Using feed additives to improve the productivity of dairy cattle

Gbola Adesogan
Department of Animal Sciences
IFAS

University of Florida

Peruvian gators

Outline

Rationale

Description

Mode of action

Effects on performance & health

Feed Additives: definition and effects

Definition

- Non-nutrient compounds or microbes added to the diet to modify metabolism and improve production, diet utilization or health

Effects

- Enhance level & efficiency of performance
- Improve digestion
- Reduce negative impacts of diets on health, performance, and environment

Feed additives target the rumen because

Feed costs represent 30 to 40% of production costs

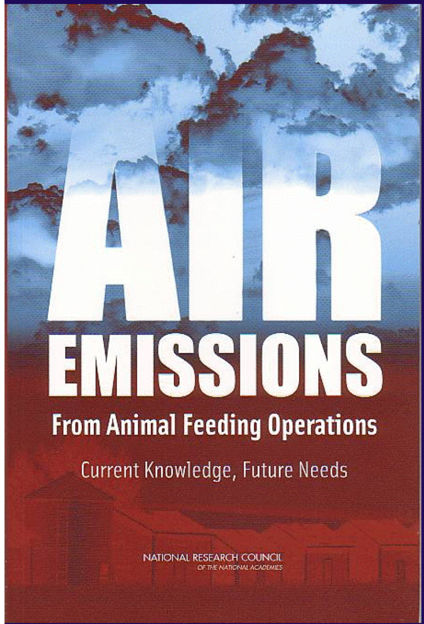
Rumen can supply 70 % of cows amino acid requirements and 70 to 90 percent of energy requirements

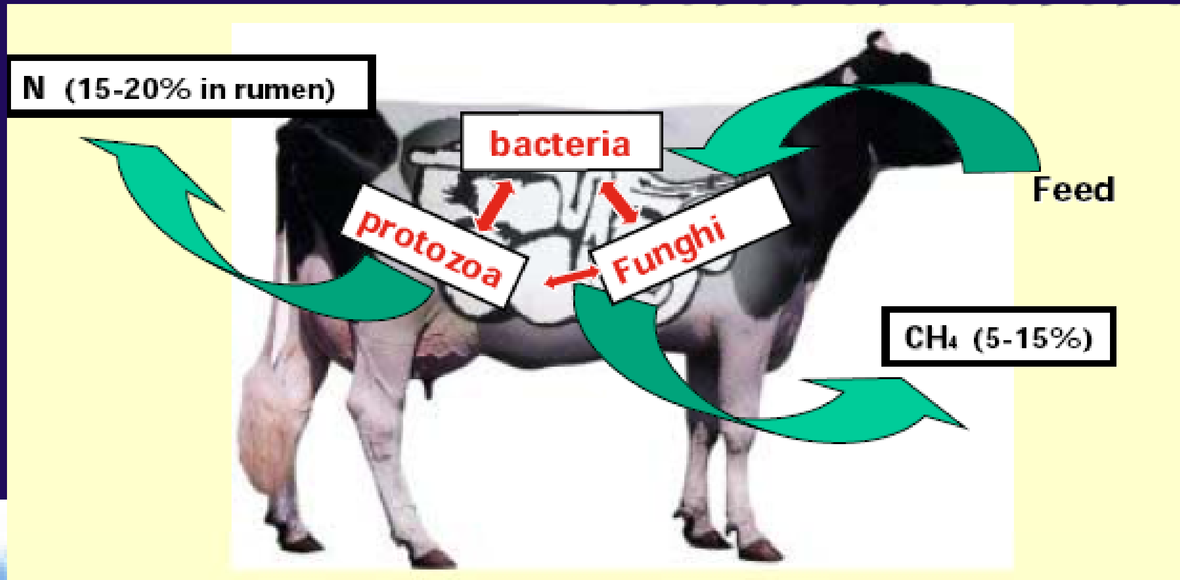
Inefficient nutrient use in rumen = wasted $$$

Rumen problems reduce intake, digestion &, health and can kill cows

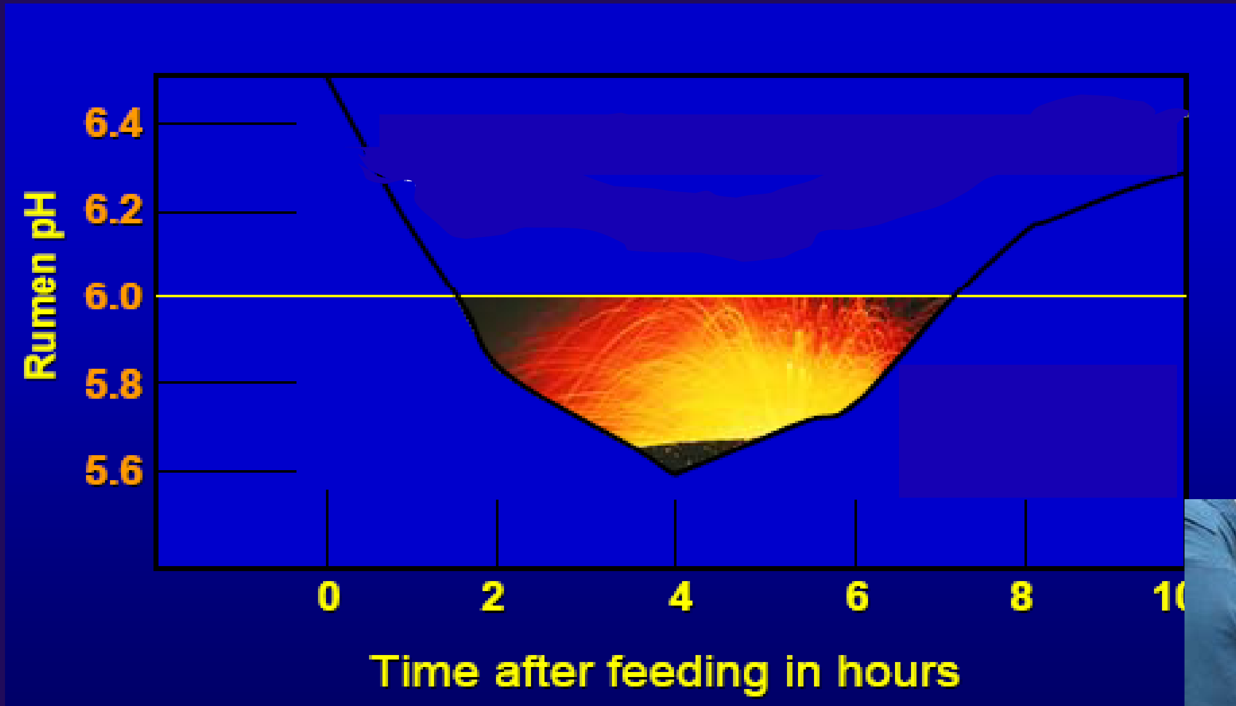
(Hutjens, 08)

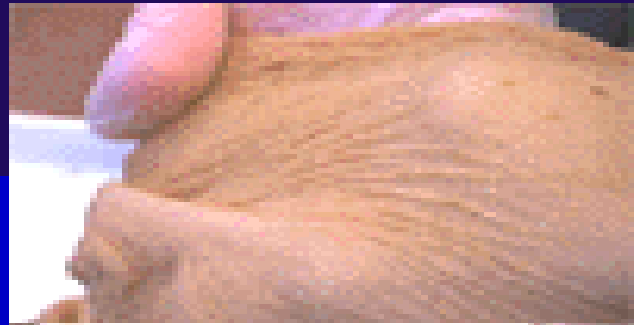
Inefficiencies in the cow





Ruminal acidosis





(Varga, 2008)

Acidosis costs

Two days of off feed $16

Laminitis/delayed reproduction $400

Premature culling $1500

Death $2,300

(Hutjens, 08)

Target effects of additives on the rumen

Prevent/reduce acidosis; maintain pH > 6

Maintain acetate to propionate ratio (2:1)

Reduce methane production

Reduce protein degradation to ammonia

Increase microbial protein synthesis

Increase organic matter & fiber digestibility

Focus areas

Ionophores

Yeasts

Buffers

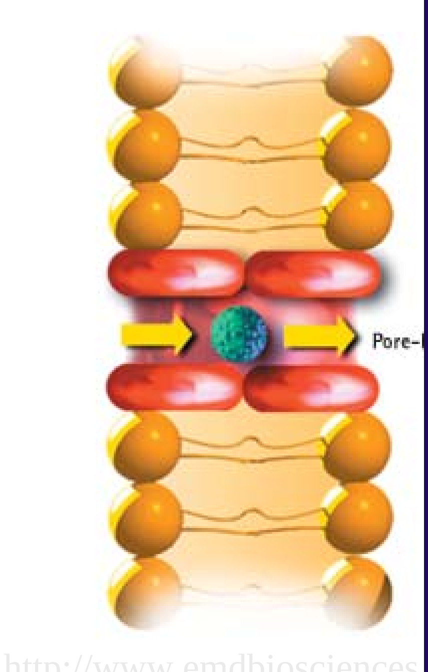
Enzymes

IONOPHORES

Organic compounds that facilitate ion transport across cell walls.

Banned in EU, approved for improving feed efficiency in US

Most produced by Streptomyces spp.



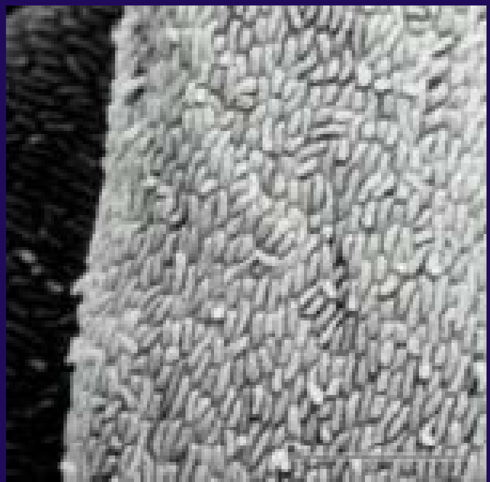
http://www.emdbiosciences.co /calbiochem/catalog/ionophore

Examples

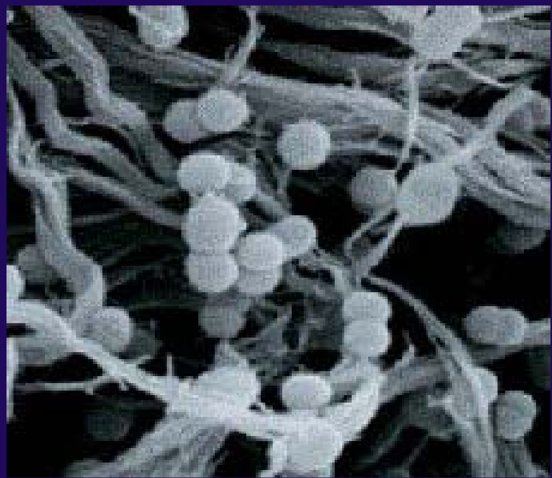
- Rumensin (Monensin Sodium)
- Bovatec (Lasalocid Sodium)
- Cattlyst (Laidlomycin Propionate Potassium)

Ionophores:Mode of action

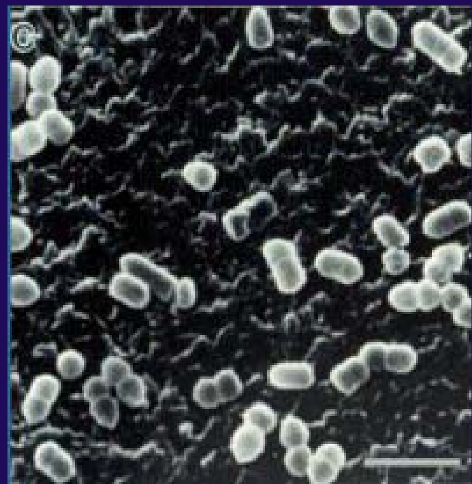
Decreases population of gram positive bacteria by modulating ion flow across their cell membranes



Fibrobacter succinogenes,
gram –ve;
v. fast fiber digester



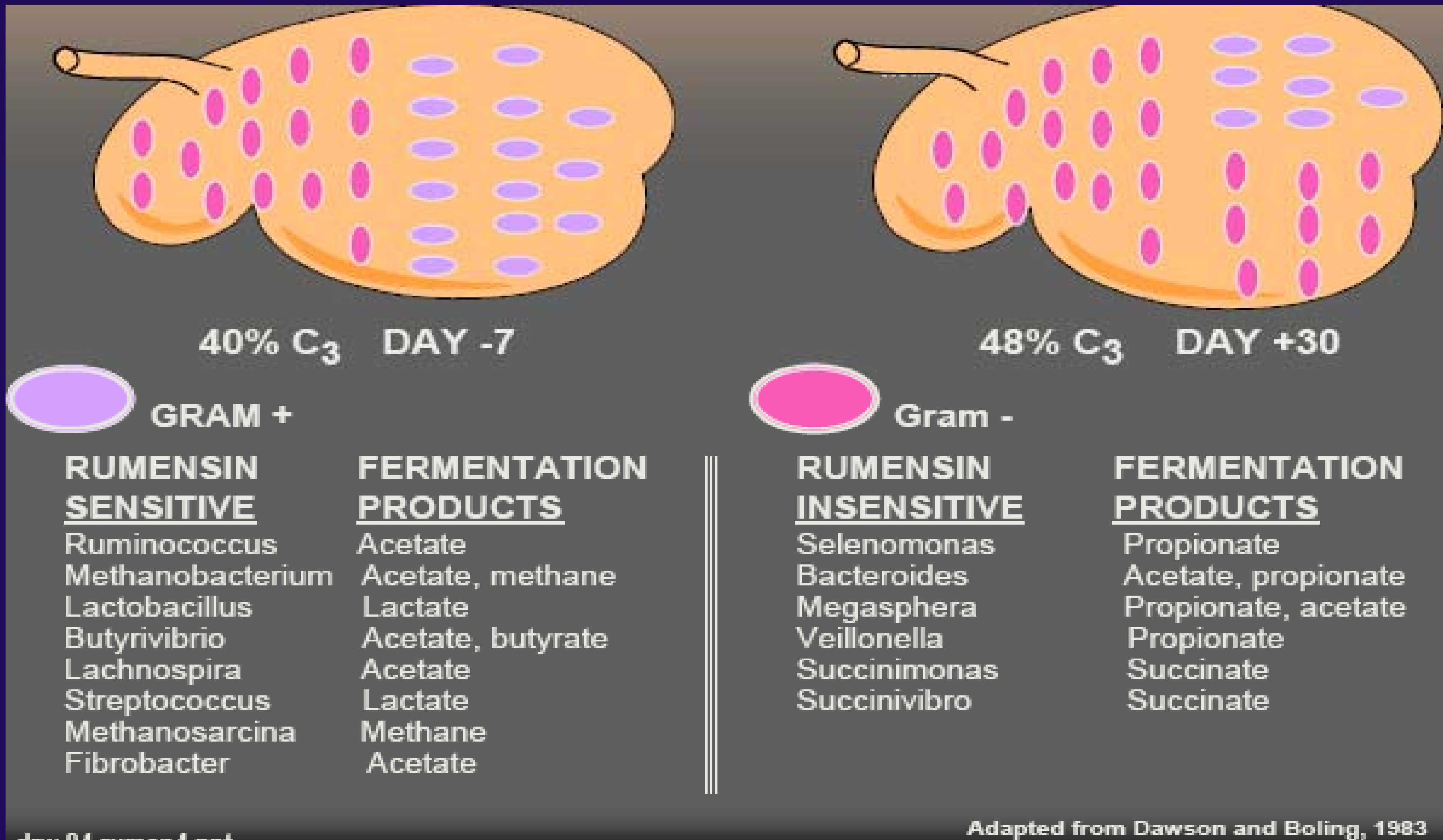
Ruminococcus albus,
gram +ve,
fiber digester



Prevotella bryantii,
gram –ve fiber-degrader; grows at low pH

http://www.tigr.org/tdb/rumenomics/genomes.shtml

Monensin effects on bacterial population



(Dawson & Boling, 1983; McGuffey et al., 2001)

Effects of ionophores

Improve energetic efficiency by enhancing propionate synthesis and reducing methane synthesis

Enhanced glucose supply increases insulin, reduces fat mobilization and subclinical ketosis

Reduces lactate accumulation thus reducing acidosis and bloat

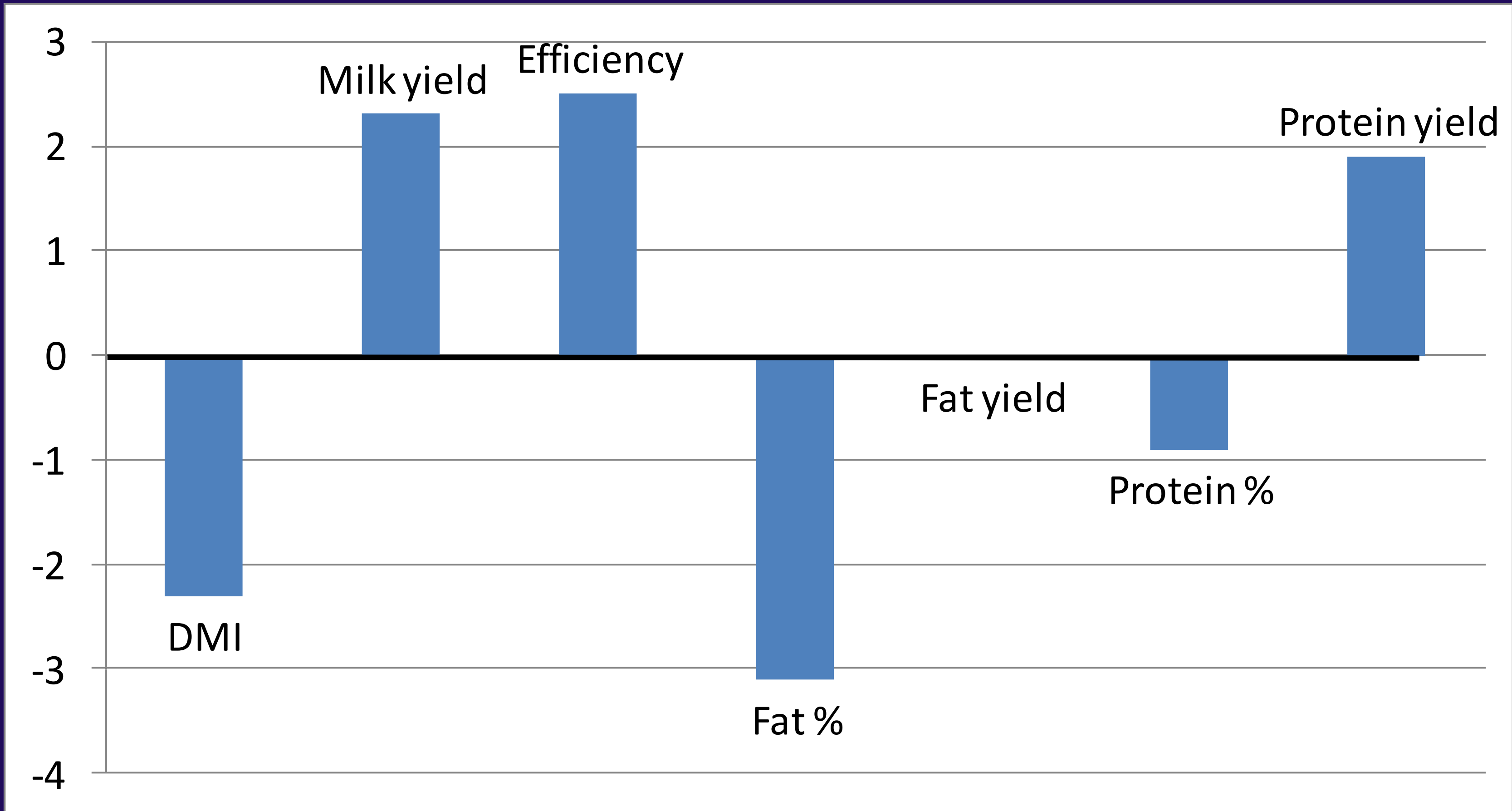
Reduces acetate and thus reduces milk fat %

Effects of monensin on rumen VFA

	Control	Monensin
Acetate, %	66.7	61.3
Propionate, %	20.1	26.1
Acetate: Propionate	3.3	2.4
Butyrate, %	9.2	9.4
Total VFA, mM	77.8	74.9
Methane production, Moles/100 moles hexose	62.3	54.2

(Dinius et al., 1976)

% change due to feeding monensin to dairy cows in 77 trials



(Duffield et al., 2008)

Effect of Sodium Monensin on Metabolic Parameters of Dairy Cows

Treatment		Item			Reference
		BHBA, mg/dl	Glucose, mg/dl	NEFA	
At calving	C	23.70	55.1	3.90	Abe et al. (1994)
	M	11.74**	58.3*	3.75	
Prepartum	C	14.91	58.6	0.46	Wade et al. (1996)
	150 mg/d	13.91	58.9	0.38**	
	300 mg/d	13.90	61.0**	0.40	
	450 mg/d	14.31	60.3*	0.39*	
Prepartum	C	15.24	65.1*	0.438	Stephenson et al. (1994)
	M	12.46*	62.8	0.581	
Postpartum	C	5.15	63.3	NA	Phipps et al. (1997)
	M	4.34	65.5	NA	

(Santos, 08)

Effect of Monensin on Performance of Dairy Cows

	Monensin, mg/kg			
	0	8	16	24
No. cows	215	210	216	217
DMI, kg/d				
Prepartum	11.1	11.0	10.9	10.5[a]
Postpartum	19.8	20.0	19.4[a]	19.2[a]
Milk, kg/d	29.3	30.3[a]	30.2	30.4[a]
Milk fat, %	3.66	3.61	3.52[a]	3.42[a]
Milk protein, %	3.15	3.16	3.14	3.12[a]

Adapted from Symanowski et al. (1999) and Wagner et al. (1999)

[a] Different from the control (*P* < 0.05)

(Santos, 08)

Ionophores: Summary

Reduce gram positive bacteria which results in:

- Greater energy efficiency (less CH_4 & ac:pr ratio),
- Improves milk yield and feed efficiency
- Reduces, coccidiosis, acidosis, bloat, DA & ketosis
- Often reduces DMI, milk fat and protein %

Monensin recommendations

Add at up to 250 to 400 mg/cow/d or 11 to 24 mg/kg (DM basis) depending on milk component effects

Cost 3 cents/cow /day

Benefit to cost ratio   5 to 1.

Feed to dry cows (reduce metabolic disorders) and lactating cow (feed efficiency)

(Hutjens, 08)

YEASTS

Single-celled fungi that reproduce by budding & ferment carbohydrates

Mainly based on Saccharomyces cerivisiae

Sold as

- Live yeasts
- Dried Yeast culture

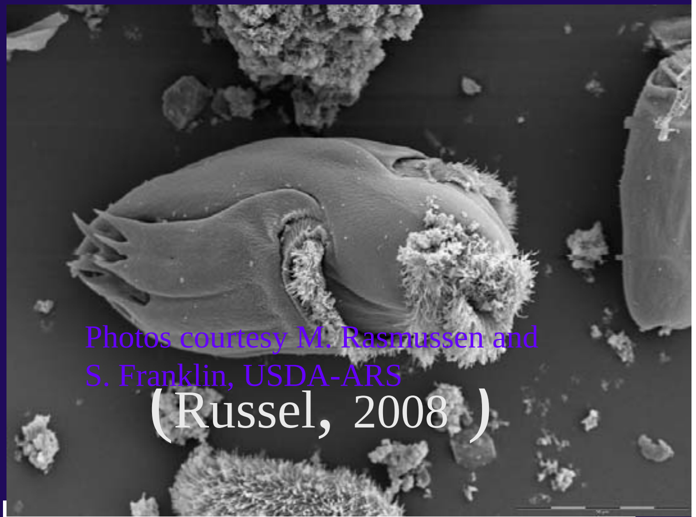
Approved in EU (Regulation 1831/2003); GRAS status in US

Mode of action summary

Stabilizes rumen pH by reducing ruminal lactate accumulation

Stimulates fiber digesting fungi and bacteria

Scavenges ruminal O_2 reducing redox potential; better for obligate anaerobes



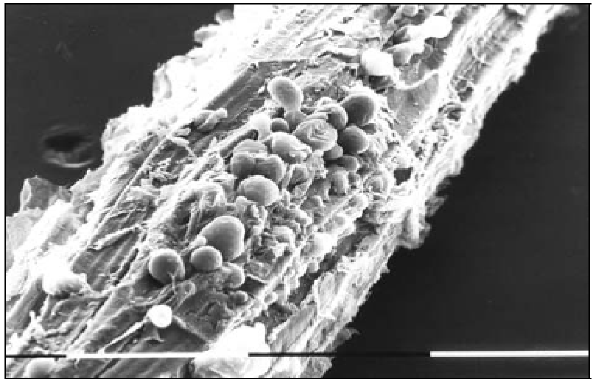
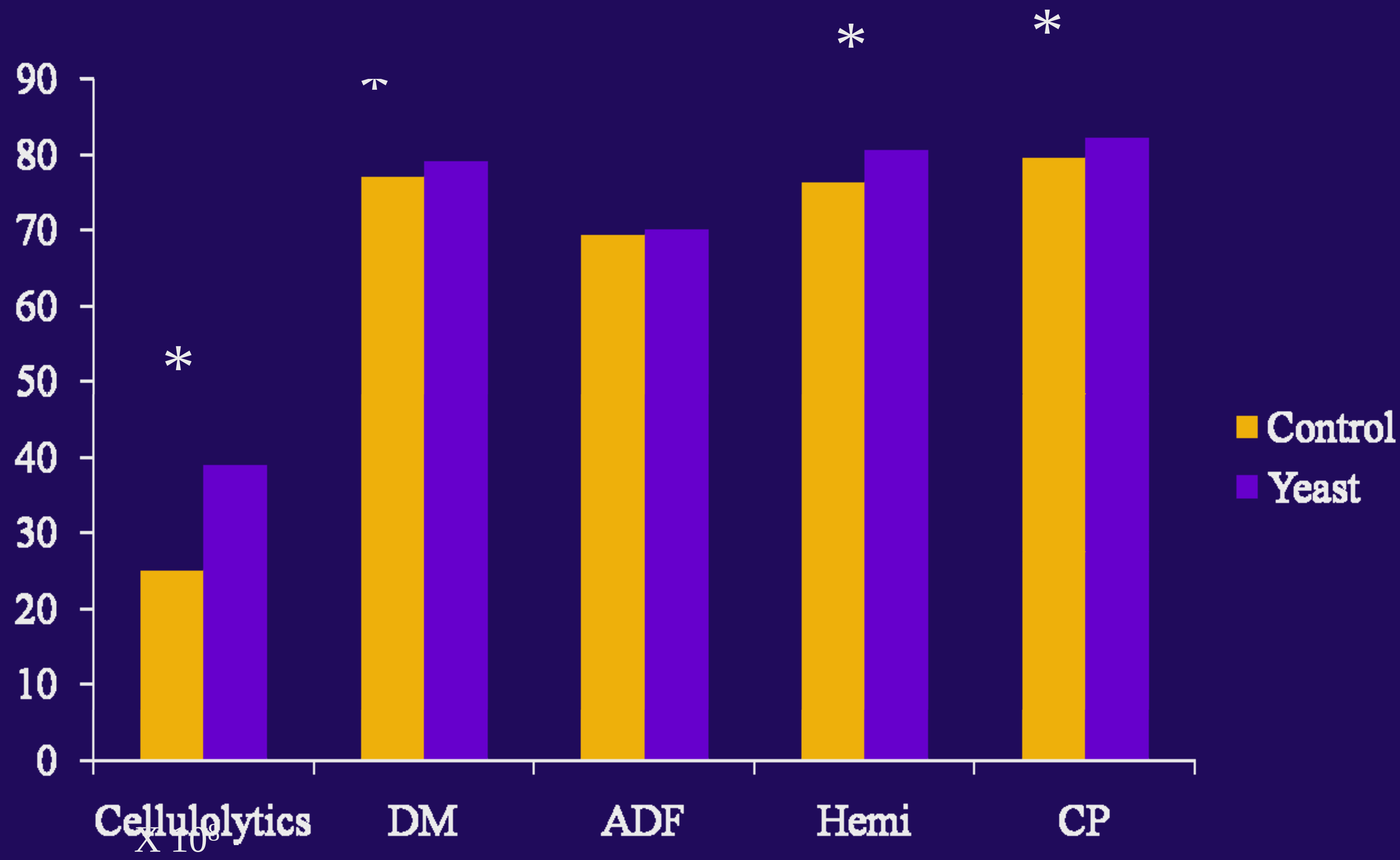


Fig. 3. Scanning electron micrograph of rumen fungi attached to a maize stem. (Gaillard-Martinie, B., Unit of Microbiology, INRA Clermont-Ferrand/Theix.)

Chaucheyras-durand & Fonty (2002).

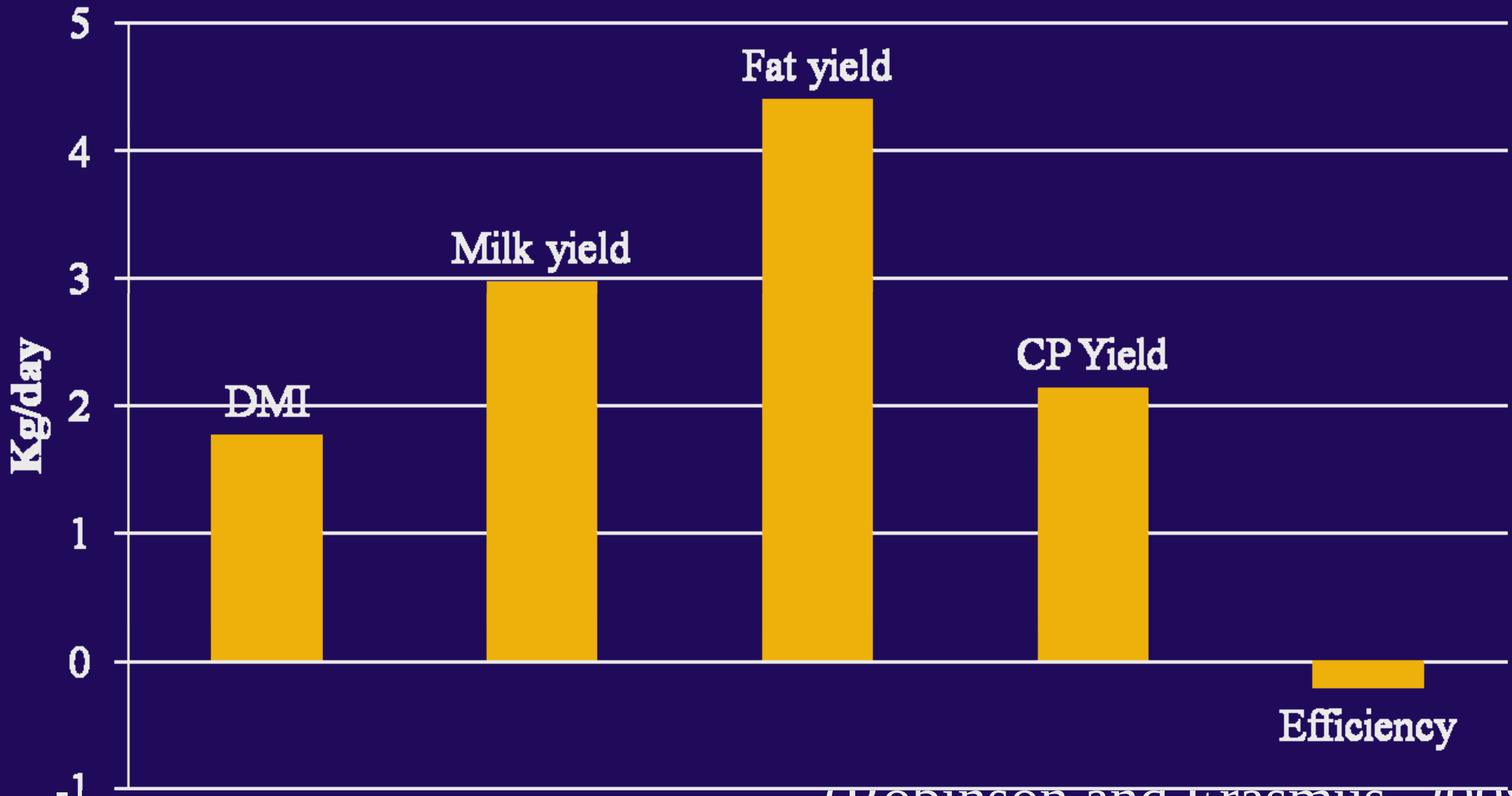
Effect of yeast supplementation on nutrient digestilbity, %



* = P<0.05

Weidemeir et al.,

% change due to feeding yeasts to dairy cows in 22 trials



(Robinson and Erasmus, 2008)

Yeasts: Summary

Stimulates numbers of total & cellulolytic bacteria which; increases fiber digestion,

Improves DMI and milk yield

Reduces acidosis and bloat

Yeast Guidelines

Add at 10 to 120 g/cow/d depending on yeast counts

Cost: 4 to 6 cents/cow/ day

Benefit to Cost Ratio: 4:1

Feed in early lactation with diets with high grain, low fiber content.

(Hutjens, 08)

Buffers

Chemicals that resist a pH change (neutralize acidity)

Complement buffering by saliva

Reduce acidosis (& bloat) in cows fed diets high in grain or acidic silages

Examples

- Sodium Bicarbonate: 0.75 - 1.5% diet DM
- Limestone: 1.0% diet DM
- Sodium Bentonite: 1 - 2% diet DM
- Magnesium oxide: 0.5 - 0.75% diet DM

Buffers mode of action

Increase fluid outflow rate due to greater osmolality

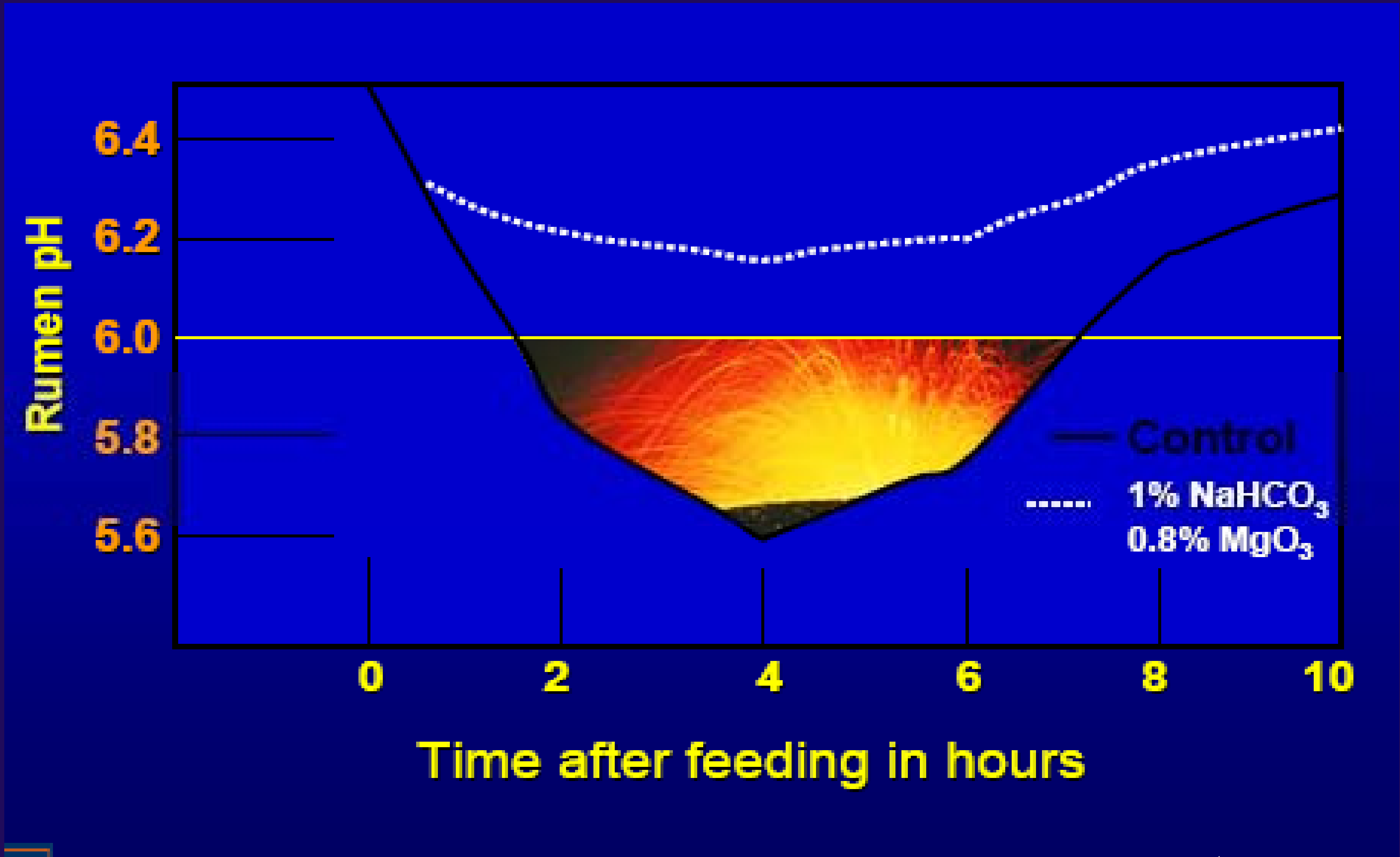
- Sodium bicarb or bentonite
- Increased water intake and outflow

Resist pH change or increase pH

- Prevent/reduce acidosis
- Prevent or reduce bloat

Increased pH may indirectly enhance fiber digestion and increase acetate to propionate ratio

Effects of buffer addition on rumen pH



(Hutjens, 08)

Effect of $NaHCO_3$ and MgO on dairy cow performance

	Control	$NaHCO_3$	MgO	Both	SE
pH	6.17[a]	6.43[b]	6.46[b]	6.34[ab]	0.04
Acetate:Propionate	2.02[a]	2.80[b]	2.85[b]	2.75[ab]	0.25
DMI, kg/d	18.6	19.8	19.8	19.6	0.4
Milk yield, kg/d	34.6	31.5	35.2	33.4	1.1
Milk fat %	3.26[c]	3.78[d]	3.96[de]	4.16[de]	0.26
Fat yield, kg/d	1.08[c]	1.14[cd]	1.37[d]	1.34[d]	0.05

(Erdman et al., 1980)

Buffers summary

Stabilizes rumen pH and increasing water intake and ruminal outflow rate.

Prevents acidosis and bloat

Sometimes increases fiber digestion and milk fat synthesis

Sodium bicarbonate/sesquioxide guidelines

Add at 0.75% of total ration dry matter intake

Cost: 6 cents per cow per day (at $0.41/kg)

Benefit to Cost Ratio: 4:1 to 12:1

Feed for 120 days postpartum with:

- High acid / moisture diets
- Low fiber diets (<19% ADF),
- Fine chopped forage/ pelleted grain
- heat stress conditions.

(Hutjens, 08)

Magnesium Oxide: Guidelines

Function: Alkalinizer (raises rumen pH) and increases uptake of blood metabolites by the mammary gland raising fat test.

Level: 45 to 90 grams per day

Cost: 21 cents per pound

Benefit to Cost Ratio: Not available

Feeding Strategy: With sodium-based buffers (ratio of 2 to 3 parts sodium bicarbonate to 1 part magnesium oxide).

Status: Recommended

(Hutjens, 08)

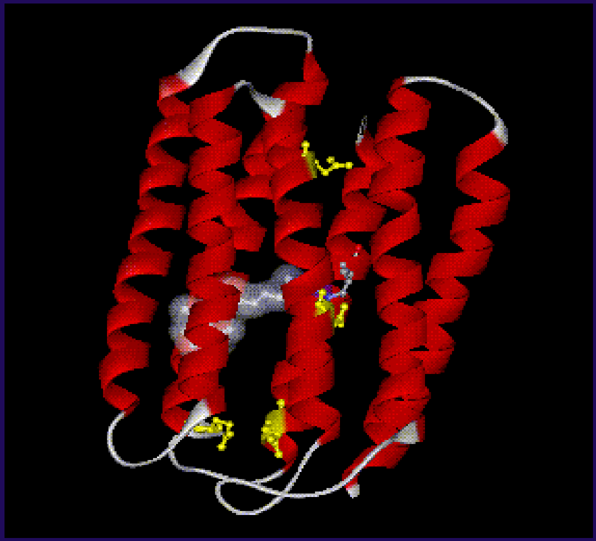
Enzymes

Globular proteins that are biological catalysts

How do they work?

Increase the rate of reaction

Increase the proximity of reactants



Enzymes in ruminant nutrition

Sources:

Fungal:

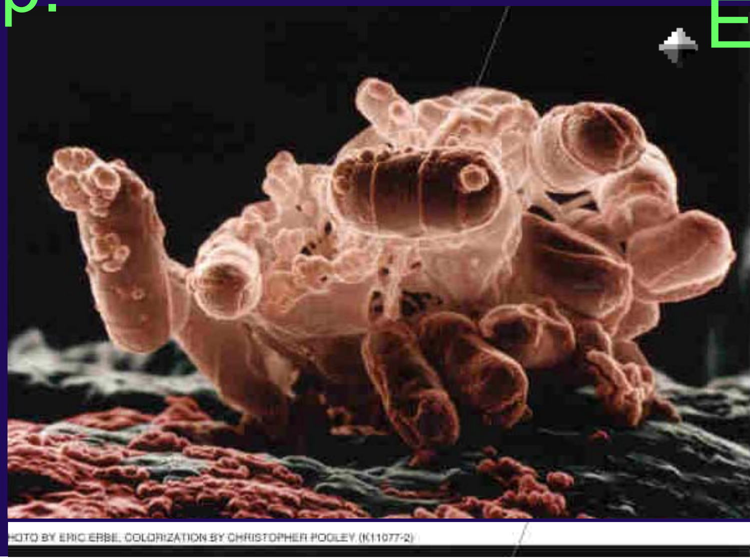
Aspergillus spp.

Trichoderma spp.

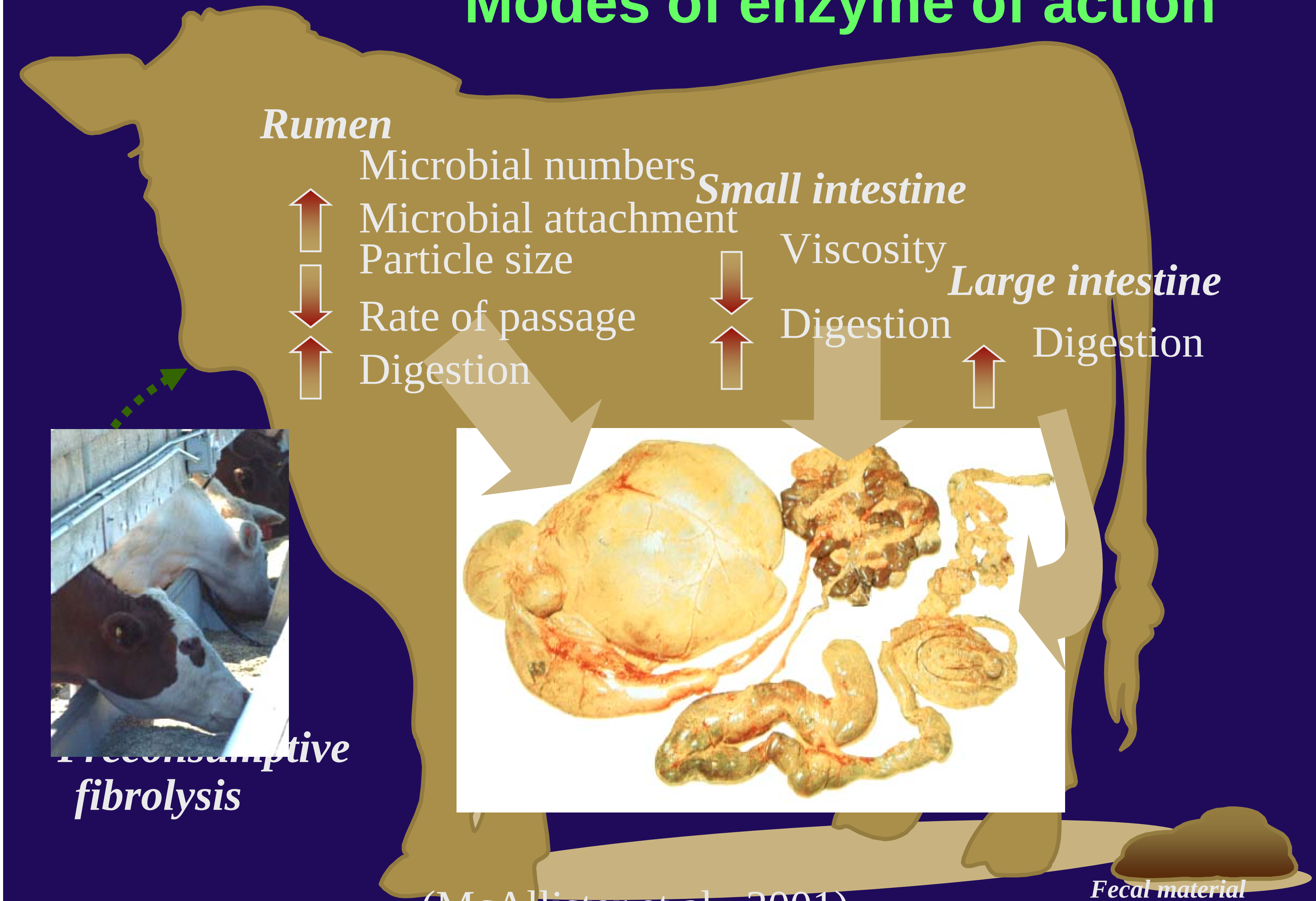
Bacterial:

Bacillus spp.

- Types:
  - Cellulases
  - Xylanases
  - Amylases
  - Proteases
  - Pectinases
  - Esterases



Modes of enzyme of action

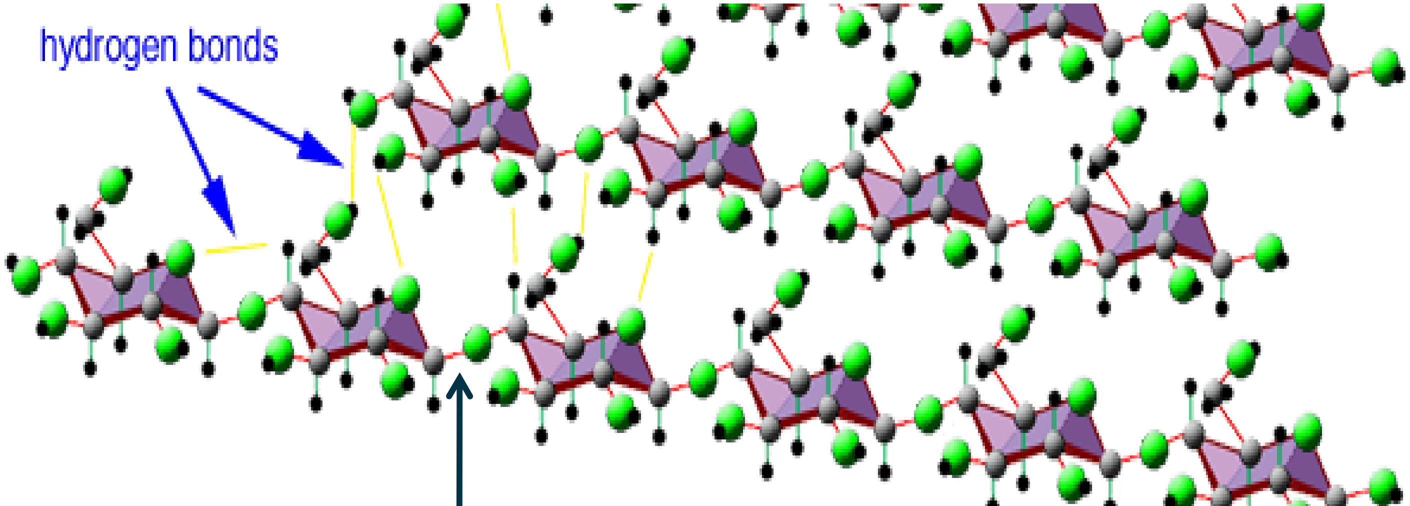


(McAllister et al., 2001)

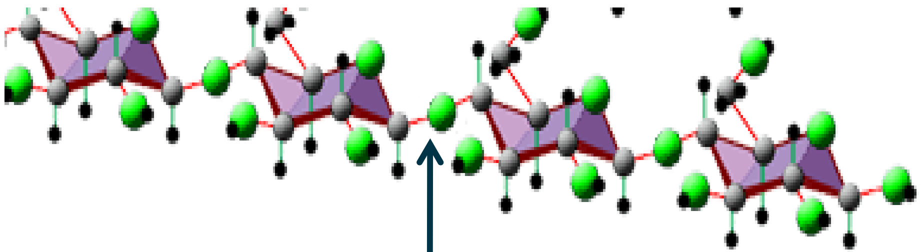
Enzyme application timing

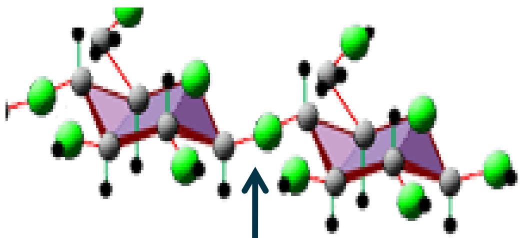
At ensiling vs. at feeding

Cellulose hydrolysis



Endoglucanase



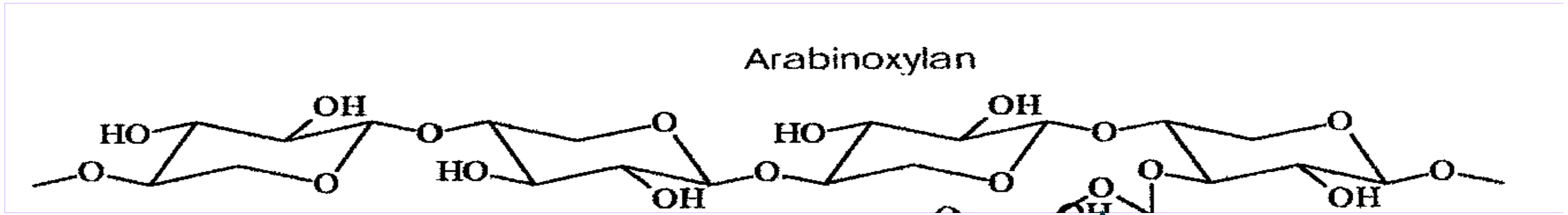


Exoglucanase

Beta glucosidase

http://www.brooklyn.cuny.edu/bc/ahp/LAD/C4c/graphics/fig_cellulose.gif

Xylanase hydrolysis



Xylanase

Xylanase

Fiber enzyme effects on milk yield from 41 treatments

Significance	% of studies	change in milk yield Kg/d	% change in milk Yield
Numerical effects (P > 0.05)	61	+1.13	3.3
Tendencies (P = 0.05 - 0.15)	20	+2.29	7.6
Real effects (P < 0.05)	20	+2.77	9.2

(Adesogan, 2006)

Potential reasons for enzyme failure

Diet

- Poor enzyme-substrate match / specificity
- Inappropriate enzyme delivery method or time
- Poor enzyme distribution
- Poor storage of enzyme / enzyme-treated feed

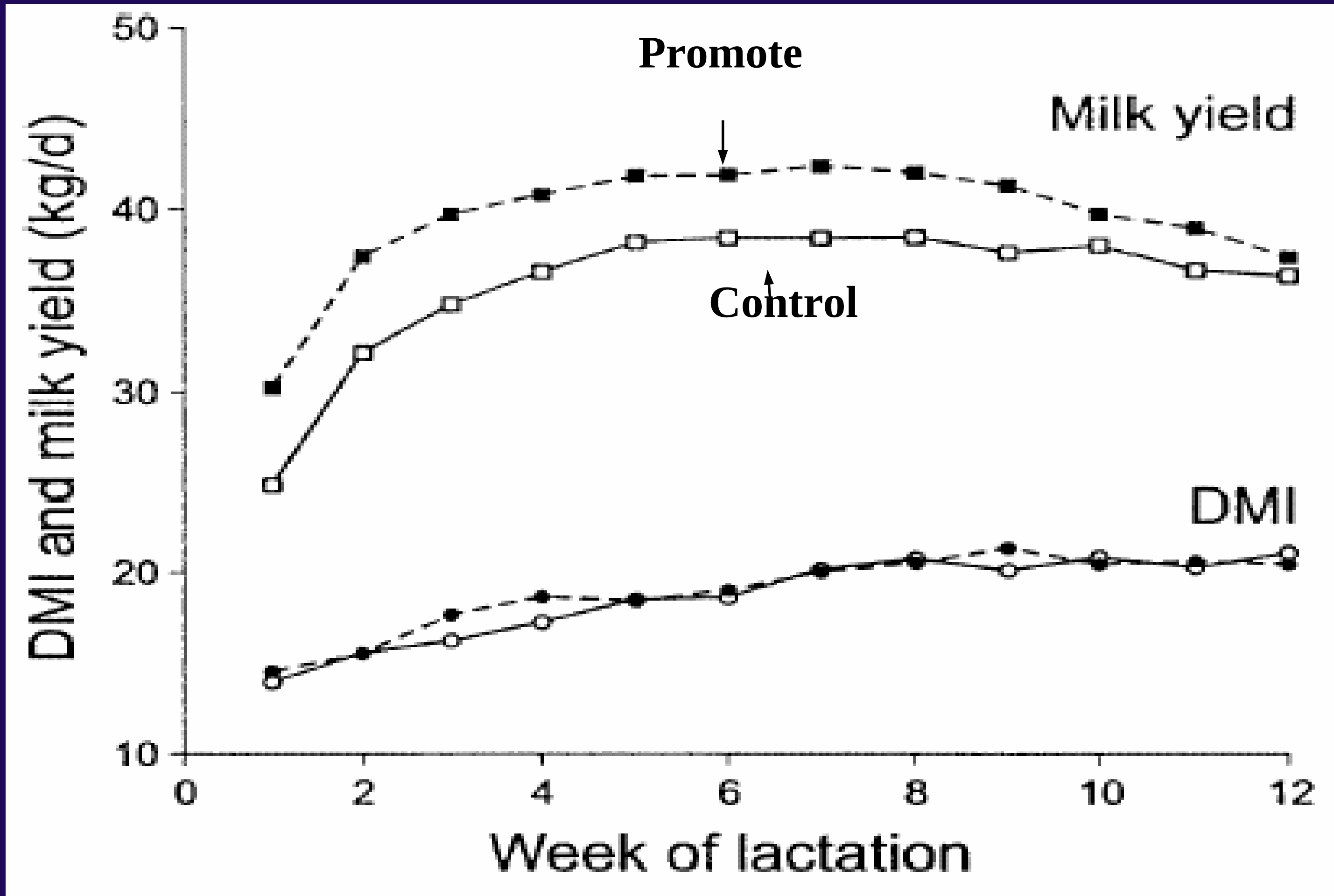
Cow

- Lactation stage & health

Enzyme

- Differences in composition & activity (between & within products)
- Wrong application rate
- Inappropriate/ insufficient activities for substrate
- Ruminal pH & temp. ≠ optima for enzyme

Promote enzyme effect on dairy cow performance



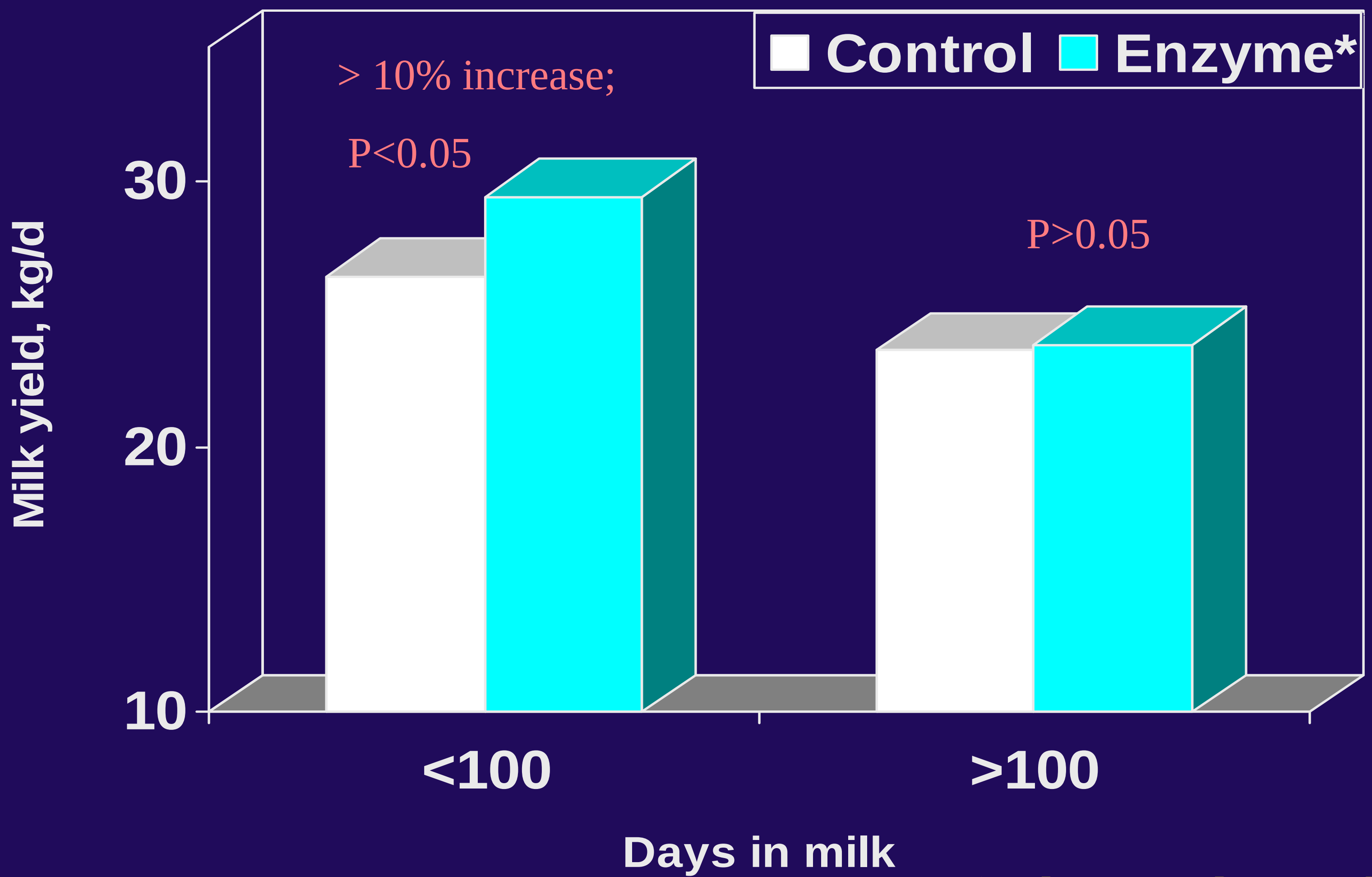
(Rode et al., 1999)

Promote enzyme effects on dairy cow performance

	Control	EConc	ETMR	EForage	SE
pH	6.32	6.11[x]	6.27	6.26	0.09
NH_3-N, mg/dL	15.1	13.6	10.1*	17	1.12
Acetate:Propionate	2.8	2.8	2.6*	2.7	0.05
DMI, kg/d	19.4	20.6	21.9[x]	18.7	1.3
Milk yield, kg/d	33.5	31.2[x]	32.5	31.5[x]	0.06
Milk:DMI	1.88	1.61	1.59	1.82	0.26

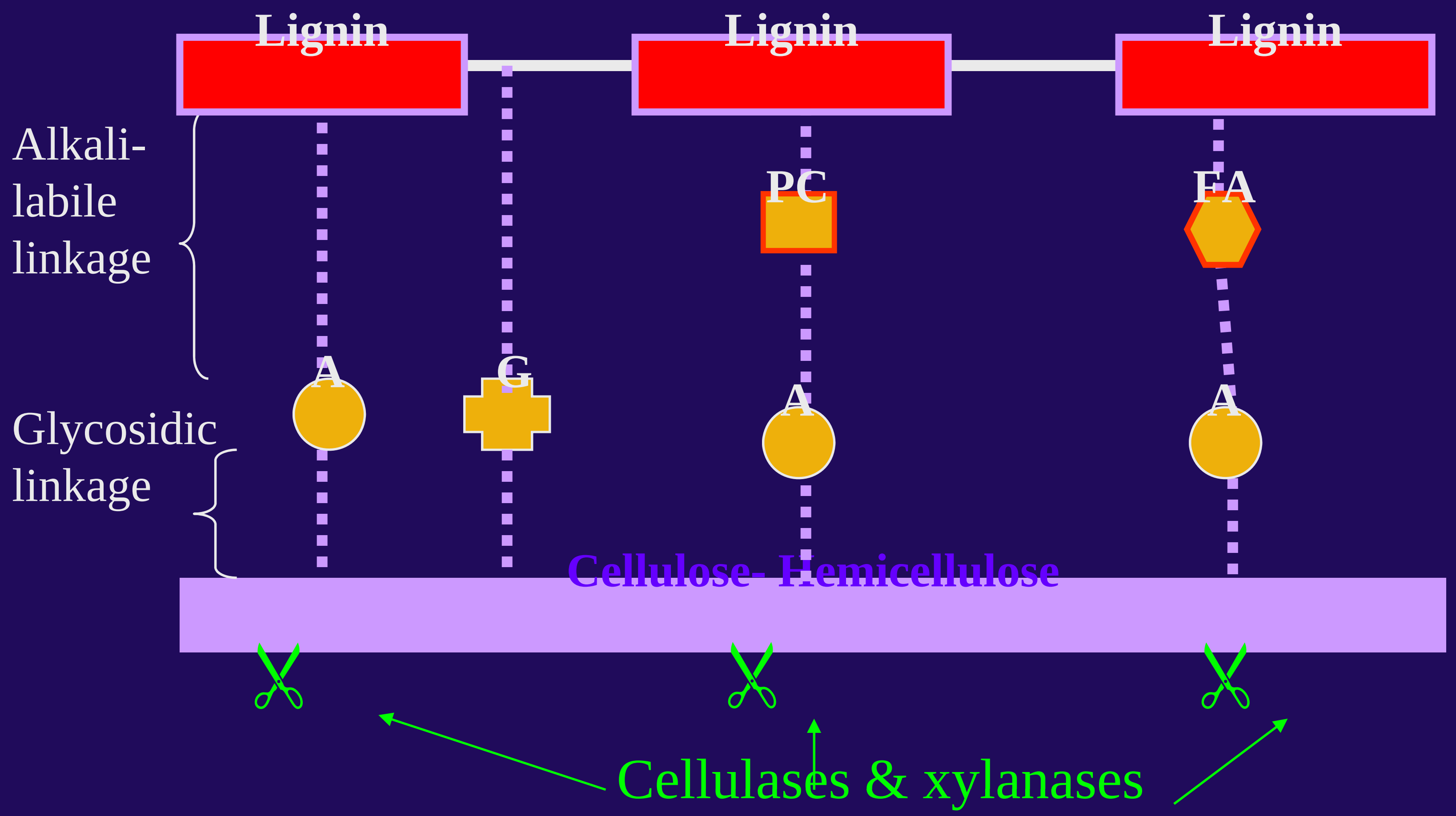
* = different from control, P< 0.05; x= tendency , P< 0.1)

Enzyme effects on milk yield from early- or mid-lactation cows

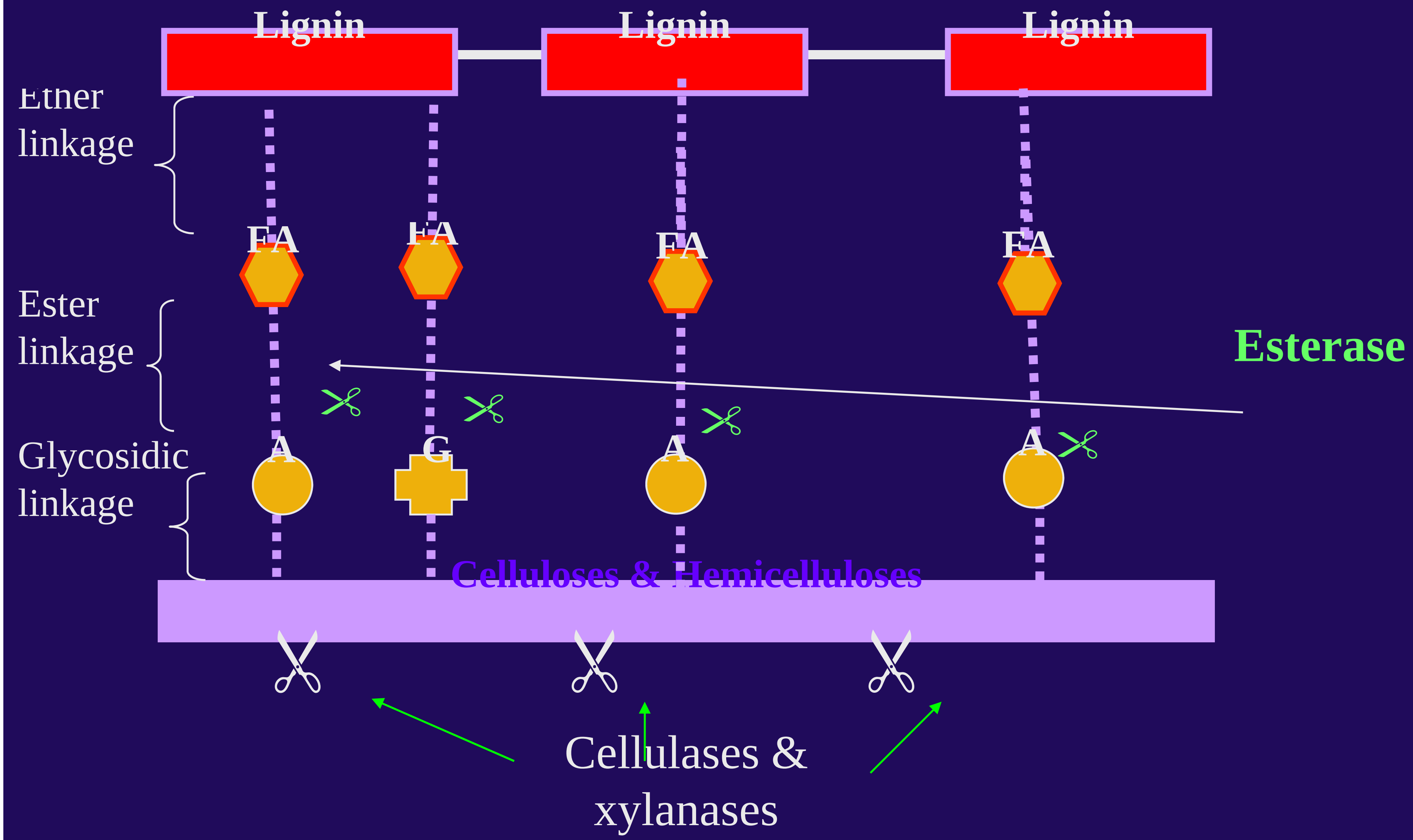


(Schingoethe et al., 1999)

Enzyme action on cell wall components



Effect of esterase enzymes on cell walls



Evaluation of an esterase-xylanase enzyme in dairy cows

Treatments:

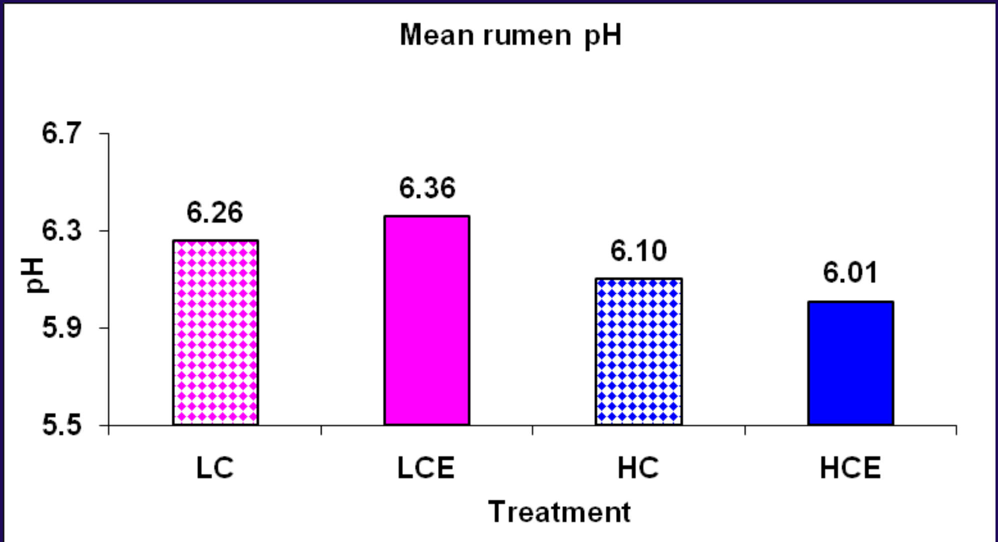
Low concentrate (33%) diet (LC)

Low concentrate (33%) diet + enzyme (LCE)

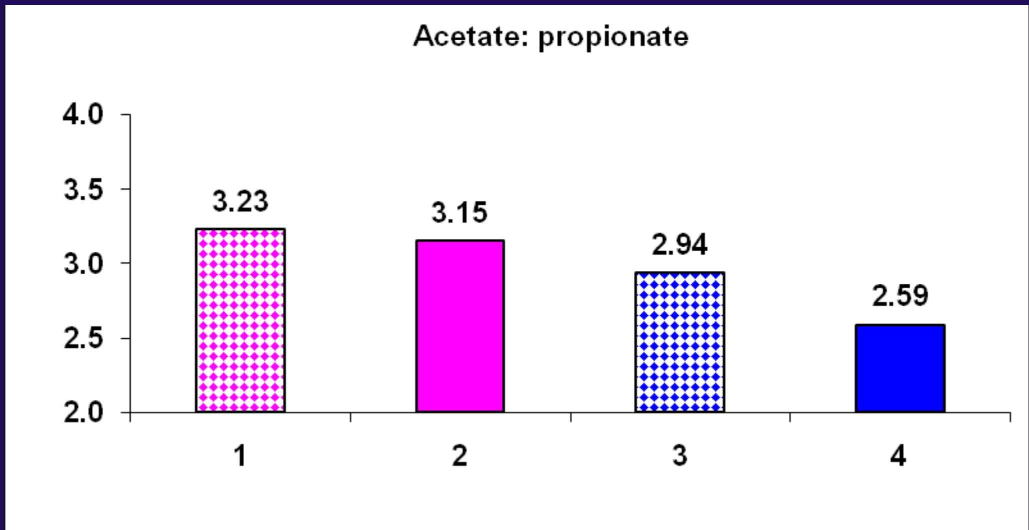
High concentrate (48%) diet (HC)

High concentrate (48%) diet + enzyme (HCE)

Effect of an esterase-xylanase enzyme application on ruminal pH

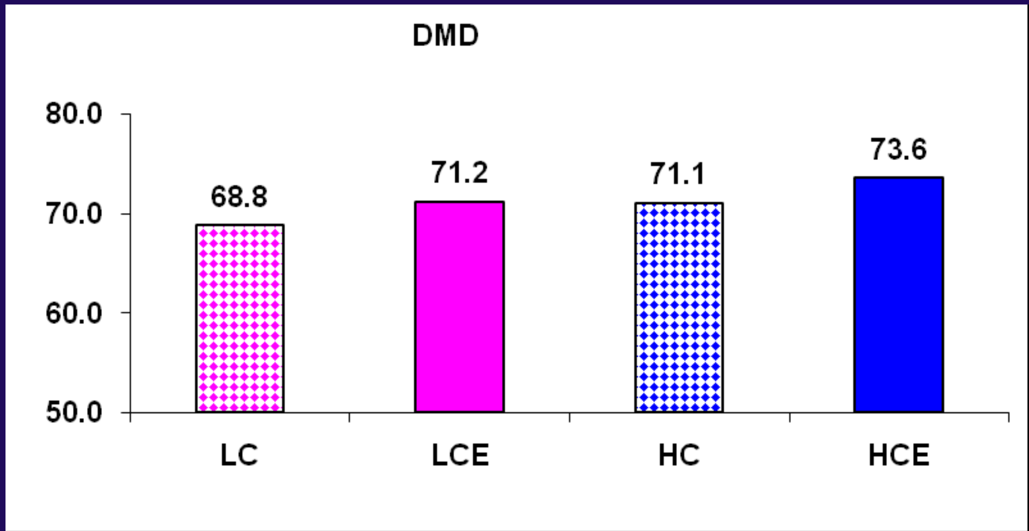


Contrasts, P =
Enzyme: 0.923
Concentrate: <0.001
LCE vs. HC: 0.006



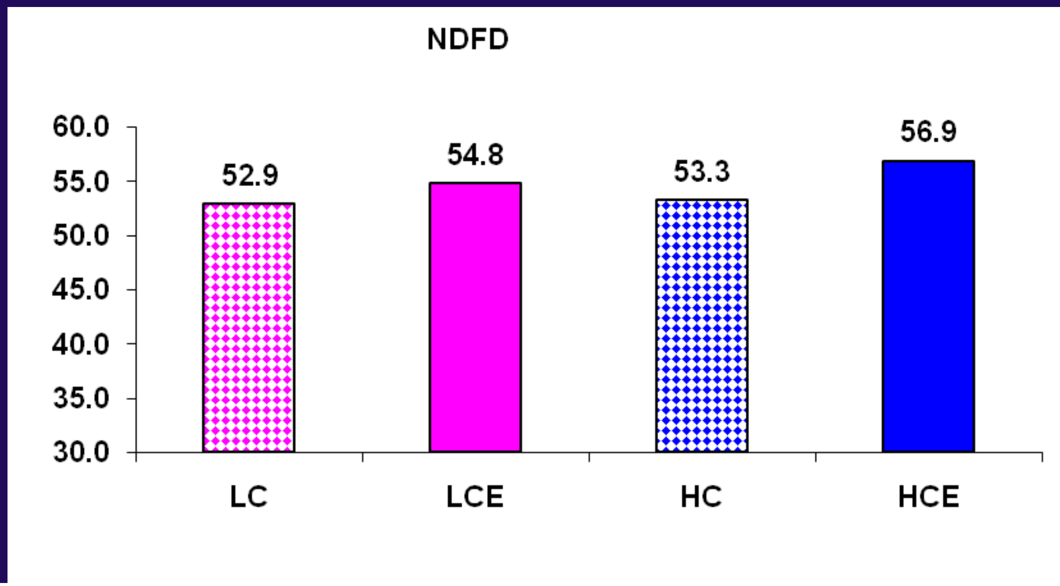
Contrasts, P =
Enzyme: 0.042
Concentrate: 0.003
LCE vs. HC: 0.285

Effect of an esterase-xylanase enzyme application on digestibility

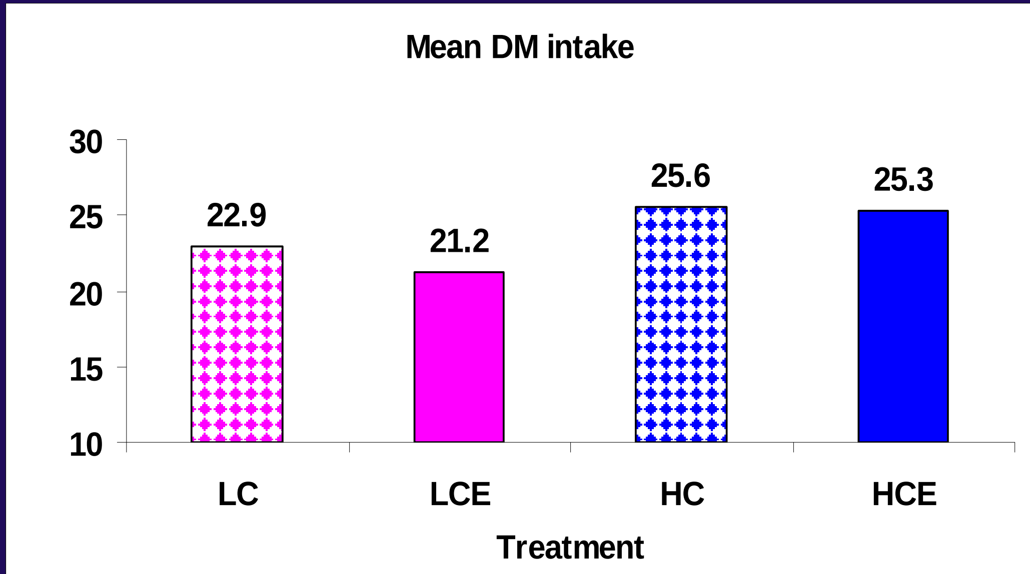


Contrasts, P =
Enzyme: 0.019
Concentrate: 0.021
LCE vs. HC: 0.976

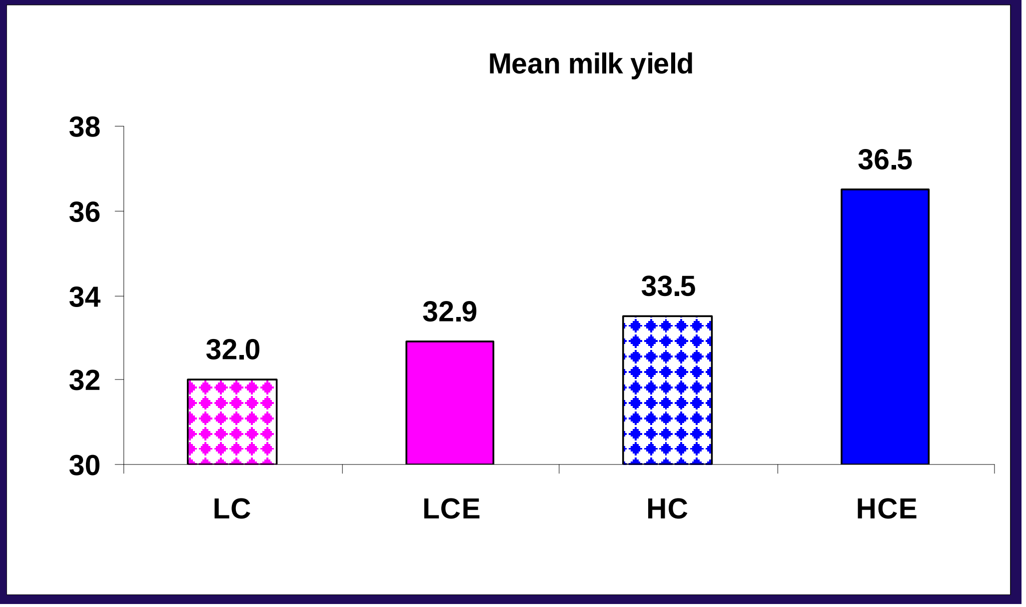
Contrasts, P =
Enzyme: 0.097
Concentrate: 0.426
LCE vs. HC: 0.540



Effect of an esterase xylanase enzyme on on DMI (kg/d) & milk yield (kg/d)



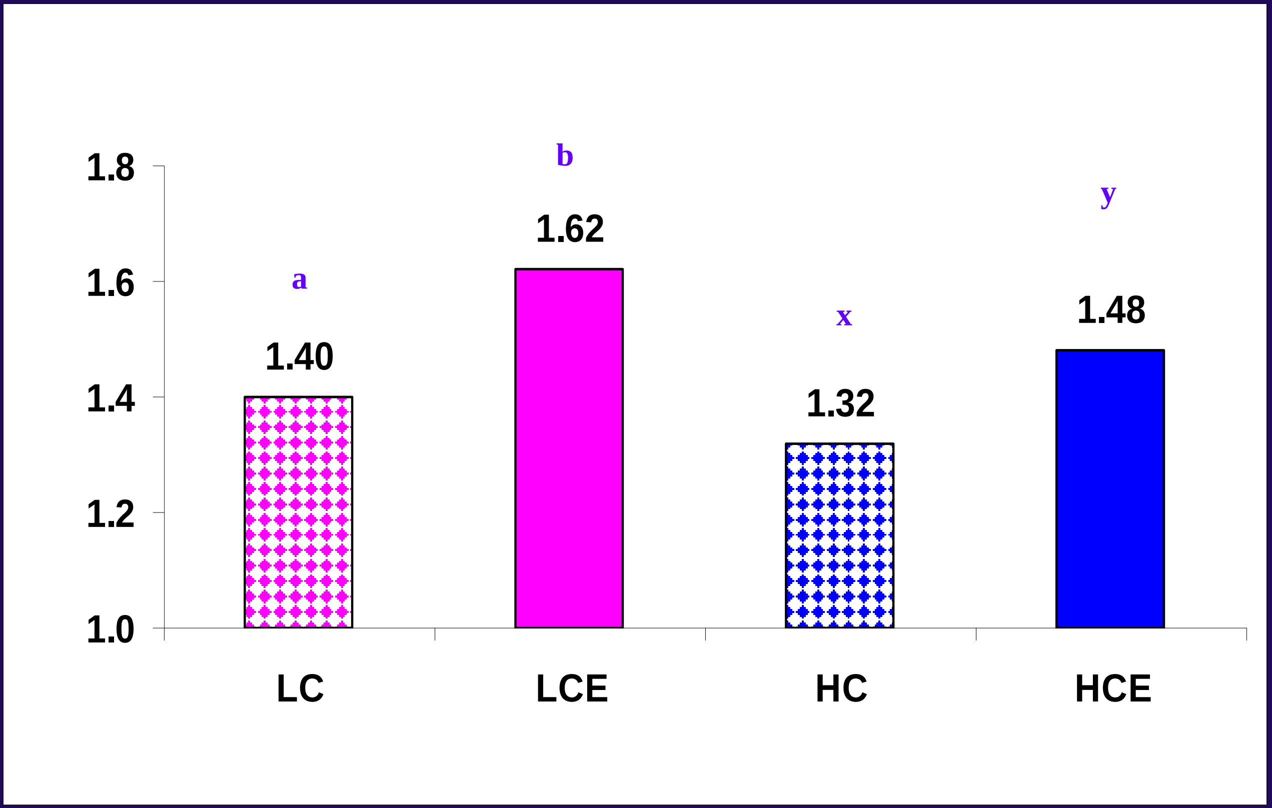
Contrasts, P =
Enzyme: 0.383
Concentrate: 0.005
LCE vs. HC: 0.009



Contrasts, P =
Enzyme: 0.063
Concentrate: 0.017
LCE vs. HC: 0.693

Effect of an esterase xylanase enzyme on feed efficiency (kg milk/kg feed)

Contrasts, P =
Enzyme: 0.008
Concentrate: 0.108
LCE vs. HC: 0.003



At the same concentrate level, bars with different superscripts differed

^{a,b} P < 0.05; $^{x\,y}$ = P < 0.15;

Daily income & feed costs per cow

	LC	LCE	HC	HCE
Milk income, $	11.31	11.81	12.09	12.93
Diet cost[1], $	4.30	3.98	4.76	4.70
Income over feed cost, $	7.01	7.82	7.33	8.23

[1]Exclusive of enzyme cost

Enzyme summary

Enzymes can improve fiber digestion and milk yield

Ensure adequate enzyme-substrate specificity;

Ensure enzyme works well at ruminal pH & temp.

Liquid enzymes are preferable; use in early lactation

Can cause SARA in high grain diets

Enzyme guidelines

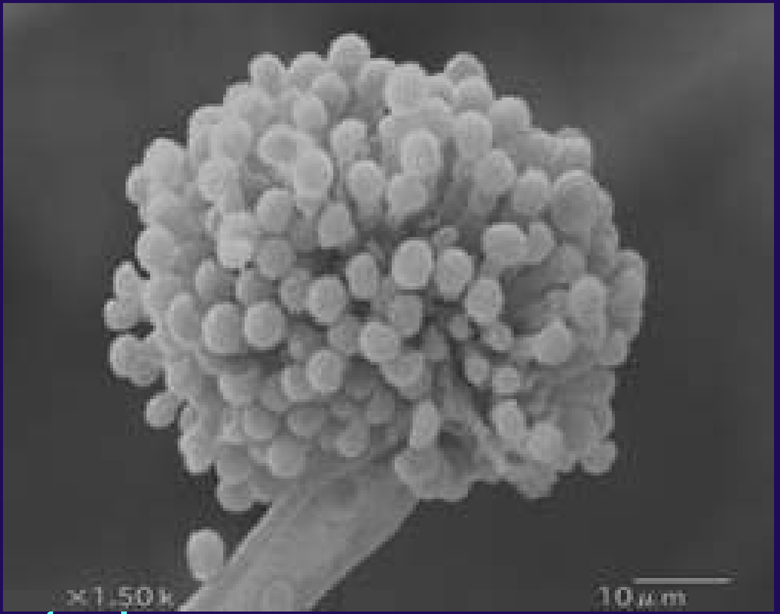
Cost: 15 to 25 cents per cow per day

Benefit to Cost Ratio: 2 to 3:1

Feeding Strategy: Apply to TMR and mix well before feeding; use in early lactation cows

(Hutjens, 08)

ASPERGILLUS ORYZAE



Fungal (mold) culture

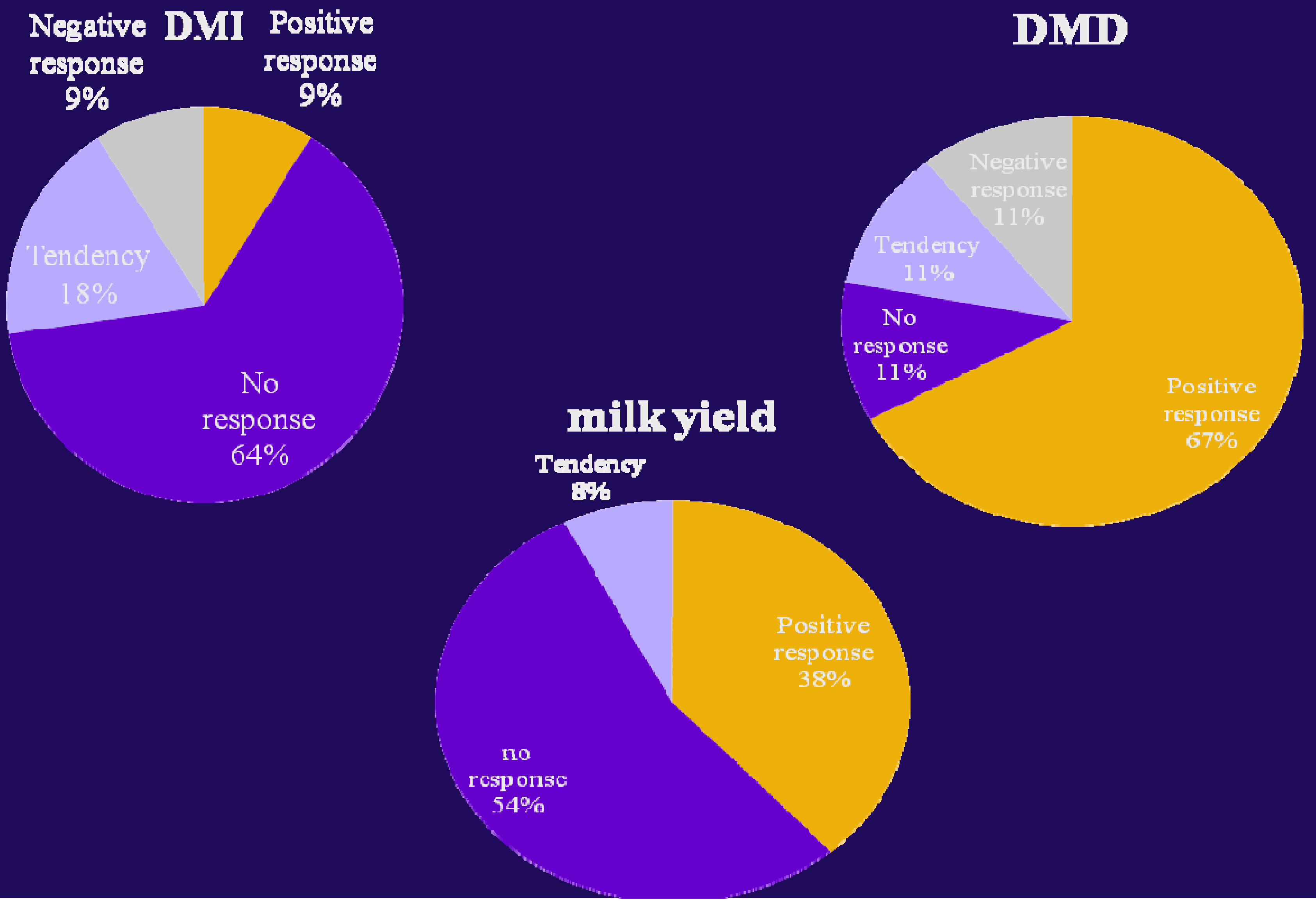
Contains fungal cells

+ fermentation extract

Mode of action

- Stimulates fiber-digesting bacteria;
- has fibrolytic enzyme activities
- Stabilize rumen pH
- Reduce heat stress

% of successful responses with A. oryzae



Aspergillus oryzae guidelines

Feed at 3 grams per day

Cost: 3 cents per cow per day

Benefit to Cost Ratio: 6:1

Feed with high grain diets, low rumen pH conditions, and under heat stress

(Hutjens, 08)

Rumen Feed Additive Summary

ADDITIVE	BENEFIT/COST	RECOMM
Monensin	5:1	Yes
Sodium bicarbonate	3-12:1	Yes
Yeast/yeast culture	3:1	Yes
A. oryzae & DFC	3:1	Watch
Enzymes	2-3:1	Watch

(Hutjens, 08)

Other issues

Feed additives are not a 'cure all'; don't substitute for poor management

Ask yourself these questions before using one

Do cows have adequate bunk space?

Is the ration balanced; are cows eating well?

Are cows split into groups and fed accordingly?

Am I keeping good records; are cows health?

If yes

Consider what do I need an additive for?

Which one will surely meet my need and provide at least a 2:1 return

Apply the 4 Rs for the chosen additive

Hutjen’s 4 Rs for Evaluating Additives

Response: What response do you want

Return: Need > 2:1 ROI to cover unresponsives

Research: Are claims verified by research

Results: Will your record keeping show a response

(Hutjens, 08)

Take home messages

Additives can be used to improve milk production

Choose carefully: Use only those matching your needs

Beware: fake and effective products abound

Use only research proven, farm tested products.

Treatments

5. Ammonia application

Anhydrous ammonia applied at rate of 30 g/kg DM

Sealed for 6 weeks and then vented