Fermentation in the Hindgut of the Horse – Possibilities of Disorders

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Summary

The microbial exosystem in the horse's large intestine degrades carbohydrates, and more particularly those contained in the cell walls, and produces volatile fatty acids; the percentages of each of these acids depend on the diet and its mode of distribution. Generally speaking, the percentage in acetic acid is higher in the horse's cecum than in the ruminants' rumen, but the methane production in the cecum during acetogenesis is lower than in the ruminants' rumen. However, although ammoniogenesis and microbial proteosynthesis are more or less intense in the cecum and the ventral colon, they remain linked to disponibility in in situ energy, but the absence of proteolytic enzymes in the distal part of the large intestine limits the degradation of bacterial proteins there, which, by the way, results more in the production of ammonia than of amino acids. It is possible to have digestive trouble like stomach rupture or colic.

Verdauung im Dickdarm des Pferdes – Möglichkeiten für Störungen

Im Dickdarm des Pferdes bauen Mikroorganismen Kohlenhydrate, vor allem Zellwandbestandteile, ab und bilden kurzkettige Fettsäuren. Das Fettsäurenmuster hängt von dem Futter und der Lokalisation im Darm ab. Allgemein ist der Acetatanteil im Caecum des Pferdes höher als im Pansen der Wiederkäuer, doch bleibt die Methanbildung bei Acetogenese geringer als im Pansen. Obwohl die Ammoniumbildung und mikrobielle Proteinsynthese im Caecum und ventralen Colon m. o. w. hoch ist, bleiben beide Vorgänge von der gleichzeitigen Verfügbarkeit von Energie abhängig. Da im distalen Colon proteolytische Enzyme weitgehend fehlen, ist der Abbau bakteriell synthetisierten Proteins begrenzt. Die Bildung von Ammoniak überwiegt gegenüber der von Aminosäuren. Störungen können auftreten, z. B. Magenrupturen oder Koliken.

Introduction

The horse is a herbiovore and yet, as opposed to ruminants, it only benefits from microbial digestion in the second part of its digestive tract. As a consequence, the fermentations from which the host animal could take advantage are closely related to what takes place before the ileocecal valve and the products which are formed are partially different from what has been observed in ruminants. This, moreover, results in possible specific disorders. That is why after examining the horse's digestive particularities and insisting on its microbial fermentary phenomena in particular we will have a look at the main disorder causes which are known at the moment.

The Particularities of the Horse's Digestion

a) *In the first part of the digestive tract*

Mastication of foods is very intense. According to *Colin* (1886) the horse takes 40 minutes to ingest 1 kg of hay and to make 3000 jaw movements. Saliva production is very abundant – approximately 40 kg per day –; it is more important in forage than in concentrated food.

A good preparation of an alimentary bolus is indispensable for deglutition. This is rendered difficult by the presence of a well-developed soft palate. Considering the regular wear of the teeth, a less abrasive forage could protect the appearance of pads or wolf's tooth on the molares which limits mastication and hinders normal deglutition.

Due to the fact of the small stomach capacity (the actual) usable volume being – 10 to 12 l – a more or less important food fraction passes directly through the stomach into the duodenum; gastric digestion concerns only the last part of the ration. The stomach usually empties itself slowly in the hours following the meal by passing small quantities to the duodenum through the pyloric sphincter. This fractionated amount is an important factor in the efficiency of digestion in the small intestine.

If the stomach has a digestive role which is not very important in the horse, its function as a regulator of intestinal passage is essential for the digestion of hydrolysable carbohydrates and proteins in the small intestine.

The wall of the small intestine is submitted to a number of variations in tonus at the duodenum. *Simonnet* et *al.* (1952) described the in vitro effect of certain plant extracts (alfalfa, vetch, bromus) stimulating the motility of the duodenum. But the intestinal motility is mainly settled within the jejuno-ileum (*Ruckebusch,* 1984). *Brunaud* and *Dussardier* (1952) noted that the sensitivity of the intestinal mucous to adrenalin action of the horse provokes atypical contractions of the epithelium of the small intestine. This could explain the fact that digestive troubles often cause colic in the horse. The hydrolysable and reserve carbohydrates are degraded with production of glucose, an energetic nutrient very profitable in horses. The production of amino acids out of food proteins allows, with an adequate diet, to meet the essential needs of horses in amino acids.

Vitamin absorption also takes place in the small intestine, but the rapid passage of forages in it reduces more or less strongly the transformation of carotene in vitamin A.

b) *In the large intestine*

The digestion in the large intestine is essentially due to microorganisms which are in the cecum and in the great colon. This last part occupies an important place in the large intestine and could be substituted to the cecum (*Sauer* et *al.,* 1979; *Meyer* et *al.,* 1979). Food residuals can stay there sometimes longer than in the cecum.

Microbial population:
According to *Kern* et *al.* (1974), bacteria which vary between 10^7 and 10^{10} per ml of cecum content are composed essentially of streptococci, species of the bacteroidal type, lactobacilli and propionic bacteria. The protozoa between 10^3 and 10^4 per ml of cecum content are mainly composed of ciliates. There is no important difference between the fauna of the ventral colon and that of the cecum, but the flora is always more abundant in the cecum (*Bellet,* 1982).

Carbohydrate utilization:
The addition of cereals to a hay ration increases the number of anaerobic bacteria, and in particular, amylolytic and proteolytic species (*Kern* et *al.,* 1974; *Baeaer,* 1974). This increase affects more the cecal than the colic flora, and oats, despite their lower amount of energy, seem to be more efficient than corn (*Bellet,* 1982).
These microbes assure the digestion of food residuals and especially fibrous carbohydrates. Cellulose degradation is effected by cellulolytic bacteria with a production of volatile fatty acids (VFA) the average molar percentages are the following: acetic acid 67 p. 100, propionic acid 19 p. 100 and butyric acid 14 p. 100 (*Kolb,* 1975). In relation to what is already known about the rumen of polygastrics, as demonstrated by *Tisserand* et *al.* (1977); it has been shown that in the cecum of the pony, receiving a ration of hay and oats, the pH (7.5) is higher despite the small concentration in nitrogen (70 mg/l). The total amount of volatile fatty acids (50 mmol/l) is less with a higher acetic acid molar proportion (70 p. 100). Variations during the day are less important than in the rumen of polygastrics as shown in table 1.
Hintz et *al.* (1971) have described the modifications of volatile fatty acid production in the pony occurring in relation to the forage concentration of the ration (table 2).

The effects of the mode of distribution of cereals and hay on the proportion of volatile fatty acids produced in the cecum of the pony are shown in table 3.

Distribution of the VFA after feeding a ration in the morning composed uniquely of cereals does not cause any increase in propionic acid production, neither during the day nor at night. This seems to prove that, in this case, oats are practically digested before arriving in the cecum.
If cereals constitute the predominant part of the amount of energy of the ration, it seems favourable to distribute them separately from hay or after the hay meal, so that they can be used in the "most complete" way in the stomach, and in the first part of the intestine.
On the other hand, if cereals are only complementary to improve the hay ration, they must be distributed at the same time as hay. This stimulates microbial activity in the large intestine and increases forage usage by the animal.
The intensity of cellulose utilization depends on the degree of plant lignification. It is more important in the cecum than in the colon. *Kolb* (1975) measured the intensity of cellulolyse in the cecum (64 p. 100) ventral colon (38 p. 100) and dorsal (23 p. 100).
The addition of oats to a ration of hay noticeably increases cellulolytic activity (+30 %) in the cecum. On the contrary, grinding and the "agglomeration" of hay cause only a small decrease whereas grinding and the agglomeration of hay and oats together provoke an important decrease of cellulolyse (–35 %). In the colon, the addition of oats to the ration of hay also increases cellulolytic activity (+20 %) but agglomeration of hay alone or with oats does not modify the cellulolytic activity.

Nitrogen utilization:
Ammoniogenesis and microbial proteosynthesis are intense in the cecum and ventral colon (*Reitnour* et *al.,*

Table 1: Average nitrogen levels + volatile fatty acids by volume in the caecum of the pony (by Tisserand et al., 1977)

	pH	Total N mg/l	NH_3-N mg/l	VFA mmol/l	Acetic acid mol %	Propionic acid mol %	Butyric acid mol %
Average value	7,49	584	69	49	69	23	5,3
Sx during the day	± 0,13	± 80	± 22	± 9	± 4	± 2	± 0,7

Table 2: Effect of forage/grain-ratio on production of volatile fatty acids in the large intestine of the pony (by Hintz et al., 1971)

	Proportion forages/grain	VFA mmol/l	Acetic acid mol %	Propionic acid mol %	Isobutyric acid mol %	Butyric acid mol %	Isovalerianic acid mol %	Valerianic acid mol %
CECUM	1/0	57.3	76.2	14.8	0.3	8.0	0.2	0.5
	3/2	51.7	70.4	21.2	0.2	7.2	0.2	0.8
	1/4	47.8	61.2	26.0	0.5	10.2	0.9	1.2
COLON	1/0	41.8	69.5	16.2	2.7	7.6	3.1	0.9
	3/2	47.6	68.2	15.0	2.9	8.8	3.9	1.2
	1/4	28.4	67.0	17.0	2.5	9.0	3.6	1.1

Table 3: Effect of the mode of distribution of oats in comparison to meadow hay on microbial digestion in the cecum of the pony (by Tisserand et al., 1978)

	Diet I O,5 kg oats + hay ad libitum morning and evening	Diet II 1 kg oats in the morning meadow hay ad libitum at evening	
		Day	Night
pH	7.45 (7.6–7.3)	7.65 (7.6–7.7)	7.65 (7.65–7.65)
NH_3 - N mg/l	47 (38–56)	30 (24–37)	37 (33–41)
N total mg/l	523 (432–614)	429 (382–477)	403 (367–439)
Volatile fatty acids	63 (53–74)	67 (65–70)	62 (54–70)
Acetic acid mol %	75.5 (74–77)	79 (78–80)	79 (78–80)
Propionic acid mol %	17 (19–15)	15 (17–13)	14.5 (17–12)
Butyric acid mol %	5.0 (5.1–4.9)	4.3 (4.5–4.1)	4.5 (4.6–4.4)

1970). Yet, proteosynthesis is linked to the presence of energy in the large intestine and more particularly starch given by the cereals which are not digested in the small intestine (table 5).

The degradation of the microbial proteins which do not benefit from the proteolytic enzymes in the small intestine remains limited and produces more ammonia than amino acids (*Slade* et *al.*, 1970). Alimentary proteins directly introduced in the cecum are not as well utilized as when they are ingested (*Reitnour* and *Salsbury*, 1972). Some authors (*Nelson* and *Tyznik*, 1971; *Hintz* and *Schryver*, 1972) point to the possibility of using urea to cover, very partially it is true, the horse's nitrogenous needs.

Possibilities of Disorder

a) *In the first part of the digestive tract*

The consequences of the position of microbial fermentation in the digestive process seem to be more important before the ileo-cecal valve. As a matter of fact, the need to break up rough forages well in the mouth results in the case of wolf's teeth in a reduction of ingestion. Moreover the very developed soft palate makes it difficult to treat the animals through the mouth except at meal times.

The small volume of the stomach can cause disorders linked to the fact that vomitting is almost impossible. As a matter of fact, the distribution of finely crushed and agglomerated bran results in the production, when it mixes with saliva, of a paste which could seal off the gastric canals – which fabours gas producing microbial fermentations – in the stomach and could lead to the deathly break up of this digestive pocket. Incidentally, the absence of gastric retention and of the digestive action of the gastric juice can greatly diminish the production of amino acids in the small intestine. This provokes proteic deficiencies in the horse. A recent study conducted by *Cabrera* in our laboratory and presented in another paper shows that the distribution rhythm of forages and concentrates plays a part on the disposal of amino acids, which constitute the main nitrogenous nutrient of the horse (figure 1).

Table 4: Effect of the diet on cellulolytic activity in the large intestine of the pony (Tisserand et al., 1980)

Diet	Caecum (1)	Proximal colon (2)
Meadow hay	22.1	32.8
Meadow hay + oats	29.3	39.5
Meadow hay, ground agglom.	19.5	31.1
Meadow hay, ground oats agglom.	14.3	34.9

(measured by the nylon bag technique) (1) 24 h. (2) 48 h.

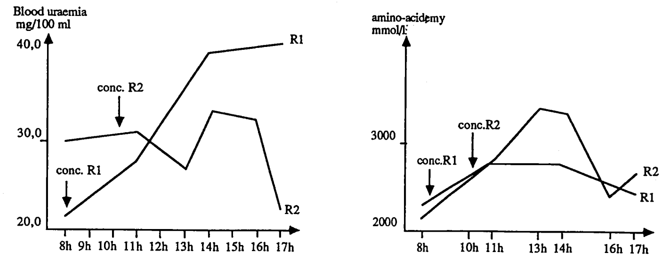


Figure 1: Uraemia and amino acidaemy in relation to concentrate distribution rhythm (*Cabrera*).
R_1 concentrate with forage
R_2 concentrate two hours after forage

Table 5: Effect of cecal corn starch administration on nitrogen retention (Reitnour, 1979)

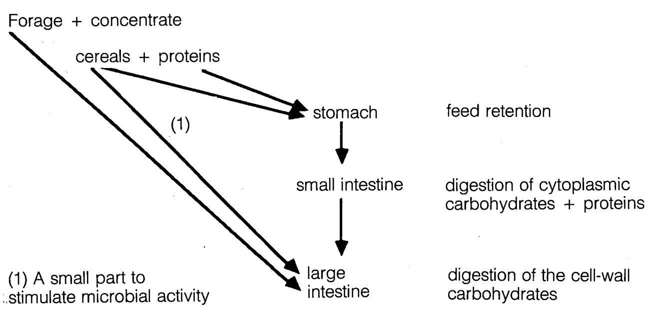
	Nitrogen intake		Nitrogen excretion				Nitrogen retention			
	feed		feces		urine					
Treatment	0	starch	0	starch	0	starch	0		starch	
	g/day	g/day	g/day	g/day	g/day	g/day	g/day	SE	g/day	SE
Basal	15.9	15.2	7.2	6.8	8.6	8.0	1	± 4	4	± 6
Corn gluten meal	33.0	32.5	10.2	9.5	22.0	21.2	8	± 4	1.8	± 5
Caesein	42.1	41.3	10.1	8.1	28.5	26.5	3.5	± 1.1	6.7	± 2.0
Urea	38.7	38.2	8.5	7.9	37.8	32.7	−7.6	± 4.4	−2.4	± 2.1

In the small intestine, the hyperexcitability of the mucous membrane is well known and breeders worry about colics which could result from feeds rich in earth, silica and potassium in particular.

b) *In the large intestine*

Unlike what happens in the case of ruminants, horses run almost no risk of distension in the large intestine. Just as acetonaemia risks linked to too important a production of butyric acid in the large intestine do not seem to make up an important problem. On the other hand, microbial digestion efficiency seems closely linked to the supply of energy which can be used for microbial growth; in order to optimize the use of feeds in the diet, one must reason out the distribution rhythm in relation with their composition (figure 2).

Figure 2: Horse rationing strategy.



Moreover, it seems that the retention of particles in the cecum is linked to their sizes, which favours the production of volatile fatty acids from cell wall carbohydrates in this digestive compartment. Too finely crushed forages in agglomerated feeds could favour direct passage into the colon and so diminish their energetic use.

Finally factors which could improve the production of absorbable amino acids from the degradation of microbial proteins should be studied to improve the nitrogenous supply of horses.

Conclusion

Microbial fermentations allow the horse to be a true herbivore, but the fact that they take place in the last part of the digestive tract limits profit for the host animal, in particular as far as nitrogenous nutrition is concerned.

Moreover they can result in specific disorders which can constitute a threat to the animal's life. It seems advisable to try and collaborate in order to optimize the horse's microbial digestion.

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