ENHANCED NITROGEN RETENTION IN YEARLING HORSES SUPPLEMENTED WITH YEAST CULTURE[1,2]

M. J. Glade and L. M. Biesik

University of Maryland[3]
College Park 20742

ABSTRACT

Diets consisting of whole shelled corn and a commercial pelleted feed were fed to growing yearling Thoroughbred horses with and without supplementation with urea or dried live yeast culture, in a 4 × 4 Latin-square design adjusted to account for residual effects. Supplementation with live yeast culture resulted in 7 to 13 g increases in daily net nitrogen retention as well as increases in hemicellulose digestibility. The proportion of fecal nitrogen that was water-solubleand therefore absorbable increased 47% with the addition of dried live yeast culture to the basal (corn and pellets) diet, suggesting that microbial production of ammonia and amino acids was enhanced. In contrast, the proportion of fecal nitrogen that was cell-bound increased 65% when the live yeast culture was added to the urea-containing diet, suggesting that the yeast culture acted by stimulating the conversion of recycled urea to microbial protein and amino acids.
(Key Words: Horses, Yeast, Nitrogen, Feed Conversion, Urea.)

Introduction

Increasing feed efficiency is a major goal of equine nutritionists. Enhanced feed-to-gain ratios are especially important when feeding young growing horses, horses undergoing intensive conditioning or horses recovering from illness or previous situations of feed inadequacy.

Several reports in recent years have described increases in feed efficiency resulting from the addition of live yeast cultures to the rations of finishing hogs (Chapple, 1981) and poultry (Thayer and Jackson, 1975; Day, 1977; Thayer et al., 1978). Godbee (1983) demonstrated increased nitrogen retention when 3-yr-old Quarter horses were fed diets supplemented with 112 g yeast culture daily. Yeast supplementation also has been reported to decrease daily feed-to-gain ratios in weanling and yearling horses (Mason, 1983).

The ability of yeast to increase nitrogen retention and rates of gain has not been explained. The addition of live yeast to the equine digestive tract may facilitate the fermentation of dietary fiber (Godbee, 1983). Enhanced microbial energetics may stimulate urea recycling, effectively improving the biological value or quality of the nitrogenous compounds absorbed from the cecum and large intestine (Glade, 1984).

The following study was conducted to assess the ability of supplemental live yeast to improve fiber digestibility, the efficiency and effectiveness of urea recycling and nitrogen retention in young growing horses.

Experimental Procedures

Four Thoroughbred yearlings (10 to 12 mo old) weighing between 310 and 330 kg were fed four different diets consisting of whole shelled corn, a commercial pelleted feed[4], dried live yeast culture[5] and livestock-grade urea (table 1). The diets were fed in a 4 × 4 Latin-square design arranged to account for potential carryover (residual) effects between periods (Cochran and Cox, 1957). This design differed from a typical Latin square in that the diet assignments

[1]Scientific Article No. A-4302, Contribution No. 7291 of the Maryland Agr. Exp. Sta. This research was supported in part by Diamond V Mills, Inc., Cedar Rapids, IA and by the Computer Sci. Center, Univ. of Maryland.
[2]Appreciation is expressed to Ms. M. Kempf for assistance in manuscript preparation and to Mrs. P. D'Andrea, Ms. D. Tate and Ms. J. Harris for technical assistance.
[3]Dept. of Anim. Sci.
[4]Pennfield Corp., Lancaster, PA.
[5]Diamond V Mills, Cedar Rapids, IA.
Received July 15, 1985.
Accepted January 20, 1986.

during the third and fourth periods were reversed. Consequently, every diet was followed by every other diet once.

A corn and pellet diet (CP) consisting of 28% whole shelled corn and 72% pelleted commercial feed was fed (table 2). The diet was formulated and fed in amounts that provided 100% of daily digestible energy (DE) and 93% of daily crude protein requirements for 325-kg yearlings (NRC, 1978; table 3). These levels were chosen to allow any beneficial effects of supplementation on nitrogen balance to be expressed, while preventing dietary energy from becoming limiting and altering the flow of nitrogen metabolism. A corn and pellet plus yeast diet (CPY) substituted 112 g dried live yeast culture for corn and pellets. A corn and pellet plus urea diet (CPU) was formulated to replace pre-formed protein with urea in order to load the urea recycling system while increasing the dietary protein deficiency, thus stimulating reliance on this system. The amounts of corn and pellets in this diet were calculated to provide 95% of daily DE and 77% of daily nitrogen requirements, with the remainder of the daily nitrogen requirement supplied by urea. The amounts of urea were determined by assuming that 100 mg urea nitrogen is equivalent to 28 mg protein nitrogen in 10 to 12-mo-old horses fed diets deficient in pre-formed protein (calculated from Godbee and Slade, 1981). A diet of corn and pellets plus yeast and urea (CPYU) was similar to the CPU diet, except for the addition of 112 g dried live yeast culture.

The horses were housed in individual 5 m^2 box stalls, were fed measured amounts of feed twice daily as described previously, and were allowed free access to water at all times. They were also allowed unlimited access to individual 5- x 15-m dirt exercise lots during the initial 14 d of each experimental period. Each 3-wk experimental period consisted of a 14-d diet adjustment followed by a 7-d metabolic balance study. For these studies, the horses were moved into individual 1- x 5-m metabolic collection stalls that allowed the separate and quantitative collection of urine and feces (Belling and Glade, 1984). While in these stalls, the horses were tethered in such a manner that they could freely shift about, lie down, rise, observe and communicate with other horses. A licensed veterinarian evaluated their health status daily; no medical complications were reported consequent to restraint in these stalls during this study.

Feed, water and excreta were sampled (Glade, 1984) and analyzed for dry matter

TABLE 1. COMPOSITION OF FEED INGREDIENTS FED TO GROWING YEARLING THOROUGHBRED HORSES

Nutrient	Ingredient			
	Corn[a]	Pellets[b]	Yeast culture[c]	Urea[d]
Dry matter (DM), %	87.65	89.49	92.55	90.63
Digestible energy, Mcal/kg DM	3.87	2.79	3.21	2.52
	% of DM			
Crude protein	10.3	14.3	14.3	291.7
Neutral detergent fiber (NDF)	14.3	48.5	31.4	.0
Acid detergent fiber	6.1	31.2	18.7	.0
Cellulose	4.7	22.8	13.7	.0
Hemicellulose	8.2	17.3	12.7	.0
Nitrogen				
Non-NDF-N	1.48	1.83	1.99	46.67
NDF-N	.17	.41	.29	.00
Total N	1.65	2.24	2.28	46.67
Lysine	.24	.81	.60	.00

[a]Whole shelled corn (IFN 4-02-931).
[b]"Green Pastures," Pennfield Corp., Lancaster, PA 17604.
[c]Live Saccharomyces cerevisiae, dried, Diamond V Mills, Cedar Rapids, IA 52407.
[d]Livestock grade.

(DM; AOAC, 1978), nitrogen (AOAC, 1978), neutral detergent fiber (NDF), hemicellulose, acid detergent fiber (ADF) and NDF-bound nitrogen contents (NDF-N; Goering and Van Soest, 1970). Feed and fecal energy contents were determined by bomb calorimetry (AOAC, 1978). The apparent digestibilities of these feed fractions and the net retention of nitrogen were calculated by difference. Lysine content of corn was estimated from published tables (NAS, 1971); lysine content of pellets and yeast was based on data supplied by the manufacturers. Nitrogen content of fecal samples was partitioned into water soluble and particulate fractions (Glade, 1984), and their relative contributions to the total fecal nitrogen excretion were calculated. The data were adjusted for carry-over (residual) effects by analyses of variance (Cochran and Cox, 1957). When the F ratio for adjusted treatment effects was significant, Tukey's HSD test for comparisons among means was applied (Cochran and Cox, 1957).

Results and Discussion

The digestibilities of DM, NDF and ADF were not significantly affected by the composition of the diets (table 4). Hemicellulose digestibility was significantly greater when horses were fed the CPY diet compared with the CP diet, and tended to be greater when they were fed the CPYU diet rather than the CPU diet. The digestibilities of total N, NDF-N, and non-NDF-N were not affected by yeast culture supplementation (table 4). It is unknown whether hemicellulose fermentation was directly enhanced by the yeast organisms, or whether the yeast triggered environmental changes in the large intestine that favored hemicellulose-fermenting organisms.

The addition of urea did not affect the digestibilities of the non-nitrogenous organic nutrients, but did result in significantly increased digestibility of nitrogen. This observation reflects the nearly total absorption of dietary urea by the equine upper digestive tract (Hintz and Schryver, 1972). However, urinary

TABLE 2. COMPOSITION OF DIETS WITH AND WITHOUT LIVE YEAST CULTURE OR UREA FED TO GROWING YEARLING THOROUGHBRED HORSES

	Diet			
Item	Corn + pellets	Corn + pellets + yeast	Corn + pellets + urea	Corn + pellets + yeast + urea
	g dry matter/d			
Ingredient				
Corn (IFN 4-02-931)	1,540	1,508	2,192	2,178
Pellets[a]	3,960	3,780	2,548	2,550
Yeast culture (IFN 7-05-520)[b]		112		112
Urea			160	160
Total	5,500	5,400	4,900	5,000
	% of feed dry matter			
Nutrient				
Neutral detergent fiber (NDF)	38.9	38.6	31.6	31.6
Hemicellulose	14.7	14.6	12.6	12.6
Cellulose	17.7	17.5	13.9	13.9
Acid detergent fiber	24.2	23.9	19.0	19.0
Nitrogen				
NDF-N	.34	.34	.29	.28
Non-NDF-N	1.73	1.75	1.61	1.61
Non-urea N	2.07	2.09	1.90	1.89
Urea N	0	0	1.53	1.50
Total N	2.07	2.09	3.43	3.41
Lysine	.67	.66	.56	.56

[a]"Green Pastures" Penfield Corp., Lancaster, PA 17604.
[b]Live Saccharomyces cerevisiae, dried, Diamond V Mills, Cedar Rapids, IA 52407.

TABLE 3. NUTRIENT INTAKES BY GROWING YEARLING THOROUGHBRED HORSES FED DIETS WITH AND WITHOUT LIVE YEAST CULTURE OR UREA

Item	NRC[a]	Diet: Corn + pellets	Corn + pellets + yeast	Corn + pellets + urea	Corn + pellets + yeast + urea
		Mcal/d			
Digestible energy					
Calculated	16.8	17.0	16.8	16.3	16.3
Measured		16.9	16.8	16.3	16.3
		g/d			
Neutral detergent fiber		2140	2028	1549	1579
Hemicellulose		809	790	619	631
Cellulose		975	947	683	696
Acid detergent fiber		1331	1293	930	949
Nitrogen					
Total N	122	113	113	168	171
Non-urea N		113	113	93	96
Urea N		0	0	75	75
Lysine		36.9	35.6	27.4	28.0

[a]NRC (1978) recommendations for 325-kg yearling horses.

TABLE 4. DIGESTIBILITIES OF FEED FRACTIONS OF DIETS WITH AND WITHOUT LIVE YEAST CULTURE OR UREA FED TO GROWING YEARLING THOROUGHBRED HORSES

Nutrient	Diet: Corn + pellets	Corn + pellets + yeast	Corn + pellets + urea	Corn + pellets + yeast + urea	SE[a]
	apparent digestibility, % of intake				
Dry matter	71.8	78.4	73.6	75.9	4.2
Neutral detergent fiber (NDF)	56.5	71.0	62.0	64.2	4.6
Hemicellulose	51.4[b]	78.5[c]	53.6[b]	66.8[bc]	5.0
Acid detergent fiber	58.0	68.5	58.5	54.8	4.1
Nitrogen					
Total N	52.9[d]	57.6[d]	76.2[e]	73.5[e]	1.9
NDF-N	62.7	67.9	66.3	56.8	3.0
Non-NDF-N	51.1[d]	55.7[d]	77.2[e]	75.0[e]	2.4

[a]Pooled standard error of a mean.
[b,c]Means within a row without a common superscript differ ($P<.05$).
[d,e]Means within a row without a common superscript differ ($P<.01$).

excretion of nitrogen was also increased following urea supplementation (P<.05; tables 2 and 4), reflecting the relatively low biological value of dietary urea (Hintz and Schryver, 1972; Godbee and Slade, 1981; Glade, 1984).

The addition of dried live yeast culture to both the CP and CPU diets resulted in increased nitrogen retention, expressed as either grams/day (P<.01) or percentages of absorbed nitrogen (P<.05; table 5). This suggests that the biological values of the yeast-supplemented diets were greater than those of the diets lacking dried live yeast culture. This effect is not attributable to the culture supplement itself, which suppled only 2.5 g dietary N daily (19 to 36% of the increase in retained N). Furthermore, the additions of the culture did not change the lysine content of the diets (table 2). Apparently, the quality of the nitrogenous compounds absorbed from the large intestine was improved, which could only have occurred by enhanced microbial ammonia liberation and amino acid synthesis (Slade et al., 1970). In order to take advantage of enhanced microbial nitrogen metabolism, microbial amino acids and ammonia would have had to have been released from their intracellular origins. The relative increase in the proportion of the absorbable water soluble nitrogen fraction of the feces and the decrease in the proportion of the nonabsorbable cell-bound nitrogen fraction accompanying the addition of yeast culture to the CP diet (table 6) provide indirect evidence that this occurred. The increased hemicellulose-digesting capability associated with yeast culture supplementation may have provided the additional microbial energy required for enhancement of microbial nitrogen metabolism.

The replacement of a large proportion of the dietary protein with urea requires efficient functioning of the urea recycling system in order to supply, at a minimum, sufficient ammonia for the hepatic synthesis of amino acids. The relative inefficiency of this process when the horses were heavily loaded with urea was indicated by the much higher proportion of water-soluble nitrogen in the feces of the horses when fed the CPU diet compared with the CP diet. Supplementation of the urea-containing diet with yeast culture decreased the proportion of fecal water soluble nitrogen to a percentage similar to that accompanying the CPY diet, indicating that the intestinal conversion of recycled urea to cell protein was increased.

As a consequence of these shifts in the balance between host and microbial metabolism, net nitrogen retention was enhanced by live yeast culture supplementation of both urea-free and urea-containing diets. An increased utilization of absorbed nitrogen for tissue production will result in an increase in feed efficiency and a decrease in feed-to-gain ratios. Net nitrogen retention increased 7 g/d when the horses were fed the CPY diet, represent-

TABLE 5. NITROGEN METABOLISM OF GROWING YEARLING THOROUGHBRED HORSES FED DIETS WITH AND WITHOUT LIVE YEAST CULTURE OR UREA

	Diet				
Item	Corn + pellets	Corn + pellets + yeast	Corn + pellets + urea	Corn + pellets + yeast + urea	SE[a]
	g/d				
Intake	113	113	168	171	
Fecal excretion	52	49	40	45	2
Digested	61[b]	64[b]	128[c]	126[c]	2
Urinary excretion	54[b]	50[c]	117[d]	102[e]	1
Retained	7[b]	14[c]	11[bc]	24[d]	1
	% of digested N				
Retained	12.6[b]	22.6[c]	8.6[b]	19.1[c]	1.4

[a]Pooled standard error of a mean.
[b,c,d,e]Means within a row that do not have a common superscript differ (P<.01).

TABLE 6. FECAL NITROGEN FRACTIONS OF WET FECES PARTITIONED BY HIGH-SPEED CENTRIFUGATION FOLLOWED BY NEUTRAL DETERGENT DIGESTION

	Diet				
Fecal N fraction	Corn + pellets	Corn + pellets + yeast	Corn + pellets + urea	Corn + pellets + yeast + urea	SE[a]
	% of total fecal N				
Water-soluble N	30.8[b]	45.2[c]	59.8[d]	39.6[bc]	.8
Cell-bound N	56.4[b]	42.3[c]	27.9[d]	46.1[c]	2.7
Metabolic N	87.2	87.5	87.7	85.7	1.9

[a]Pooled standard error of a mean.
[b,c,d]Means within a row that do not have a common superscript differ (P<.01).

ing a potential increase in daily gain of 218 g (assuming muscle contains 20% protein by wet weight; Lloyd et al., 1978).

The statistical analyses of the data indicated that there were no significant carry-over effects between periods for any of the variables that were measured or calculated. This finding emphasized the reversible nature of the beneficial effects of the live yeast culture supplementation of horse diets, and suggests that the effects may be transient and the result of relatively short-term alterations in the postprandial microbial environment. It is known how live yeast culture affects the equine digestive tract; it would be useful to determine whether an alternate feeding plan or some modification of the yeast cultures could prolong their effectiveness, perhaps further increasing the improvements in microbial energy and nitrogen metabolism.

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