{d}
SEM	.21	.87	4.53	3.33	1.69	.43	2.17

^{a,b,c,d}Means in a column with uncommon superscripts differ (P ≤ .10).