THE ROLL OF PROBIOTICS IN DAIRY CATTLE DIETS

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1. Introduction

As milk production continues to increase nationally and as more dairymen see the need for increasing the performance of their herds, new ideas and approaches to feeding cows will be explored. Consequently, any new feedstuff, feed additive or compound that is capable of enhancing animal health and performance will interest producers, nutritionist and veterinarians.

The term probiotic as used in this paper will include both fungal and microbial probiotics. While the definition of a probiotic is not a concise one, they are microorganisms or yeast that are selected for their ability to assist in maintaining a bacterial balance in the host animal's digestive tract. In an effort to clarify confusion in terminology, the Food and Drug Administration (FDA) in 1989 adopted the term direct-fed microbials (DFM) to refer to "a source of live (viable), naturally occurring microorganisms", which includes bacteria, fungi, and yeasts. Each of the organisms accepted by FDA are naturally occurring bacteria from the gut of normal, healthy animals, and are not genetically engineered. They are the same genus and species as those used in human foods and are not toxic to humans or to animals.

Direct-fed microbials (DFM) are being marketed as feed additives to improve animal health and performance. As early as 1925, Eckles and Williams reported the use of yeast as a supplementary feed for lactating dairy cows. For a number of years, their usage was to enhance nutritional programs for cattle by promoting health and countering stress problems. More recently, (Wiedmeier et al., 1987; Martin et al., 1989; Smith et al. 1993) have observed increased ruminal fermentation and fiber digestion.

The question that frequently arises is whether or not DFM's should be live (viable) cultures or non-viable fermentation products. Lilly and Stillwell (1965) demonstrated that the biochemical end products of a bacterial fermentation can stimulate the growth of other microbes. Commercial products are presently available which fall into both viable and non-viable categories.

The microbial population of the rumen is enormous. The ruminal microorganisms are exclusively responsible for fiber degradation in the rumen and therefore make a critical contribution to digestion and nutrition. While there are hundreds of different species of protozoa, bacteria and fungi in the rumen, only a few actually produce the enzymes necessary for fiber degradation. It has been suggested that the rumen protozoa may supply one-fifth of the food utilized by the host. Even so, elimination of the protozoa by copper

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sulphate appears to have no effect on growth of the young ruminant or the digestibility of cellulose (Becker et al., 1930). Perhaps this is because of the large number of bacteria present in the rumen (perhaps 2.5 to 15 billion/gram of rumen contents).

Cellulose presents microorganisms with a difficult challenge because of its insolubility and highly-ordered structure. The microorganisms therefore have to produce a complex array of enzymes to digest the structure and to break bonds in a variety of conformations. The goal of the researcher is to identify those organisms that are more active and suitable in performing this task.

In recent years, a number of studies have been conducted to help isolate, characterize, and identify existing organisms that might enhance the fiber degradation process. Already, it has been reported (Dawson, 1993) that not all strains of yeast culture have the same effects on animal production systems (Table 1). With the advent of new screening procedures, it may soon be possible to identify the appropriate applications for each strain of yeast based on specific biochemical characteristics and stimulatory activities.

Table 1. The effects of several yeast strains on the cellulolytic activities of representative strains of ruminal bacteria.[1]

Yeast strains	Cellulose digestion (mg) by cultures of:	
	F. succinogenes (at 48 h)	*R. albus* (at 72 h)
Control (no yeast)	0.34	1.38
Test strain 1	5.90	1.80
Test strain 2	3.92	4.76
Test strain 3	5.94	3.66

[1]Dawson, (1993).

It appears from these studies that responses to yeast are strain dependent and that not all yeast strains have equal abilities to stimulate representative strains of ruminal bacteria. As those strains are identified that stimulate ruminal bacteria more than others, strains can be selected and targeted for use with particular diets to enhance performance.

2. Suggested Potential Modes of Action

Because of the variable responses observed in the feeding of DFM to lactating dairy animals, it has been difficult to establish a true mode of action. In general, the primary action of DFM appears to be related to enhanced development of rumen function by minimizing growth of pathogenic bacteria, increasing desirable microbial populations in the gut, and facilitating fiber digestion. While the mechanism by which growth of undesirable pathogens is retarded remains uncertain, several potential modes of action have been proposed to explain the observations (Williams, 1989; Kilmer, 1993).

Table 2. Potential Modes of Action

1.	Increase in bacteria numbers, especially cellulolytic.
2.	Feeding a DFM results in a beneficial change in the gut microflora with a reduction in the population of *E. Coli*.
3.	By suppressing the population of *E. Coli* there are fewer toxins released.
4.	Production of stimulating substances.
5.	Production of beneficial enzymes could improve nutrient availability.
6.	Reduction in ammonia and toxic amines.
7.	Reduction in rumen lactate.
8.	Greater stability in rumen pH.
9.	Improved microvilli health/nutrient uptake.

The improvements in forage degradability and the increases in digestibility of the fibrous component of diets suggests that microbial cultures affect cellulose degradation in the rumen. Increases in total viable bacteria, in numbers of cellulolytic bacteria and in the numbers of cellulolytic bacteria as a proportion of the total have been reported both in vivo (Wiedmeier et al., 1987; Harrison et al., 1988) and in vitro (Newman and Dawson, 1987) following the addition of either yeast culture or *Aspergillus Oryzae* (AO) or a combination of the two microbial cultures, but as yet there is no data on the particular species of bacteria which are affected.

Williams (1989) reported more stability in rumen pH in steers following feed consumption when yeast was in the diet. Also, they reported that the presence of live yeast culture resulted in a significantly lower level of lactic acid in the rumen liquor of steers and prevented a peak in lactic acid concentration which occurred two hours after the meal. In their explanations, they noted that the presence of starch in the rumen results in the proliferation of bacteria that produce lactate. Inhibition of the growth of these organisms will reduce the amount of lactate produced. In contrast, stimulation of the growth of organisms that utilize lactate will result in the reduction in concentration of lactate in the rumen. Interaction between yeast culture and any of these organisms will result in changes in lactate concentration. Both Harrison et al. (1988) and Alikhani et al. (1991) concluded that ruminal fermentation was more stable in cows receiving *S. cerevisiae*.

3. Bacterial DFM for cattle

<u>Dairy</u> - Published data on bacterial DFM for dairy animals is somewhat limited. Calves receiving *L. acidophilus* have been reported to have reduced incidence of diarrhea (Bechman et al., 1977) and increased weight gains. Ellinger et al. (1980) observed decreases in number of coliform bacteria in feces of young dairy calves fed unfermented whole milk containing *L. acidophilus*. Also, Bruce et al. (1979) reported that feeding *L. acidophilus* cultures of human or calf intestinal origin increased the numbers of lactobacilli in feces of calves and reduced the numbers of coliform in feces. Gilliland et al. (1980) fed *L.*

Acidophilus isolated from a human and calf intestinal tract to newborn calves and observed an increase in lactobacilli in the feces from day 1 to 14.

Thirty-two Holstein cows were used in a 60-day study (Jaquette et al. (1988) to determine the effect of *L. acidophilus* on DMI, MY, milk composition and SCC. Milk production (64 vs. 68 lb/d) was significantly higher ($P < .01$) with the addition of *L. acidophilus*. No other differences were observed. Similar increases in milk yield (70 vs. 73.9 lb/d; $P < .05$) were obtained in two california field studies (Ware et al., 1988).

Beef - A number of studies have shown favorable responses when calves or cattle receive bacterial DFM under stress conditions. Crawford et al. (1980) reported that feeding a living *L. acidophilus* culture to beef calves, pre- and post-calving, or arrival only, gained more with less feed than controls during the initial 2 weeks after arrival. Gill et al., (1987) reported that when a probiotic was added to the feed of newly arrived feeder cattle, morbidity was decreased from 41 to 36%. Average daily gains were improved from 1.65 to 1.75 lb/hd/d; however, feed intake was not affected. *Lactobacillus spp.* was used in convalescing calves which had been treated previously with antibiotic therapy and had a history of diarrhea. After a 2 week evaluation period, calves receiving the *Lactobacillus spp.* had gained 17.7 lbs compared to the control gains of 7.8 lbs (Beeman, 1985).

4. Fungal DFM for Dairy Cattle

Fungi cultures have been used in ruminant diets for a number of years. In 1925, Eckles and Williams published a report on the use of yeast as a supplementary feed for lactating cows. Beeson and Perry (1952) reported a 6% increase in daily gain of steers fed 8 g/d of active dried yeast. Other studies, (Norton, 1945; Lassiter, et al. 1958) reported little to no response in growth or production. In recent years, a more scientific approach has been developed for using yeast.

The two types of fungal cultures receiving the most interest in recent years are *Aspergillus oryzae* (AO) and *Saccharomyces cerevisiae* (SC). There are many strains of both fungal cultures. *Aspergillus oryzae* is a fermentation extract produced from a selected strain of enzyme-producing Aspergillus and is marketed by a number of companies. *Sacchanomyces cervisiae* is marketed as a yeast culture, which contains both viable yeast cells and a dried preparation of the media in which those cells were grown. It is dried in order to preserve the fermenting capacity of the yeast. Results of numerous studies with fungal DFM in diets of lactating dairy cows are in Tables 3 and 4.

5. Summary

The most critical period in the life of the dairy cow is during the prepartum period and early lactation. The dairy cow must remain healthy and peak at a high level of milk production if maximum milk production is to be attained. The key is to have the cow in the right body condition at the time of calving. After calving, the ration must be designed so that dry matter intake continues to increase over the next few weeks. Because feed intake lags behind peak milk production, a negative energy balance occurs in early lactation.

Table 3. Effect of direct-fed microbials on dry matter intake, milk yield, and milk composition in lactating dairy cows - *A. oryzae.*

Ref.	Treatment	DMI (lb/d)	MY (lb/d)	Fat (%)	Protein (%)
		(AmaFerm)-Trial 1			
Denigan et al. (9)	0	49.7[a]	67.9	3.74	2.92
	1.5 g/d	56.9[b]	67.7	3.88	2.96
	3.0 g/d	53.0[ab]	67.7	3.71	3.03
	6.0 g/d	51.1[a]	67.8	3.85	2.92
		(AmaFerm)-Trial 2			
	0	56.1	57.7	3.97	3.42
	1.5 g/d	49.9	56.7	3.63	3.23
	3.0 g/d	55.8	56.5	3.89	3.21
	6.0 g/d	52.6	57.1	4.18	3.29
		******************			
		(AmaFerm)			
Sievert & Shaver (31)	0	53.2	76.6	3.10	2.94
	3.0 g/d	54.3	77.3	3.09	2.96
		******************			
		(VitaFerm)			
Van Horn et al.(34)	0	49.9	53.9	3.46	2.93
	56.7 g/d	51.7	57.6	3.30	2.90
		******************			
		(VitaFerm)-Silage			
Harris et al.(18)	0	50.2	54.3	3.55	--
	56.7 g/d	53.5	55.7	3.66[*]	--
		*****************			
		(AmaFerm & VitaFerm)			
Kellems et al.(23)	0	46.9	57.2	3.73	--
	Amaferm	46.9	60.9	3.68	--
	VitaFerm	46.6	58.5	3.72	--
		*****************			
		(AmaFerm - Heat Stress)			
Huber et al.(21)	0	43.8	51.7	--	--
	3.0 g/d	41.8	49.7	--	--

[a,b]Means in same column with unlike superscripts differ (P <.06).
[*]MY plus increase in fat % made 3.5% FCM significant (P <.05).

While a negative energy balance is common, the magnitude of the energy balance should be minimized. In general, cows should not lose more than one body condition score during the first 5 to 6 weeks of early lactation. To be successful, good feeding and management strategies such as: 1) balanced nutrition, 2) feed bunk management, 3) stress management and 4) high quality feedstuffs should be incorporated into the total management program. Feed additives should be used as needed.

Feed additives such as yeast are used by many dairymen. While all studies with yeast are not positive, an increasing amount of studies show favorable responses in milk yield and

Table 4. Effect of direct-fed microbials on dry matter intake, milk yield and milk composition in lactating dairy cows - *S. cerevisiae.*

Ref.	Treatment	DMI (lb/d)	3.5% FCM (lb/d)	Fat (%)	Protein (%)
		(Saccharomyces cerevisiae)			
Arambel & Kent (2)	C	48.2	79.9	3.33	2.97
	T	48.0	78.1	3.37	2.94
		*************************			
Bernard (5)	C	49.1	64.0	3.75	3.00
	T	48.8	70.0	3.59	2.91
		*************************			
Erasmus et al. (11)	C	48.0	39.4	3.19	4.41
	T	51.0	42.0	3.19	3.38
		*************************			
Erdman & Sharma (12)	C	43.1	55.2	3.42	3.44
	T	41.8	53.5	3.46	3.50
		*************************			
Harris et al.(15)	C	50.4^a	57.2	3.38	3.03
	T	48.4^b	55.1	3.43	3.12
		*************************			
Harris et al.(16)	C	--	79.0	3.16	2.87^a
	T	--	81.0	3.28	2.93^b
		*************************			
Harris & Lobo(17)	C	46.0	58.5^a	3.36^a	3.05^a
	T	47.1	60.7^b	3.57^b	2.97^b
		*************************			
Smith et al.(32)	C	57.2	48.2	3.53	3.22
	T	54.6	49.9	3.27	3.03
		*************************			
Williams et al.(37)	C	36.7	47.1	3.61	3.50
	T	38.9	46.0	3.58	3.29
	C	38.7	44.9^a	3.32	3.35
	T	42.2	51.9^b	3.46	3.48
		*************************			
Wohlt et al.(38)	C	42.2	57.2	3.96	3.23
	T	40.7	59.8	3.91	3.12
		*************************			
Piva et al.(30)	C	--	(4%FCM) 41.1^a	3.77^a	3.49^a
	T	--	" 43.4^b	3.97^b	3.55^b
		*************************			
Hoyos et al.(20)	C	--	68.0^a		
	T	--	72.2^b		

[a,b]Means in same column with unlike superscripts differ ($P < .05$).

Table 5. Effects of supplementary yeast culture on rumen parameters.

Source	Parameter	Control	YC
Wiedmeier et al. 1987.	DM digestibility , %	77.0	79.1
	CP " . %	79.5	82.2
	ADF " , %	69.3	70.0
	pH	6.34	6.34
	Total bacteria(CFUx10^8)	196.2	255.0
	Cellulolytic bacteria	25.0	39.8
	Ammonia (mg/dl)	18.21	18.72
Smith et al. 1993	DM digestibility , %	61.1	63.6
	CP " , %	64.1	66.1
	ADF " , %	45.2	50.3
	Ammonia (mg/dl)	11.5	12.9
Newman & Dawson 1987	Total anaerobes (CFU x 10^9/ml)	104.0	157.0

milk fat percentage. Also, digestibilities of various nutrients are frequently improved. As new strains of yeast are identified that have greater stimulatory activities, the responses will become even greater. Yeast appears to be in a position to play a greater role in the future with more cows producing more milk as a result of using BST in highly managed herds. Any feed additive that will increase bacteria numbers, improve nutrient utilization, and reduce stress will help maximize performance.

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