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Yeast culture in animal nutrition: A review

M. T. A. Bakory*

Sebha University- Faculty of Agriculture, Department of Animal Production, Sebha – Libya **North Africa**.
***Corresponding author**

Many studies have indicated that the use of yeast products as feed supplements may have a significant impact on the performance of domestic animals. The ability of yeast culture to alter the metabolic activities of gastrointestinal bacteria may improve the efficiency of feed utilization by providing more useful supply of nutrients to the animals for growth and milk production. A summary of studies describing the effects of yeast culture in ruminant diets indicate that yeast culture supplements do not have equal beneficial effects with all type of diets. Moreover, many of these studies were carried out under different management and production conditions. As result it is currently not possible to define the dietary conditions which should be provided for the optimal response to yeast culture supplementation.

Key words: Yeast, Animal nutrition, rumen, digestive processes.

The increasing demand for food to feed a growing world population has highlighted the importance of maximizing the efficiency of animal production. An integrated approach to this problem, involving improvement in nutrition, genetics, husbandry, etc., has led to significant progress.

Various food additives for manipulating rumen fermentations to improve feeding efficiency are easily obtained. Recent studies (El-Ashry et al. 2003, Salem et al. 2002) have reported on dietary supplements including yeast culture. Major applications of yeast as a dietary supplement in animal production include: 1) yeast that is used solely for one of its metabolic products, namely the use of Phaffia rhodozyma for carotenoids; 2) yeast acquired from normal microbial populations within the rumen of ruminant animals and the functional calcium of species like horses, pigs and rabbits; 3) the importance and the performance of some yeasts as a modifier of the gut microflora of livestock and to stimulate the immune system, and; 4) the application of Sacchromyces cerevisiae added to feed, to counteract aflaxoxicosis in broiler chickens and duckings. This review summarizes observations that show the importance of yeast culture in ruminant nutrition and its probable action in influencing microbial ecology in the rumen and improving animal production.

Pattern of action of yeast culture in the rumen.

Adding yeast culture to ruminant fluid affects the pattern and end products of fermentation (Dawson 1987) It stimulates the activity of a type of important bacteria (Celluloytic bacteria) which are actively involved with the processes of digestion in the gastrointestinal tract. Live yeast culture affects rumen metabolism by influencing the rate of microbial fermentation and affecting the turnover of the microbes, hydrogen ion exchange, and carbohydrate metabolism. There is an improvement in the digestibility of carbohydrates and thus of crude fibre which leads to increased feed consumption. Thus, the energy available to the microorganisms increases. The outcome of yeast culture on hydrogen ion exchange in the rumen increases methane build up and stimulates formation of propionic acid. This results in an increase in the efficiency of fermentation. Microbial protein synthesis is also stimulated, so that more amino acids of microbial origin flow to the bacteria in the rumen [and later specific function in the rumen. Preferentially, there are signs that cellulolytic bacteria and lactic acid utilizing flora are stimulated. (Edwards, 1991 and Kumar, et al. 1994).

Recently, it has been discovered that different yeast strains capable of stimulating specific bacterial population in rumen stimulate continuous cultures as well (El-Hassan, et al. 1993). Additional surveys (El-Hassan, et al. 1993 and Khattab et al. 2003) showed that there is a difference in the ability of yeast strains to alter the rates of cellulose digestion by specific strains of rumen bacteria. In this way, yeast yea_sacc 1026 modified the rumen environment by stimulating the production of fibre digesting bacteria like Ruminococcus albus, Firobacter succinogens, and Butyrivibrio fibrisolvens. Lactic acid-utilizing species such as Selenomonas are stimulated to greater degree by yeast yea_sacc8417 (Mir and Mir 1994) Disadvantages of yeast culture supplementation on ruminal fermentation have been investigated in number of studies (Kumar, et al. 1994, Olson, et al. 1994, El-Ashry, et al. 2003). Many of the responses to yeast culture supplements in ruminant diets can be related to the effects of yeast cells on microbial activities in the rumen. Initially, it was reported that a 4-5 day period was needed from beginning of yeast culture supplementation before postrumenal (Offer, 1990).

Increased nutrients supplied from the diet, in the form of either energy or protein, which can occur from changes in the digestibility of the diet or from increases in feed intake, might explain the positive responses in body weight or milk yield.

Effect of yeast culture supplementation on microbial populations

An increase in the number of rumen microbial populations is commonly observed when yeast culture is used as a food supplement (Table 1). Such increases in the number of culturable bacterial cells suggest that live yeast cells in supplements can stimulate certain groups of bacteria in the rumen and later specific functions in the rumen. There are indications that cellulolytic bacteria and lactic acid utilizing flora are preferentially stimulated Edwards 1991) and Rumar et al. 1994). Two important functions associated with such stimulation are cellulose-digestion and lactic acid-utilization.

Recent studies have shown that different yeast strains are able to stimulate specific bacterial population in rumen simulating continuous cultures with various results (Table 1) Additional studies established that there are also differences in the ability of yeast strains to alter the rates of cellulose digestion by specific strains of rumen bacteria. Yea_sacc1026 modifies the rumen environment by stimulating the production of fiber digesting bacteria like Ruminococcus albus, Fibrobacter succinogens and Butyrivibrio fibrisolvens. However, yea_sacc8417 stimulates lactic acid utilizing species such as Selenomonas ruminantium to greater degree Newbold, et al. (1995).

Effect of yeast culture supplementation on ruminal fermentatation

The effects of yeast culture on ruminal fermentation have been examined in a number of studies (Table 2). Many of the responses to yeast culture supplements in ruminant diets can be related to the effects of viable yeast cells on microbial activities in the rumen. Initially Offer, (1990) reported that a 4-5 day period was required from the beginning of yeast culture supplementation before maximal improvement in rumen activity was obtained, and there was a 4-5 day carry-over from the withdrawal of yeast culture before the rumen activities returned to pre-treatment values. However, Kumar et al. (1994) observed that the effect of yeast culture on ruminal metabolism was evident after one week of supplementation, reached the maximum after 2 to 3 weeks, and then remained constant up to the 4th week of supplementation. The effects of yeast culture supplementation started to disappear when it was withdrawn from the diet and by the 3rd week after withdrawal, values returned to the level of the control group.

One of the common observations associated with yeast culture supplements has been the reduction of ruminal ammonia concentrations (Olson, *et al*. 1994) and Chiquette 1995).

Table: 1. Summary of studies describing responses of microbial population to yeast culture supplementation.

Diet	Total bacteria	Cellulolytic bacteria	Comment	Reference
77% hay +23% conc.	3.3 7.8	8.0 12.5	In vivo	Dawson *et al*. 1990.
30% beet pulp +70% grains	11.7	8.9	In vivo	Edwards. 1991.
Barley / Urea	8	3.3	In vivo	El-Hassan *et al*. 1993.
35% roughage +65% conc.	55.4	66.8	In vivo	Kumar *et al*. 1994.

Table: 2a. Summary of studies describing responses of ruminal fermentation to yeast culture supplementation.

Diet	PH	NH3-N	VFA's			Liquid dilution rate	Reference
			Total	Acetate	Propionate		
35% roughage + 65% conc.	+	8.5	ND	2.8	2.5	9.1	Malcolm and kiesling 1990
Conc. based diet	-2.0	-3.2	8.9	9.1	9.2	ND	Mutsvangwa et al. 1992
35% roughage +65% conc.	1.7	-11.3	7.9	13.5	10.8	ND	Kumar et al. 1994
a) 75% alfalfa silage + 25% barley	ND	-11.0	ND	-6.0	10.5	ND	Mir and Mir 1994
b) 95% corn silage + 5% soya meal	ND	-14.5	ND	2.5	8.1	ND	
c) 25% hay + 75% barley	ND	-60.7	ND	10.2	-20.2	ND	
a) 80% roughage + 20% barley **b) 50% roughage+ 50% barely**	-1.6 -1.6	-32.6 -57.1	-6.8 0.8	5.0 -3.5	+ 8.7	ND ND	Rouzbehan et al. 1994

Table: 2b.

Diet	PH	NH3-N	VFA's			Liquid dilution rate
			Total	Acetate	Propionate	
Roughage based diet	4.2	-29.2	-4.4	1.6	-7.8	22.5
40% hay + 60% barley	ND	ND	-1.7	-2.4	±	ND
a) 70% Roughag + Ni concentr (ED)	-0.05	2	-10.8	5.7	-4.4	-
b) BD + yeast culture	0.16	12	7.0	5.2	-4.9	-

ND Non-detected ± Non- affected

Reduced ammonia levels appear to be related to increased ammonia utilization by microorganisms in the digestive tract. Greater concentrations of total anaerobic bacteria may explain why ruminal ammonia concentrations are lower in animals fed yeast culture. Ammonia is the preferred source of nitrogen for a large portion of the ruminal microbial population. Many studies have suggested that yeast culture supplementation can significantly increase protein synthesis in the rumen and the flow of microbial protein from the rumen (Kumar, *et al.* 1994 and Rouzbehan, *et al.* 1994). Specifically, Williams and Newbold (1991) observed that daily absorption of non-ammonia nitrogen in the intestine was increased by 23% when yeast culture supplements were provided in the diet. This represents an increase in the flow of useful microbial protein to the small intestine. Moreover, Edwards (1991) detected increased allantoin nitrogen in the urine and decreased urea nitrogen concentrations in plasma which support a mechanism for enhancing the conversion of ammonia nitrogen in the digestive tract into microbial cell mass. Several studies have suggested that yeast culture may increase production of VFAs (Total Volatile fatty acids), enhance the relative production of propionate, and decrease the ratio of acetate to propionate in the rumen of animals fed a forage based diet (Williams and Newbold, 1990, Edwards, 1991 and Salem *et al.* 2002). Such changes are indicative of improved fermentation efficiencies and decreased methane production in the gastrointestinal tract, and could provide additional energy for animal production. The increase in the level of propionate in the rumen could have been the reason for the reduction in the methane production, Mutsvangwa *et al*. (1992) showed that production of propionate involves the utilization of metabolic hydrogen, leading to a reduction in the synthesis of methane. Other studies have reported an increase or non-significant changes in the acetate to propionate ratio when high concentrate diets were fed to ruminants. Differences in the ability of yeast culture to alter fermentation patterns may be related to the differences in dietary treatments.

Similarly, yeast culture supplements have been reported to have different effects on rumial pH. Harrison *et al*. (1988) reported that pH in the rumen of animals receiving a yeast culture supplement decreased whereas other investigators (Chademana and Offer, 1990; Kumar *et al*. 1994; Rouzbenhan *et al.* 1994 and El-Ashry, *et al.* 2003) reported little or no effect of yeast culture supplementation on ruminal pH. Slight increases in ruminal pH, have been shown by (Olson *et al*. 1994 and Khattab *et al.* 2003).

Dawson *et al.* (1991) and Girard, *et al*. (1993) suggested that yeast cells are able to stimulate both of growth and the ability of lactate utilizing bacteria to metabolize lactic acid to propionate. This might be explain the lower ruminal lactic acid concentration in the rumen of animals fed yeast culture diet compared with those fed the non-supplemented diet. Girad, *et al.* (1993) suggested that the use of specific yeast cultures to stimulate lactic acid utilization and propionate production in the rumen may provide a tool for controlling ruminal fermentations in fast growing animals fed high concentrate diets. Moreover Mir and Mir, (1994) and Salem, *et al.* (2002) observed that incidence of acute ruminal acidosis was lower in steers fed a high-grain diet supplemented with yeast culture. This observation concurs with finding that yeast culture in diets promotes lactate utilization in the rumen. Several studies reported that inclusion of yeast culture in the diet resulted in an increase in liquid dilution rate, which may account for an increase in the number of bacteria in the rumen. Isaacson, *et al.* 1975) reported that an increased liquid dilution rate is associated with more efficient microbial protein synthesis.

Effect of yeast culture supplementation on digestive processes

As shown in tables 3a and 3b, several studies have suggested that yeast culture supplementation may have little effect on the total tract digestion, but influence the initial digestion rates of fibrous substrate in the rumen (William, *et al.*1991 and Salem, *et al.* 2002). These studies indicate that yeast supplementation may have a significant effect on the time course of digestive processes in the rumen. Such changes in digestive function could increase the availability of nutrients in the rumen and could have a significant impact on intake (Williams and Newbold, 1990, El-Ashary, *et al*. 2003). The lack of an increase of the fibre fraction digestibility of the ration when yeast culture was added to feed is in contrast to expectations, given the increase in number of cellulolytic bacteria in the rumen. Jung and Varel (1987) noted that increases in the number of cellulolytic bacteria did not correspond to increase in digestion of cell walls, cellulose or hemicellulose. However, other workers have reported positive effect on fibre fraction digestibility with yeast culture supplementation (Mir and Mir 1994). In an earlier study, Offer (1990) suggested that fibre-degrading microorganisms provide the only source of enzyme systems for the digestion of structural carbohydrates which make up a high proportion of fibrous feeds. The possibility that yeast cells interact in the rumen with anaerobic fungi should not be ignored as these have been shown preferentially to colonise cellulose and hemicellulose making the fibre more accessible to bacteria.

Increases in crude protein digestibility as a result of yeast culture supplementation and suggestions that yeast culture may increase

Table (3a): Summary of studies describing response of nutrient digestibility to yeast culture supplementation.

Diet	Digestibility %						Reference
	DM	OM	CP	NDF	ADF	Comment	
Conc. based diet	- 9.4	- 3.1	-3.8	-0.2	ND	In vivo	Mutsvangura et al. 1992
a) Wheat straw	3.91.9	ND	ND	ND	ND	In vivo	
b) Berseem	1.6	ND	ND	ND	ND	In situ	
c) Groundnut cake	1.8	ND	ND	ND	ND	In situ	
d) Wheat flower	1.9	ND	ND	ND	ND	In situ	
e) Wheat bran		ND	ND	ND	ND	In situ	
a) 75% alfalfa silage + 25% barley	2.0	ND	0.6	5.1	1.5	In vitro	Mir and Mir, 1994
b) 95% corn silage+ 8% soya meal	-1.3	ND	1.0	0.9	2.7	In vitro	
c) 25% hay + 75% barley	19.1	ND	33.6	69.2	12.9	In vitro	
Roughage based diet	4.1	ND	6.6	4.3	ND	In vitro	Olson, *et al*. 1994

Table (3b): Summary of studies describing response of nutrient digestibility to yeast culture supplementation.

Diet	Digestibility %						Reference
	DM	OM	CP	NDF	ADF	Comment	
40% hay + 60% barley	-0.2	-0.2	0.9	-0.1	0.2	In vitro	Chiquette, 1995
a) Hay 0h	9.0	ND	ND	ND	ND	In vitro	Newbold, *et al*. 1995
16h	20.5	ND	ND	ND	ND	In vitro	
24h	18.4	ND	ND	ND	ND	In vitro	
48h	1.3	ND	ND	ND	ND	In vitro	
b) Straw 0h	3.7	ND	ND	ND	ND	In vitro	
16h	7.9	ND	ND	ND	ND	In vitro	
24h	26.2	ND	ND	ND	ND	In vitro	
48h	12.2	ND	ND	ND	ND	In vitro	
a) 70% Roughag +30% concentrate (BD) + yeast culture	-1.1	-1.3	1.7	1.7	-	Invivo	
b) BD+ Coalactoolrgosacchariedes	-1	-2	-0.9	-3.1-	-	Invivo	

Relative change % ND= Non-detected ± = Non- affected

ruminal proteolysis that could result in an increase in nitrogen have been reported by (Wiedmeier, *et al.* 1987; Wohlt *et al*. 1991; Olson, *et al*. 1994 and Salem, *et al*. 2002). Arambel and Kent (1990) and Olson, *et al*. (1994) suggested that yeast culture may increase ruminal proteolysis which could result in increased N balance and increased dietary N availability. Retained dietary N was increased in yeast culture supplemented sheep fed medium concentrate diets (Cole, *et al.* 1992 and Khattab, *et al*. 2003).

Effect of yeast culture supplementation on production responses

Production responses to yeast culture supplementation have been recorded in lactating and growing animals (table 4 and 5). There is little doubt that production responses to yeast culture have been variable and in many cases no significant differences are detected. Differences in production responses may be related to the differences in dietary treatments and conditions of management and production. Responses range from a 9.1% reduction in live weight gain (Mir and Mir 1994) to a 20% increase in daily gain (Hudyma and Gray 1990). The effectiveness of yeast culture is altered by the diet and nutritional demands of the host. For example, Edwards, *et al*. (1991) found greater response to yeast culture in steers fed an ad lib silage diet than in bulls fed a diet containing a high proportion of barley.

Table 4: Summary of studies describing growth responses to yeast culture supplementation.

Diet	Dry matter in take	Body weight gain	Comment	Reference
50% hay + 50% conc.	ND	3.7	240kg steers for 73d	Adams *et al*. 1981
Conc. Ad.lib+ milk replacer	ND	19.1	45kg calves from birthto 84d.	Fallon and Harte 1987
50% hay +50% conc.	ND	13.7	Calves from birth to 84d.	Hughes 1988
Grass silagead. Lib. + 3.8 kg/d. conc.	ND	6.3	315 kg bulls for 205d	Drennan 1990
Corn silage ad. Lib.	4.3	20.6	240 kg steers for 120d	Hudyma and Gray 1990
a) 70% conc. + 30% roughage	4.6	4.4	365kg steers for 120d	Edwards 1991
b) Grass silage ad. Lib. +3kg/d conc.	0.9	13.1	440kg steers	
70%corn +30% roughage	1.3	7.0	250kg steers for 112d.	McLeod *et al*. 1991.
65% Corn+ 35% roughage	-4.3	-5.2	194kg steers for 65d	Cole *et al.* 1992.
Conc. Based diet	4.3	1.9	133kg bulls for 196d	Mutsvangwa *et al*. 1992.
a)barley/urea	1.7	2.3	340kg bulls	El-Hassan *et al.* 1993.
b) barley/soya	-0.3	4.2		
a) 75% alfalfa silage +25% barley	1.4	8.3	230kg steers for 70d	Mir and <ir 1994.
b) 95% corn. Silage+ 5% soya meal	4.8	-9.1	315 kg steers for 64d	
c) 25% hay +75% barley	4.4	±	380kg steers for 64d	
a) 80% roughage + 20% barley **b) 50% roughage + 50% barley**	-0.6 -14.0	-1.3 0.2	36kg Lambs for 90 days	Rouzbehan *et al.* 1994.
a) 70% Rougher +30% concentrate + yeast culture	ND		697kg	Mwenya *et al.*
70% Rougher +30% concentrate + galactooligosaccharieds	ND		687 kg	

* Relative change % ND = non-detected ± = Non- effected

Table 5: Summary of studies describing milk yield responses to yeast culture supplementation.

Diet	DMI	Milk yield	Comment	Reference
Grass silage+ barley	ND	2.8	Mid lactation	Bax, 1988
40%Corn silage +60% conc.	-3.1	-1.6	154d post partcim	Erdman and sharma 1989
58% roughage +42% conc.	ND	17.4 14.7	Mid lactation Late Lactation	Gunther 1989
50% roughage	-0.3	-2.2	Early Lactation	Arambel and Kent, 1990
50% corn silage +50% grain	8.0	4.5	Mid Lactation	Wohlt *et al*. 1991
a) 50% conc. 50%straw b) 50% conc 50% hay c) 60% conc. 40% straw d) 60% conc. 40% hay	ND 5.1 ND 3.9 ND 5.1 ND 13.3	-3.1 -2.3 -6.7 -2.4 -14.7 17.5 15.9 14.0	Early Lactation Mid Lactation Early Lactation Mid Lactation Early Lactation Mid Lactation Early Lactation Mid Lactation	Willams *et al*. 1991
40% hay + 60% barley	-5.0	-1.0	Early Lactation	Chiquette, 1995
Cron silage + hay + 2.5 kg/d conc.	1.4	1.6	Early Lactation	Robinson 1997

* Relative change (%)   ND = non detected

However, (milk yield of dairy cows responses increase range from a reduction in milk yield of 14.7% (Williams, *et al*. 1991) to an increase in milk output of 17.4% (Gunther, 1989). Additionally, Gunther (1989) found that the response to yeast culture inclusion to be greater in early as opposed to mid or late lactation. Response to yeast culture may also be modified by more subtle variations in the diet. Williams, *et al*. (1991) observed larger responses in milk yield to yeast culture as the ratio of concentrate to forage in the ration increased. They also reported a 17.5% increase in milk yield in response to yeast culture addition to the diet consisting of 60% concentrate and 40% straw, but this response was reduced to 14% increase in milk yield when straw was replaced by grass hay. Bax (1988) found that yeast culture stimulated milk yield in cows fed a diet of alfalfa hay plus wheat but not when the wheat was replaced by corn.

Inclusion of live yeast culture in diets of dairy cows has resulted in increased production of milk fat (Williams *et al*. 1991; and Salem *et al.* 2002) whereas Robinson (1997) reported that yield of milk components were not influenced by yeast culture supplementation.

Increased dry matter intake (DMI) by beef and dairy animals has been reported when diets were supplemented with yeast culture (Philips and Von-Tunglein, 1985, Cole *et al*. 1992 and Salem et al. 2002). Conversely, others have found that yeast culture had no effect on DMI (Erdman and Sharma 1989, Malcolm and Kiesling 1990). Yeast also has increased feed efficiency (Hudyma and Gray, 1990) in concentrate fed cattle.

Other benefits of yeast culture.

1- It chelates with several important minerals. (Peterson, *et al*. 1987) noted an increased retention of K, Cu,and Zn in ruminants fed diets supplemented with yeast culture. Moreover (Cole, *et al*. 1992) reported that lambs fed yeast culture tended to have greater Zn and Fe balance than control lambs.
2- It is a nutural source of vit.-B complex (Dawson 1987).
3- It is a source of immune stimulants such as glucans and mannanoligosacchairdes (MOS) which influence and enhance the non-specific defence mechanisms in animals (Macdonald 1995).

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