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RESUME - «Besoins nutritionnelles du dromadaire». L'anatomie et la physiologie de l'appareil digestif du dromadaire présentent des particularités par rapport au schéma classique du ruminant. L'estomac ne comporte que 3 poches et la première poche a une motilité très différente de celle d'un ruminant. Le dromadaire apparaît particulièrement apte à recycler l'urée sanguine par la voie salivaire. Il est capable de trier très fortement sa nourriture et se nourrit essentiellement de prélèvements sur des arbustes et dans les broussailles. Il peut résister à de mauvaises conditions d'abreuvement. La détermination de ses besoins nutritionnels reste très empirique et souvent déduite des besoins des bovins.

Mots-clés: Dromadaire, digestion, besoins nutritionnels.

SUMMARY - The anatomy and physiology of the dromedary digestive tract present certain particularities with respect to the typical ruminant. The stomach has only 3 compartment, the first one having a very different motility from that of a ruminant. The dromedary seems particularly fit to recycling blood urea through saliva. It is capable to greatly select its food and to feed basically from shrubs and underbrush. It can withstand harsh watering conditions. Assessment of its nutritional requirements remains very empirical and often inferred from cattle requirements.

Key words: Dromedary, digestion, nutritional requirements.

There has been relatively little research on nutritional aspects of the Camelidae. This section therefore draws on all available sources of data for all the species of camelids and is not confined to research on *Camelus dromedarius* alone.

Anatomy of the digestive tract

The mouth and upper throat

Camels have a prehensile and split upper lip which is used for selectively grasping plant parts. The lower lip is large and pendulous. The upper dental pad is hard and horn-like in texture. The membrane of the inner cheek is covered with conical papillae which point backwards. The hard palate is long and the soft palate («dula'a») is extensible and is often protruded from the mouth, particularly in the rutting male. The tongue is small but very mobile and has five to seven papillae of large diameter along each side. Dentition differs from that of the true ruminants in that there are incisors in the upper jaw and both upper and lower jaws have canine teeth («tushes»). The salivary glands are similar to those of other ruminating animals.

Pharynx and oesophagus

The pharynx is a long and narrow tube whit a constriction partly dividing it into two chambers. The oesophagus is 1-2 m. long and of large capacity: it has secreting glands which apparently function to moisturize the food.

Stomachs

The camelids have only three distinct chambers in the stomach (figure 3). They differ from the Ruminantia in gross anatomy in that there is no clear distinction between the third and fourth chambers (figure 4). Although it is conventional to refer to the different parts of the camel stomach by the same terminology as used for true ruminants, it is not certain that the parts which perform analogous functions are truly homologous.

The «glandular sac» areas of the rumen, once considered to be the water store of the camel, consist of a number of small chambers separated by folds of mucosa. The mucosa is covered by a columnar epithelium which has up to 100 million short tubular glands. Similar areas are found in the reticulum and the omasum. These glands probably act as absorption and fermentation areas, as well as areas of secretion of enzymes. The stomach of true ruminants does not have analogous mucosa. The rumen essentially performs the same functions as in the Ruminantia and its contents are normally equivalent to 11 to 15 per cent of total body weight.

In tylopods the oesophagus enters directly into the rumen while in ruminants it joins the stomach between the rumen and the reticulum. The ruminant reticulum has a honeycomb-like appearance while that of tylopods is of glandular sac appearance. As already noted (figure 3 and 4), there is no sharp distinction between omasum and abomasum in the tylopods and it has been suggested that it would be better to describe camelid stomachs as two-chambered, with a forestomach (comprising the reticulo-rumen) and a tubular stomach, being the whole of the after part (von ENGELHARDT, RUBSAMEN & HELLER, 1984). The terminal part of the tubular stomach is very small, being less than one fifth of it in the llama: this terminal part does not contain any ridges except in the foetus.

Intestines

The small intestine is about 40 m. in length in a full grown one-humped camel. A common duct from the pancreas and the liver opens into the looped duodenum. The jejunum is large and occupies most of the abdomen. There is a chain of mesenteric lymph nodes along the jejunum. The lymph nodes of the ileum are associated with those of the large intestine.

The large intestine is about 20 m. in lenght in the dromedary and has a blind caecum attached to the mesentery. The colon is of large diameter over about 4 m of its lenght and is situated on the left side of the abdomen in a large mesenteric fold. The site of much water resorption is where the colon narrows. The lymph supply of the large intestine is concentrated at the entry and near the terminal part where the colon becomes the rectum.

Liver, pancreas and spleen

The liver is markedly lobulated with much interlobular tissue. There is no gall bladder. The bile duct is common with the pancreatic duct as it enters the duodenum. The spleen is not attached to the diaphragm but high to the left side of the rumen. The peritoneum is similar to that of cattle.

Nutritional physiology

There are significant differences in nitrogen, glucose, fatty acid and ketone metabolism between the Camelidae and the true ruminants. The proportions of volatile fatty acids in the forestomachs are, however, similar (MALOIY, 1972) which would indicate no major differences in the metabolic processes occurring there.

The motility of the camelid stomach (as determined on the llama) differs considerably from that of ruminants. The mean retention time of digesta is shorter in camels than in zebu steers, by about 20 per cent. It is considered that this could be due to the more rapid contractions in the camel stomach and the shorter rumination cycle (VALLERAS & STEVENS, 1971). In the llama, the cycle of motility is followed by a single rapid contraction in the second compartment, this being subsequently followed by a sound contraction. The upper part of the first compartment then contracts. There are then a series of contractions in both first and second compartments. In resting llamas the duration of each cycle is just under 1.5 minutes but this is shorter in feeding animals. Filling of the secod compartment with food decreases the number of contractions per cycle but increases the speed of cycling. The strong contractions result in food moving round the first compartment in an anti-clockwise direction and fluid is squeezed out of the rather dry contents into the glandular sac region where most absorption occurs.

In the third compartment it appears that contractions along the length occur simultaneously and they are probably not peristaltic (EHRLEIN & VAN ENGELHARDT, 1971). Contractions in the forepart of this compartment, which occur at the rate of about 10 per minute, are rather weak, but are stronger farther back.

The contents of the alimentary canal pass from the fore to the tubular stomach when the strong contraction of the second compartment leads to an expansion of the canal. The mode of transfer appears to be similar to that of ruminants. In llamas the flow rate has been estimated at 850 ml per hour or about 17 ml. at each contraction (VON ENGELHARDT, ALI & WIPPER, 1979). Retention of fluids totals about 15.3 hours in the llama: for small particles less than 20 mm. in length it is about 29.3 hours. This compares whith small particle retention times of 46.0 hours in the one-humped camel. Larger particles in llamas may also be retained for up to 40 hours.

Regurgitation of the food bolus takes place at maximum contraction of the upper part of the rumen and can occur three or four times per cycle. Eructed gas also occurs three to four times per cycle with the volume being similar to that of cattle on a comparative basis.

There is a high concentration of short chain fatty acids in the camel rumen and fermentation rates and pH are similar to those observed for cattle. It appears that the differences in stomach morphology between camelids and ruminants do not influence the fermentation rate but, as already noted, fluid and small particle outflow is faster. Ruminal protozoa are however different in camels from those in sheep with *Entrodinum* sp. accounting for about 75 per cent of all protozoa in both sheep and camels when fully hydrated but this species dropping to 68.4 per cent in sheep when water-deprived while increasing to 83.8 per cent in camels under these conditions. *Epidinium, Metadinium* and *Eudiplodinium* account for the rest of the protozoa in camels, these species being totally absent, and replaced mainly by *Diplodinium,* in sheep.

Absorption rates of fatty acids, sodium and chloride are two to three times faster in the forestomach of the camel than in the goat and sheep and farther back other solutes and water are rapidly absorbed. About 60 per cent of the sodium, 70 per cent of fatty acids and 30 per cent of water are absorbed in the forestomach. Acidification is high in the hind stomach with high concentrations of chlorine.

Camels are well adapted to low protein diets (although their feeding selectivity to some extent allows them to ingest material with a higher total nitrogen content than the feed on offer) through efficient urea cycling mechanisms. The general model is shown in figure 5. The recycling rate increases under stress as was first demonstrated in a pregnant camel which excreted very little urea with its urine (SCHMIDT-NIELSEN, 1959). Recycling efficiency in camels has been shown to increase from 47 to 86 per cent in animals in which dietary protein was reduced from 13.6 to 6.1. per cent. In llamas on a high energy low protein diet the recycling rate can be as high as 95 per cent. In llamas fed rations of the same energy content 78 per cent of the nitrogen from the recycled urea was used for metabolism when total protein in the diet was low but this dropped to 10 per cent with adequate protein in the diet. The concentration of urea in the blood does not apparently affect the amount of urea returned to the alimentary canal and it is obvious that the permeability of the stomach lining to urea changes with the type of diet fed. Most recycled urea is absorbed in the forward part of the stomach. Both the VFA and the CO_2 levels influence the permeability, higher concentrations increasing the rate and butyric acid having greater effects than either acetic or propionic acid.

In general the Camelidae appear to be significantly more efficient in digesting dry matter, fibre, cellulose and crude protein than other ruminants and domestic non-ruminants (HINZ, SCHRYVER & HALBERD, 1973) and this is probably due to the rapid ad frequent cycling of the stomach contents.

The food of camels

The natural food of Old World camels derives from browse, many of these being leguminous trees and shurbs and many being salt bush plants of the family Chenopodiaceae and similar families. Dromedaries take as much as 90 per cent of their diet under semi-natural conditions from browse plants. In general this is even more than that taken by goats from this source. An important feature of camels' browsing habits is that they are not in direct competition with other domestic stock either in terms of the type of feed eaten or in the height at which they eat above the ground. Feeds selected by camels are usually high in moisture, nitrogen, electrolytes and oxalates. Acacias, *Balanites, Salsola* and *Tamarix* are important constituents of the dromedary diet wherever these plants are found. Table 1 lists some of the most common plants eaten by dromedaries and provides details of their chemical composition and nutritive value.

Under open range conditions camels tend to move rapidly from one feeding station to the next and they are thus able to exploit a wide variety of plants and of plant parts. Ingestion rates can be rapid where preferred or selected browse is plentiful but are much slower on thorny species that have little leaf. Feeding times required may be as much as 15 or more hours per day, as recent studies have shown that total dry matter intake needs to be about 4 per cent of body weight. A mature dromedary weighing 650 Kg. would thus require more than 25 Kg. of dry matter, which might represent between 80 and 100 Kg. of total food intake of plants with high moisture contents. In general, it would appear that camels can achieve these amounts of intake provided they are not required to do too much walking to and from the grazing area. The imposition of work obviously restricts the amount of time available for feeding and thus total feed intake. Camels can overcome this problem, provided work is not continuous, by eating in excess of their immediate needs and storing the extra as fat in the hump.

Camels have a normal requirement for minerals, most of which they appear to obtain from their natural regime but where saltbush is not a part of the diet the animals usually have to be taken, at various times of the year, to a «salt cure» of feed, water or earth. Table 2 indicates, for an area of northern Mali, how camels are provided with salt throughout the year. Although minerals other than salt rarely present a problem, disorders can arise in camels from an imbalance in the calcium/phosphorus ratio. A metabolic disorder, known as «krafft», due to this imbalance is well known in North Africa (DURAND & KCHOUK, 1958).

Water

The dromedary is the subject of myth and legend regarding its supposed water storing abilities. Not the dromedary, nor any other of the camels, contain, large quantities of water. Dromedaries are extremely efficient at «storing» water because of their physiological, anatomical and behavioural adaptations. Their efficiency in conserving water is, however, in inverse proportion to the use they are allowed to make of these adaptations and the imposition of work or other forms of stress greatly reduces their ability.

The mayor mechanism of the camel in conserving water is the range in body temperature which may rise by as much as 7° C during the day. This reduces the need to shed the heat load by sweating or panting and the excess heat is dissipated in the cooler night temperatures without loss of water. By this and other methods camels can go not only for the commonly quoted four to seven days without water but on occasions for several months (figure 6), especially when plants with a high moisture content are eaten.

Water requirements of camel in relation to body size and normal functions do not differ greatly from other animals. After severe dehydration amounting to 30 per cent of the initial body weight, as much as 90.1 of water can be drunk in a very short time.

Energy and protein requirements for productivity

There has so far been little experimentation on feeding standards for camels performing different functions. All the information in this section is based on literature sources and on general information from various manuals. Many of the rations suggested are of considerable age but appear to have stood the test of time and it can be considered that, until more exacting work is done, they are a good practical guide for camel feeding.

Maintenance

Maintenance requirements are those required to keep and animal's body functioning in a stable state. In grazing animals maintenance can also be considered to include the requirements for movement while feeding. The figures provided in Table 3 should be regarded as guides for camels in various sex, age and function classes.

Milk production

The demands for milk production are high in terms of energy. The requirement for one litre of milk is equivalent to almost 10 per cent of the maintenance requirement. In terms of protein, milk is even more demanding of nutrients and one litre requires about 20 per cent of the maintenance requirement of a 400 Kg. female. Table 4 provides an indication of the energy and protein requirements of such a female. The daily requirements for 15 Kg. of milk could not be met from free range grazing and a concentrated feed would be required. If recent claims of 40 litre yields are to be believed, it would be of great practical interest to have a clear statement of the feed intake of these animals.

Meat production

It has been claimed that camels fatten rapidly when fed 15 to 20 Kg. of a mixture of straw, beet pulp silage, molasses and 10 to 15 per cent barley grains and that camels feeding on growing sugar beet tops gain as much as 1.5 Kg. per day and can be made ready for slaughter in 60 days.

Corroborative work is needed to determine if these rates can be repeated but it should always be borne in mind that the comparative advantage of the camel is in harsh environments. High quality feeds are probably better fed to advanced ruminants in this context.

Work

Camels appear to be at least as efficient as other traction animals in producing draught power but their main work output is in the form of pack transport. Energy is the main nutrient loss in any form of work and this needs to be replaced by food. If camels produced an output of 455 watts and energy is converted to power at an efficiency of 20 per cent, the energy expended is equivalent to 8,2 MJ per hour. The energy to be supplied in food using various assumptions is shown in table 5. Although it is reasonable to assume that pack animals expend similar amounts of energy for a similar output, no data are available. Working camels on supplementary feed usually have an excess of protein provided, while milking camels are usually deficient in protein supply. Camels in traditional herds are normally expected to provide work for short periods at a time and it is possible this is due to a lack of energy; this suggestion is supported by the fact that in these herds it is only male baggager camels that are normally provided with supplementary feed.

Some examples of typical supplementary rations in a number of situations are provided in table 6. The lesson to be drawn from this table is that our knowledge of waht the feeding standards of camels are is very rudimentary and has progressed little in recent years. This is in spite of the considerable research output on camels in the last two decades (WILSON & BOURZAT, 1987).

Additional research on camels under controlled conditions with standardization of work and feed regimes is an urgent necessity.

Table 1

CHEMICAL COMPOSITION AND NUTRITIVE VALUE OF SOME CAMEL BROWSE SPECIES

Family and species	Composition per cent						DCP g per Kg DM	Net energy MJ per Kg DM	Nutritive ratio DP/NE
	Dry matter	Crude protein	Crude fibre	Fat	Nitrogen-free extract	Ash			
Asclepiadaceae: *Leptadenia hastata* (green leaves)	21-3	13-9	14-6			15-6	97	6-7	14-48
Boraginaceae: *Cordia* sp. (dry and green leaves)	63-3	8-9	18-6		50-1	16-1	51	6-0	8-50
Capparidaceae: *Boscia* spp., *Cadaba* ssp. *Capparis* spp., *Crataeva* spp., *Maerua* spp. (leaves and fruit)		20-7	17-4	2-7	45-4	13-9	151	5-6	26-96
Combretaceae: *Combretum micranthum* (leaves and twigs)	47-7	16-7	20-9	2-9	50-3	9-6	105	5-6	18-75
Guiera senegalensis (twigs, flowers, fruit and leaves)	57-6	16-7	24-9	4-6	50-8	6-2	89	5-5	16-18
Leguminosae:		16-8	22-7	3-1	48-2	6-8	121	5-8	20-86
Acacia raddiana (pods)	81-3	16-5	18-3	2-6	54-9	6-4	120	6-1	19-67
Rhamnaceae: (*Ziziphus* spp.)		13-6	13-4	3-8	60-4	8-5	91	7-0	13-0
Salvadora persica (twigs, leaves, fruit)	30-1	13-4	12-2	2-5	44-2	29-1	91	4-8	18-96
Balanites aegyptiaca (flowers, leaves, fruit)	51-1	12-3	14-6	4-7	51-3	13-4	84	6-1	13-77
All browse species Dry season grasses	81-7	3-1	39-8			7-7	trace	2-8	

Source: LE HOUEROU, 1980.

Table 2

SEASONAL GRAZING PATTERN IN THE ADRARN IFORAS IN NORTHERN MALI

Period	Climatic conditions	Type of grazing and main species
May/mid-July	Hot humid	dry pasture: *Tephrosia polystachia Blepharis edulis* early green browse green pasture.
end-July/mid-August	Relatively wet	*Panicum turgidum* green pasture.
August/October	Wet-hot humid	becoming dry: *Tribulus terrestris. Tephrosia polystachya, Triant-hema pentandra; Convolvulus fatmensis, Blepharis edulis*
		salt cure
end-Oct/mid-Nov	Hot-cooler drier	dry pasture, browse.
late Nov/mid-March	Cool dry	dry pasture, browse *acheb* mainly *Shouwia thebaica.*
late March/early May	Hot dry	*acheb* in north, mainly *Cornulaca monocantha.*
		Salt cure
May		browse mainly in dry wadi beds.

Source: JOUSSELIN, 1950.

Table 3

PROBABLE ENERGY AND PROTEIN REQUIREMENTS OF CAMELS PERFORMING VARIOUS FUNCTIONS

Function and animal class and weight	Daily requirements	
	Energy MJ ME	Protein g DCP
Maintenance		
500 Kg. male or castrate	54	300
400 Kg. breeding female	45	260
300 Kg. «average» camel at MPW	36	210
Milk production		
1 litre milk	5	50
Work		
1 hour work 500 Kg. draft or pack animal	8-2	probably none

Source: WILSON, 1984

Table 4

ENERGY AND PROTEIN REQUIREMENTS FOR BREEDING FEMALES OF 400 KG LIVEWEIGTH

	Requirement	
	Energy MJ ME	Protein g DCP
Daily maintenance	45	260
1 litre milk	5	50
Daily requirement for maintenance plus peak yield of 15 litres milk	90	1,010
Annual requirement for one female for maintenance plus lactation yield of 1500 litres milk	23,925	169,900
Average annual requirement for breeding female assuming 50 per cent reproduction rate	20,175	132,400

Source: WILSON, 1984

Table 5

ENERGY AND PROTEIN REQUIREMENTS FOR WORKING CAMELS OF 500 KG LIVEWEIGTH

	Requirement	
	Energy MJ ME	Protein g DCP
Daily maintenance	54	300
1 hour work	8.2	
Daily requirement for camel for maintenance and 10 hours work	136	300
Annual requirement for one camel for maintenance and 8 hour work in 250 days of the year	36.110	109.500
Annual requirement for one camel for maintenance and 6 hour work in 60 days of the year	22.662	109.500

Source: WILSON, 1984

Table 6

SUPPLEMENTARY RATIONS FOR CAMELS WITH NOTES ON NUTRITIVE VALUE (WEIGHT IN KG)

TYPE OF FEED[1]	SUDAN RIDING CAMELS[2]	SOUTH YEMEN RIDING CAMELS[2]	SOMALIA MILITARY CAMELS[3]	INDIA HEAVY WORKING CAMELS[4]	INDIA HEAVY WORKINGS CAMELS[5]	TUNISIA PLOUGH CAMELS[6]
Grain (sorghum)	6.8					
Grain (barley)						3,0
Pulse (Phaseolus spp.)			1.8		2.7	
Cotton seed		2.3		2.3		
Oilseed concentrate		2.3				
Bran			0.9			
Hay			4.5			
Chopped millet straw		11.3				
Barley straw				11.3		5.0
Phaseolus spp. haulms					9.1	
Green cactus						10.0
Nutritive value						
energy MJ/day	50.7	59.0	27.4	54.4	58.2	39.7
DCP g/day	469	1440	448	990	1512	440

Sources: 1. ACLAND, 1932.
2. LEESE, 1927.
3. PECK, 1938.
4. YASSIN and ABDUL WAHID, 1957.
5. LEESE, 1927.
6. BURGEMEISTER, 1975.

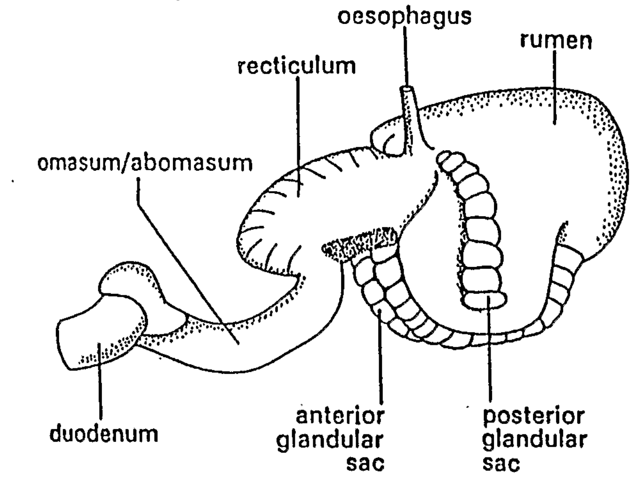

Figure 1. L'estomac du dromadaire.

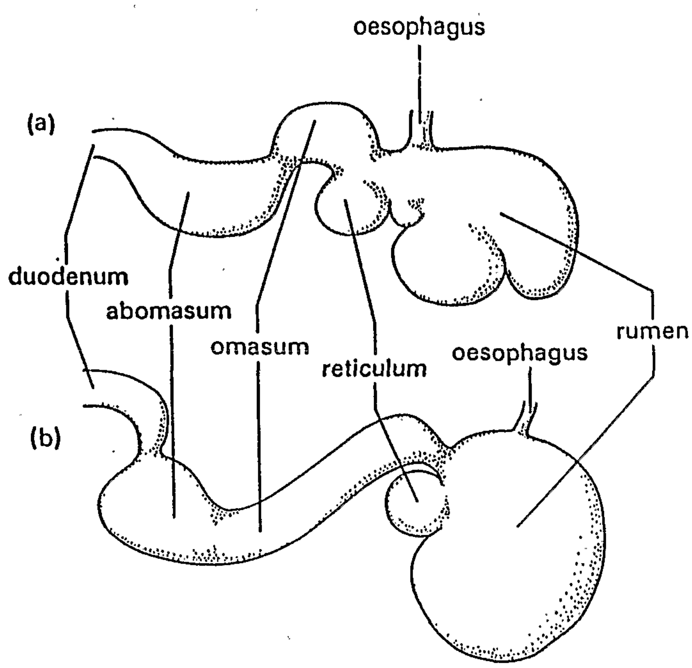

Figure 2. Comparaison de l'anatomie de l'estomac chez les ovins (a) et chez le dromadaire (b).

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