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ANIMAL RESOURCES DEPARTME

ADVANCED ANIMAL NUTRITION

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FOOD INTAKE IN RUMINANTS

Although food intake can be controlled at the metabolic level in ruminants, the signals are likely to be different from those in monogastric animals. The amount of glucose absorbed from the digestive tract of the ruminant is relatively small and blood glucose levels show little relation to feeding behavior. It would therefore seem unlikely that a glucostatic mechanism of intake control could apply to ruminants. A more likely chemostatic mechanism might involve the volatile fatty acids absorbed from the rumen. Intra ruminal infusions of acetate and propionate have been shown to depress intake of concentrate diets by ruminants, and it is suggested that receptors for acetate and propionate occur on the luminal side of the reticulo-rumen. Infusions of these acids into the hepatic portal vein also reduce intake, apparently via signals sent from the liver to the hypothalamus. Butyrate seems to have less effect on intake than acetate or propionate, probably because butyrate is normally metabolised to acetoacetate and β-hydroxybutyrate by the rumen epithelium. With diets consisting mainly of roughages, infusions of volatile fatty acids have had less definite effects on intake. As mentioned above, in ruminants on such diets, control of intake appears to be exercised at the level of the digestive system.

Factors affecting feed intake

1- **Food characteristics**

❖ Ruminants are adapted to the utilisation of bulky foods, but they may nevertheless have difficulty in processing such foods. Rumination and fermentation are relatively slow processes, and fibrous foods may have to spend a long time in the digestive tract for their digestible components to be extracted. If foods and their indigestible residues are detained in the digestive tract, the animal's production and hence its daily intake will be reduced.

❖ In ruminants there is a positive relationship between the digestibility of foods and their intake, and adding a concentrate supplement to roughage depends on the digestibility of that roughage. If its digestibility is low (e.g. cereal straw with dry matter digestibility of 0.4) total intake will be increased more than if its digestibility is high (e.g. young grassland herbage, 0.8).

- Foods that are digested rapidly, and are also of high digestibility, promote high intakes. The faster the rate of digestion, more rapidly the digestive tract is emptied, and the more space is made available for the next meal.
- The primary chemical component of foods that determines their rate of digestion is neutral detergent fiber (NDF), which is itself a measure of cell wall content; thus, there is a negative relationship between the NDF content of foods and the rate at which they are digested.

  Example: At equal digestibility, legumes contain less cell wall and are consumed in quantities about 20 % greater than grasses. Another difference between legumes and grasses is that in grasses the lignin is more widely distributed and has a greater inhibitory effect on rate of digestion.

- The physical form of the cell walls also affects intake. The mechanical grinding of roughages partially destroys the structural organisation of cell walls, thereby accelerating their breakdown in the rumen and increasing food intake. Grinding and pelleting was achieved despite a *reduction* in digestibility. The fine particles produced in ground roughages pass rapidly out of the rumen, leaving room for more food but allowing some digestible material to escape undigested; this may be digested in the small intestine or if cell wall by fermentation in the caecum.

- Chemical treatments of forages that disrupt the cell wall structure cause large increases in intake.

- Another example of the influence of cell wall structure comes from the comparison of intakes of the leaves and stems of pasture plants, the cell walls in leaves are more easily broken down, so animals given leaves eat about 40 % more dry matter per day than those offered stems.

- ❖ Nutrient deficiencies that reduce the activities of rumen microorganisms are liable to reduce food intake. The most common is protein or nitrogen deficiency, which may be corrected by supplementation with rumen-degradable protein or with a simple source of nitrogen such as urea. However, supplements of undegradable protein may also increase the intake of low protein forages. Other nutrients whose deficiencies are liable to restrict food intake in ruminants are sulphur, phosphorus, sodium and cobalt.

- ❖ There are some foods that are eaten in lesser quantity than would be expected from their digestibility or cell wall content. These include some types of silage.

- ❖ Some plants may be rejected because they are rendered unpalatable by protective spines or by contamination with excreta.

2- Animal factors

- If the capacity of the rumen is a factor in determining the food intake of ruminants, then relationship between the size of the rumen and the size of the whole animal are likely to affect intake. Food intake follows approximately the proportionality to metabolic body weight $(W)^{0.75}$. cattle have a greater intake per unit of metabolic body weight than sheep**.**

- When animals become excessively fat, their intake tends to stabilise or, in other words, not to increase as body weight continues to increase. This may be due to abdominal fat deposits reducing the volume of the rumen, but it may also be a metabolic effect. Conversely, in very lean animals, intake per unit of metabolic body weight tends to be high. This effect is seen in animals showing compensatory growth after a period of food restriction .in some developing countries, where animals appear to be constructed of skin and bone enclosing a large rumen.
- In pregnant animals, two opposing effects influence food intake. The increased need for nutrients for fetal development causes intake to rise. In the later

stages of pregnancy, the effective volume of the abdominal cavity is reduced as the fetus.

- The increased intake in ruminants with the onset of lactation is well known. May be a physical effect from the reduction in fat deposits in the abdominal cavity. In early lactation, the dairy cow loses weight, which is replaced at a later phase of lactation when milk yields are falling while intakes of DM remain high.
- Sex (male consume 2-5% more than female) and breeds.

3- Environmental factors

- The intake of ruminants in their natural habitat (i.e. at pasture) is influenced not only by the chemical composition and digestibility (or rate of digestion) of the pasture herbage but also by its physical structure and distribution. The grazing animal has to be able to harvest sufficient herbage to meet its needs without undue expenditure of energy. Its intake is determined by three factors – <u>bite size</u> (the quantity of dry matter harvested at each bite), <u>bite rate</u> (number of bites per minute) and <u>grazing rat.</u>

  Cows normally graze for about 8 hours per day, but sometimes for as much as 10 hours per day.
- Environmental temperature influences the intake of ruminant at temperatures below the thermoneutral zone intake is increased, and at temperatures above the thermoneutral zone, intake is reduced. Well feed ruminants have a broad thermoneutral zone, For example, for temperate (i.e. *Bos taurus*) breeds of cattle, it has been estimated that intake falls by 2 % for every 1 °C rise in average daily temperature above 25 °C.
- The environment has an effect on intake is day length. This effect is most evident in deer, which reduce their food intake very severely as day length declines; Sheep also reduce their intake as days get shorter, but to a much lesser extent than do deer. Cattle seem not to be affected by day length.

- Health can reduce the intake of both ruminants and non-ruminants. Gastro intestinal parasites tend to reduce intake, because the interference with digestive function overrides any metabolic stimulus arising from a reduction in the absorption of nutrients. There is also evidence that stimulation of the animal's immune system.

Microbial protein

Synthesis of microbial protein in rumen

Ruminants are distinguished from other animals by their microbial activity in the upper part of the stomach. This specificity allows them to convert roughage feeds and low-quality proteins, even non-protein nitrogen, into nutritious substances such as microbial protein and volatile fatty acid. Bacteria, protozoa and fungi are ecosystems in ruminants that have different requirements for nutrients and metabolic processes. These organisms ferment feed components (polysaccharides, monosaccharides and proteins) to maintain their balance and ensure their growth. The processes carried out by these organisms include reforming amino acids for body tissues. These amino acids are synthesized from ammonia and carbon structures that are produced during the degradation of feed.

- Ruminants have low levels of production when they consume only non-protein nitrogen (urea and ammonia) as a source of nitrogen in the diet.
- when there is a large amount of ammonia due to the high degradation of proteins, the excess ammonia is absorbed through the rumen wall, later it is converted into urea in the liver to limit its diffusion because it is toxic to animals, and the produced urea can be recycled from saliva into the rumen. To be used from a portion of microbes or excreted with urine from an animal with consequent loss of nitrogen, this process, known as the urea cycle,
- The use of protein concentrates increases production costs and increases risk. However, microbial protein in rumen provides more than half of the amino acids absorbed by ruminants, and can be between 70 and 100% of the

nitrogen available in the lower parts of the digestive system in animals fed on roughage feed and low protein content.

- The microbial protein synthesis in the rumen has the same digestibility as the undegradable protein in the rumen, which reaches 80 - 90%, while the vital value of the microbial protein ranges from 66 – 87.
- 1.25 RDN/MJ of ME(ARC,1980)
  1.34 RDN MJ of ME (ARC,1984)
  RDN*6.25=RDP
  Total protein=RDP+UDN
- Protein reaching the small intestine in ruminants consists of three sources
  - which undegradable diet protein in rumen(RUP),
  - microbial protein
  - endogenous protein

Factors affecting microbial protein synthesis

1- The level and source of energy in the diet

The most important factor in reducing microbial protein synthesis in the rumen is the energy released in the rumen during the fermentation of carbohydrates in the form of organic acids,

The carbohydrate sources are classified into two groups:

- Those rich in nonstructural carbohydrates (sugars and starch),
- Those rich in structural carbohydrates (pectin, cellulose and hemicellulose).

The synthesis of microbial protein is determined by the production of Adenosine triphosphate (ATP) and is largely dependent on the availability of carbohydrates and nitrogen in the rumen.

The fermentation rates in soluble sugars and starches are very high after 2 hours of feeding and decrease after approximately 4 hours. After the morning feeding, as soluble sugars and starch provide higher levels of ATP compared to structural carbohydrates, but they often do not provide ATP for microbial growth 4 hours after the morning feeding

About 3 to 4 hours after the morning feeding, cellulose and hemicellulose begin to degrade and continue to degrade for a long time (up to 96 h) after the morning feeding, and providing ATP for microbial growth at a later time.
Therefore, feeding a mixture of roughage and concentrated feed increased microbial protein synthesis compared to feeding on concentrated or roughage feed separately.

starch may have negative effects on microbial synthesis in the rumen because its fermentation reduces the pH of the rumen, affects the degradation of fibers, increases energy losses, and reduces amino acid recycling , not all Energy sources have the same effect on microbial protein synthesis, and it has been shown that soluble sugars (sucrose, lactose and fructose) increase more microbial protein synthesis in rumen compared with the use of supplementation from grains rich in starch, the injection of sucrose into the rumen stimulated microbial protein synthesis by providing adequate levels of NH3-N in the rumen .

2- **The level and source of protein in the diet**

A decrease in the level of crude protein in the diet will lead to a decrease in NH3-N in the rumen and then the efficiency of microbial protein synthesis will decrease, affecting the performance of ruminants.
Ammonia is the main source of nitrogen for microbes in the rumen, but the availability of amino acids and peptides in the food, both of which increases the growth of cellulolytic and amylolytic bacteria , and this may be due to their direct combination with the microbial protein or to the fact that they increase the availability.
Crude protein sources such as soybean meal appear to have properties that improve microbial growth in animal rumen. Crude protein sources that are less degradable than soybean meal sometimes reduce microbial growth.
However, these less degraded protein sources can compensate for the decline in microbial protein synthesis by providing the crude protein to the rest of the gut after

the rumen, In general, it is believed that the microbes in the rumen do not have absolute amino acid requirements.

Although some amino acids limit microbial growth because rumen microbes have difficulties to remodel such as phenylalanine, leucine, isoleucine and lysine.

The use of amino acids in the rumen should differ according to the protein source.

The degradation of the crude protein in the rumen is one of the main reasons for its inefficient use in ruminants. Thus, resistance of proteins to microbial degradation may limit microbial protein synthesis; however some researches indicated microbial protein synthesis was not affected by the crude protein level and level of degradation.

3- **Intake level and feeding frequency**

Due to increasing the intake, the flow of particles from the rumen is increased. Thus, the number of bacteria attached to the food that comes out from the rumen and passes to the stomach and duodenum increases the recycling of microbial protein in the rumen is reduced. There is a positive relationship between dry matter intake and microbial growth. Some forage sources with a high content of starch-rich concentrates raise high intakes and tend to reduce the efficiency of microbial yield, due to energy expenditure by maintaining balance pH, when rumen pH is low.

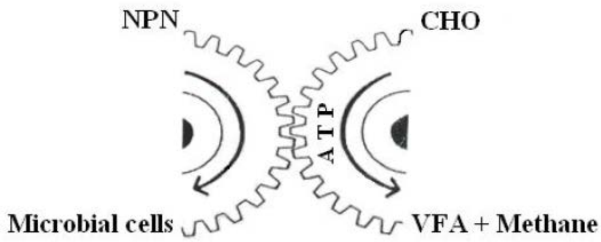
Repeat feeding leads to NH3-N remaining in the rumen at a moderate level for longer periods due to increased utilization of degradation protein in the rumen, which increases the speed of nutrient fermentation and accelerates microbial growth.

Repeated feeding by providing concentrated feed several times a day leads to better digestion of nutrients and more cellulosic substances in the rumen.

4- **Synchronization between degradation of protein sources and energy sources**

Microbial protein synthesis can be maximized, if the availability of fermenting energy and nitrogen is synchronized by the microbes in the rumen. when the rate of protein degradation exceeds the rate of degradation of carbohydrates, large amounts of nitrogen are lost in the form of ammonia and microbial protein production decreases , however, degradation of carbohydrates in the rumen provides energy in the form of ATP required by the microbes for the purpose of metabolism.

Diets containing 10-13% of the hydrolyzed protein in the rumen and 56% of the total carbohydrates as carbohydrates Starchy increases microbial protein production



5- **Effect of anti-nutrients on microbial protein synthesis**

One of the most studied anti-nutritional agents is tannin, tannins influence microbial protein synthesis in various forms, either directly by their action on rumen microbes or by their interaction with nutrients that depend on them for energy and nitrogen , due to their harmful action by rumen microbes, these compounds effect on the growth rate and microbial protein synthesis.

Although it is not clear whether it is a direct inhibition effect on protozoa. the tannins interact with proteins to form a complex (tannin - protein) and this affects the enzymes secreted by the rumen bacteria and prevents the fermentation of carbohydrates and proteins , besides that the tannins It affects proteolysis in the rumen because it binds with soluble dietary proteins and protects them from rumen microbial action.

However, it has been reported that the inclusion of tannin in the diet has a positive effect on the animal because it increases the amount of non-degradable dietary protein in the rumen, without significantly affecting the flow of microbial protein into the duodenum.

6- The ratio of concentrated feed to roughage fodder

Several studies indicated that the diets consisting of roughage feed mainly negatively affect the synthesis of microbial protein and fermentation is relatively slow in the rumen and with more roughage feed in the diets, there was greater saliva flow, higher pH (more than 6.5) in the rumen, increase the production of acitic acid, Decrease in the efficiency of microbial protein passage into the small intestine.

Diets containing more than 70% of concentrated feed could be caused by the rapid rate of degradation of non-structural carbohydrate sources, leading to asynchronous fermentation. Provide rumen microbes with easily fermentable carbohydrates, and in this case, salivary secretions are reduced due to reduced chewing activity. Therefore, microbial protein synthesis and efficiency can be decreased due to lower pH(less than 5.5) , due to increase the production of Propionic acid, , which negatively affects the growth of rumen microorganisms.

7- Effect of rumen pH and rumen environment

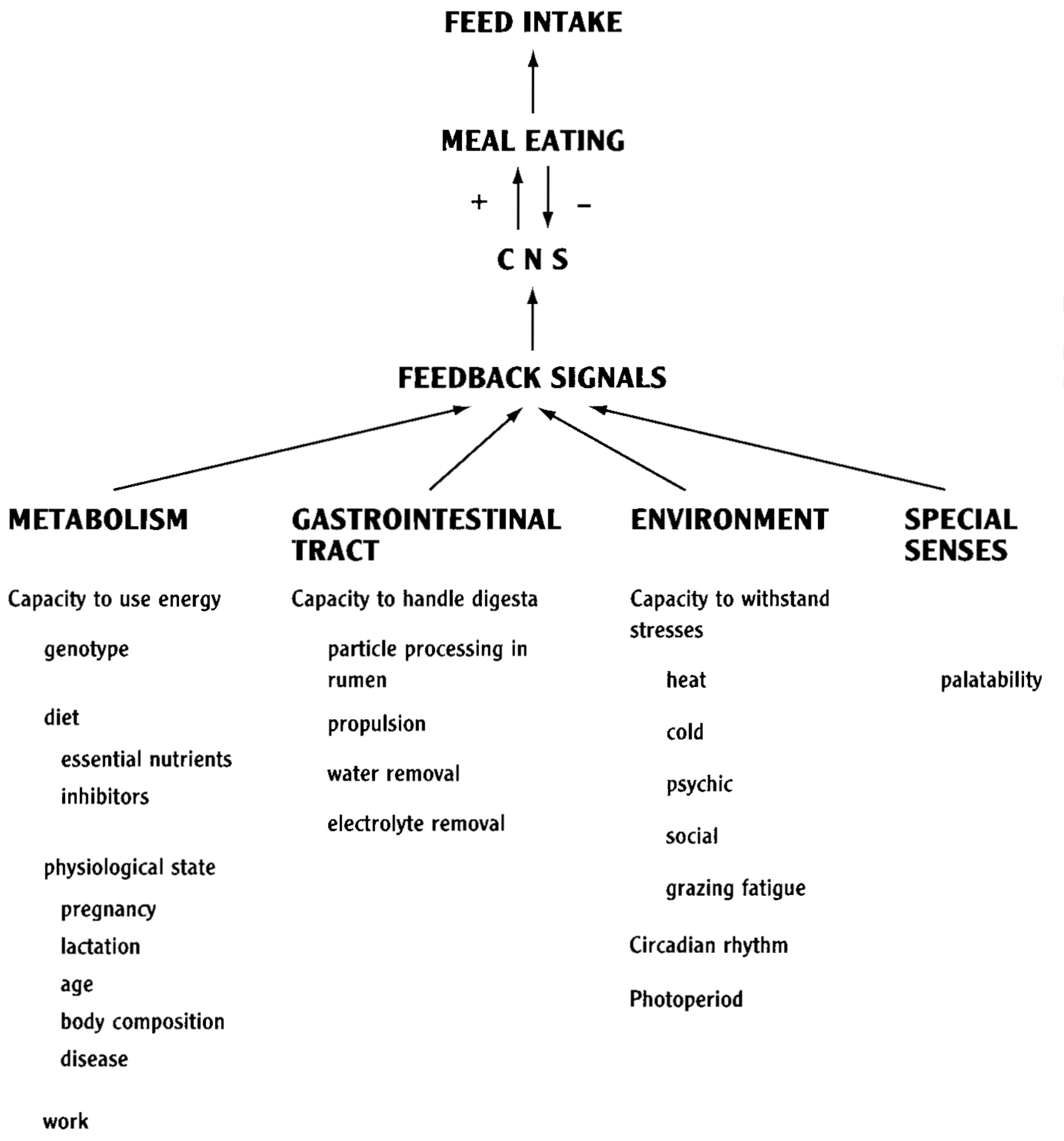
low rumen pH negatively affects rumen microorganisms and reduces fiber digestibility in diets, and negatively affects the conversion of energy within the rumen to abnormal functions, such as maintaining a moderate rumen pH, which effects on the synthesis of microbial protein due to the decrease in fiber degradation and energy losses, this negatively affects the growth of rumen microorganisms and the decrease in amino acid synthesis.

several studies indicated that a low level of NH_3-N in the rumen leads to a decrease in the level of microbial protein production, level of NH_3-N in the rumen ranges form 5 - 9 mg / 100 ml, for maximum production of microbial protein.

8- Minerals and vitamins

Sulfur, phosphorous and magnesium are important minerals in the synthesis of microbial protein, as sulfur is included in the synthesis of methionine and cysteine. Therefore, the amount of sulfur required to manufacture these amino acids ranges from 0,11 to 0,20% of the total diet. Therefore, the lack of diets in their sulfur content negatively affects the synthesis of microbial protein.

while phosphorous is important in the synthesis of microbial protein and ATP, phosphorous can be partially recycled through saliva, while the availability of phosphorous in the rumen depends on the amount of phosphorous Diet, absorption and extent of phosphorous secretion of saliva and this is related to the physiological state of the animal.



ıure 1. Factors affecting feed intake in ruminants.