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Feeding behavior of ruminants: an evaluation of factors influencing frequency of feeding and rumination

Bachelor thesis

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Declaration

I, Ondřej Přibyl, declare that I have elaborated my thesis independently and that I cited only literature listed in References.

Prague, April 17th, 2015

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Ondřej Přibyl

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Abstract

The food intake and its processing are necessary for functioning of all living organisms, and therefore also for ruminants. The food intake in the ruminants is affected not only by the dietary strategies of individual species, but also by the factors that influence the animal. These factors may be the internal or external factors and may often have a negative effect on food intake and the following food processing. It is necessary to know these factors to ensure the proper functioning of the animal. A summary of some important factors and their influence on the animal described in this work can serve as an aid for determining one specific negative factor and can help us to remove it.

Key words: ruminants (*Artiodactyla*), inner factors, external factors, rumination time, intake food

Abstrakt

Příjem potravy a její zpracování je nezbytné pro fungování všech živých organismů, tedy i u přežvýkavců. Přežvýkavci mají ovlivněný příjem potravy potravní strategií jednotlivých druhů, ale také faktory, které na ně působí. Tyto faktory mohou být vnitří nebo vnější a mají často negativní vliv na příjem a následé zpracování potravy. Znalost těchto faktorů je nezbytná pro zajištění správného fungování zvířete. Shrnutí několika významných faktorů a jejich vlivu na zvíře v této práci může sloužit jako pomůcka pro určení faktoru a jeho následné odstranění.

Klíčová slova: přežvýkavci (*Artiodactyla*), vnitřní faktory, vnější faktory, přežvykovací čas, příjem potravy

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1. Introduction

The ruminants are a group of mammals of the order *Artiodactyla*, which is significantly different from the other mammals, because stomach of ruminants is divided into four parts - *rumen, reticulum, omasum* and *abomasum* (Hofmann, 1973). (However, it is possible to find exceptions – the animals form suborder Tylopoda have not *omasum* (they have only 2 forestomach)). The animals with such composition of the stomach are called polygastrics. The last part, *abomasum*, is the true stomach and its function is the same as in other mammals. Digestive tract of ruminants is very long (up to 30 × longer than the body in specifics cases) (Hofmann, 1989). The ruminants are forestomach fermentors. This means that the largest proportion of the digestion takes place in the forestomach. Most other herbivores digest their food in the intestine - they are the intestine fermentors.

The most important part of the digestive tract is the *rumen*, the first and largest forestomach. It contains small micro-organisms that are able to utilize nutrients from food with low nutrient density. In *rumen* food is digested and then regurgitation back to the mouth follows, where the food is reduced to the smallest part. While swallowing the food and returning it to the rumen, the food is re-digested. Thanks to this ability the maximum of the nutrients in food is utilized. With this ability the micro-organisms can also create most of the vitamins and the ruminants are therefore not dependent on its content in the ration.

With the change of the ration, the care must be taken to slow adaptation. The individual micro-organisms in the *rumen* processed a typical nutrient and a sudden change could lead to complete destruction of microflora, thereby to malfunctioning digestion and subsequent weakening of the animal, until the death of the animal.

“The ruminants are the animals important to man. Some species are bioindicators of the first order in polluted human environments. More species are living barometers of man's in-ability to understand and handle ecological interactions and most, if not all ruminant species can benefit nutritionally from what man cannot digest.“ (Hofmann, 1989)

Like every other living organism also the ruminants must derive energy. It acquires intake and subsequent processing of food. However, food intake is not always without problems. Some problems can be solved by adjusting the ration. If the animals are kept in captivity, it is necessarily experience caregiver. However, some solutions are not so simple and they often require a considerable amount of adaptability.

A large degree of customization is already visible on dietary strategy of the ruminants themselves. In some cases, for example, they switch to a new food source. The intensity of their reception and processing can also be adjusted.

Food intake may be influenced by factors that restrict the intake or food processing. These factors can negatively affect the overall condition of the animal. The exact determination of factors can be often a problem even for the experienced staff farms or zoos. In addition, there is often an underestimation of the impact of these factors on the animal itself. This work could recall the importance of the influence of negative factors.

2. Subject of the thesis and the methodology

The subject of the thesis was to review knowledge on the factors influencing feeding strategy thorough frequency of feeding and rumination. It includes internal and external factors on the ingestion and digestion of food.

Collection of information on the topic was conducted from specific internet databases. Mostly used were: Web of Knowledge (apps.webofknowledge.com) and Scopus (www.scopus.com). To connect to these databases: The Website of Czech University of Life Sciences http://infozdroje.sic.czu.cz/cs/ was used. For the formulation of references the citations database EndNote was used (https://www.myendnoteweb.com). All sources are listed in the list of references.

3. Literary review

3.1. The ruminants

Just as it is possible to find the differences between mono- and poly-gastrics, it is possible to find significant differences between the ruminants themselves. And these differences are not only in the size. The most important differences between the ruminants are found in their feeding habits and types. Due to these facts, we can divide the ruminants into three groups: concentrate selectors, grass and roughage eaters and intermediate, opportunistic, mixed feeders (Hofmann and Stewart, 1973). Every ruminant belongs due to his special food demands into one of these groups. Food requirements differ for the individual species according to their location, size and feeding possibilities. This allows the use of local food sources. Furthermore, they can also occur in locations with large foraging limited resources (Fig. 1) (Hofmann, 1989).

However, it is also necessary to determine the rules that help us to classify the different types of groups stated above. For this purpose a simple indicator was found – the food. Groups differ in the way of eating which also allowed the evolutionary changes in the structure of the digestive tract (Fig. 2). It is important to note that the main part of the digestion progress in the ruminants takes place in the cranial part of the digestive tract, i.e. in the mouth and the rumen (Hofmann, 1968). Due to the type of food the individual species receive specific morphological changes occurred among the three groups: we can find these changes in food and salivary gland and also in the first forestomach mucous membrane (Hofmann and Stewart, 1973). Differences in dietary strategy of each species show that their development lasted a long time and allowed therefore good adaptation to the environment (Hofmann, 1989).

Finally it should be noted that in the third group seasonal changes of surface mucosa in the stomach have been demonstrated. This is the evidence that the development of ruminants is still in progress (Hofmann, 1968).

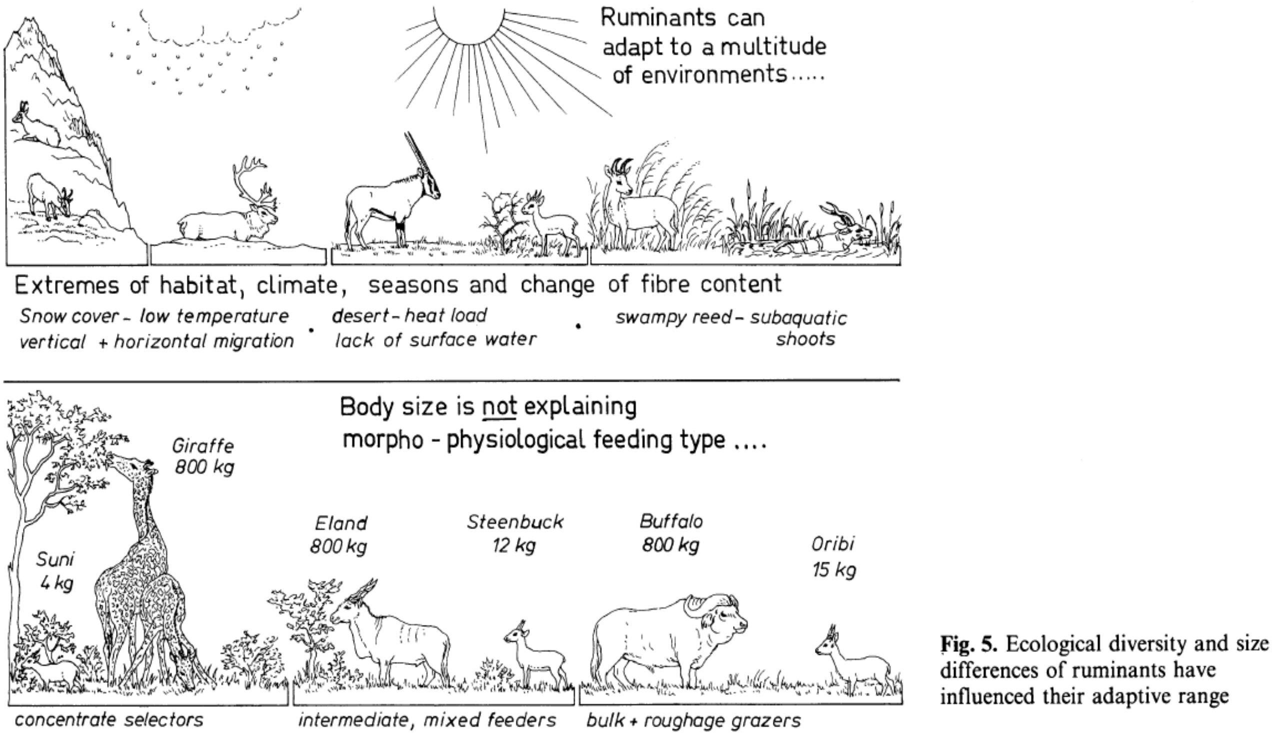


Fig. 1: Diversity of the ruminants (Hofmann, 1989)

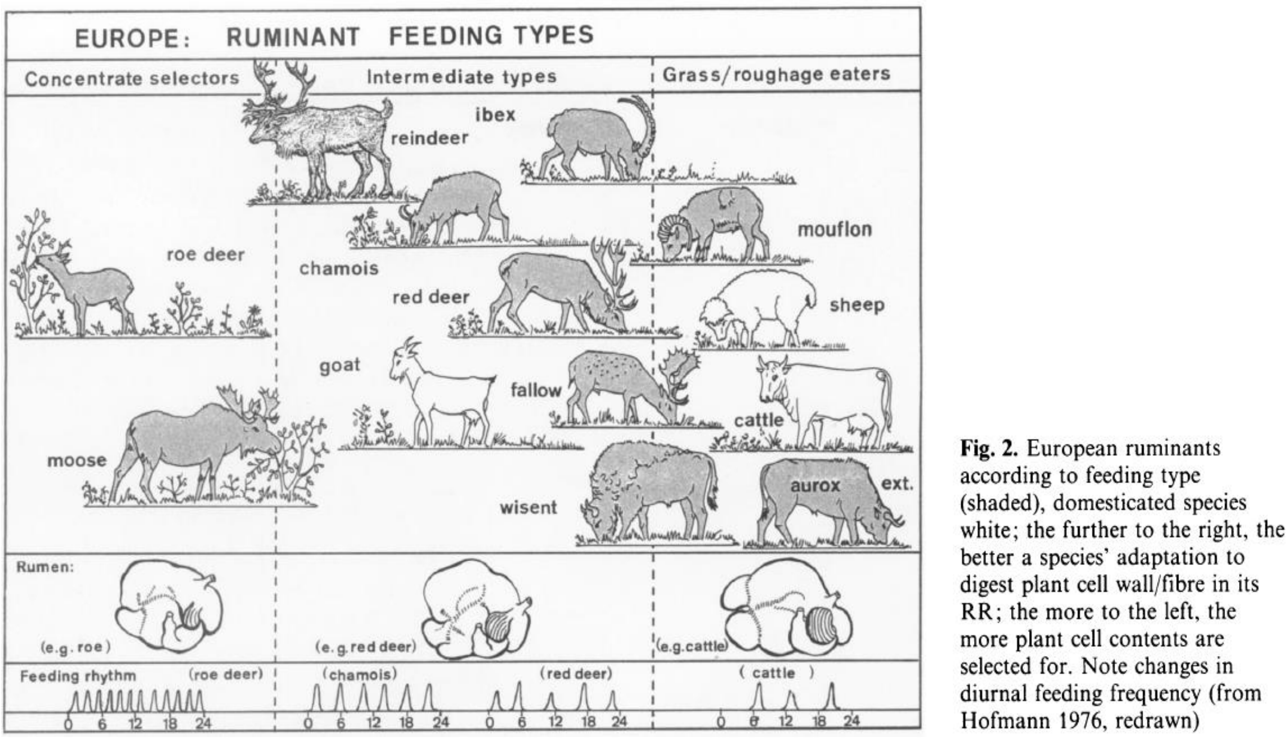


Fig. 2: Ruminant feeding types (Hofmann, 1989)

3.2. The concentrate selectors

The other options to name this group are "browser", "selectors of juicy" or "Concentrated herbage" (Hofmann and Stewart, 1973).

To make it simple, even this group can be divided. The division shall be based on the type of food they prefer. This lets you "Tree and shrub foliage eaters" (here we discuss all types of giraffes *Giraffa* spp. as a typical representative) and "Fruit and dicotyledonous (tree, shrub or forb) foliage selectors" (*Cephalophus harveyi*) (Hofmann and Stewart, 1973).

Food intake begins in ruminants, as well as all higher animals, in the oral cavity. It is externally covered by lips. And already here are differences between the feeding types. Concentrate selectors have more serous glands in the lips. These are used to control painful stimuli associated with food intake. Most plants use a variety of defensive practices to prevent its consummation. These are different essential oils in the leaves or stems or even visual defense like the thorns for example. The main component of food for concentrate selectors are mainly leaves, around which, however, are branches with thorns. Limitations of sensitivity to these stimuli will allow better food intake. The lips are also relatively long and very mobile. They can also open the mouth gape widely. This allows the side intake which also reduces the risk of the injury (Hofmann, 1989).

The next part of the oral cavity, which is directly involved in food intake, is the tongue. It is covered by squamous epithelium that protects the entire oral cavity. The significant part of the tongue is torus linguae. It pulverizes the food between it and the hard palate. (Ruminants do not have complete dentition (missing upper *incisors* and *canines*), and so this can be seen as a substitute.) Concentrate selectors also have this part of the tongue, although shorter, but up to one-third of the tongue is fully movable. The most mobile part of the tongue is its tip which is used to grip the food. On the tongue taste receptors are positioned which, however, can be found only in a small number of concentrate selectors. Hard palate, which forms the upper border of the oral cavity, has a special surface pattern. "Cooperation" with the tongue allows to sort the food for dilution between the teeth or to move it into the pharynx (Hofmann, 1989).

To the oral cavity also salivary glands belong. These are exocrine glands which open into the oral cavity, where the saliva is used for initial digestion of ingested food. The four largest salivary glands are the parotid, mandibular, sublingual and buccal ventral. Produced saliva also has the ability to buffer, i.e. to adjust the pH in the oral cavity and in the *rumen*, thus allowing the development and maintenance of local bacteria. The main difference of the salivary glands in individual food types is their size. Concentrate selectors have the largest salivary gland, forming 0.36% of the total weight (Hofmann, 1989). In addition, the parotid glands are noticeably larger than in the other two types of eaters and produce also more saliva. The reason is to reduce the risk of decreased pH in rumen and to allow better absorption of food. Another reason for bigger glands is better digestion of plant cell components and enabled absorption of certain nutrients (e.g., carbohydrates) already in the forestomach. The final reason is to overcome chemical protection of plant (Hofmann, 1989).

Stomach and forestomachs are the most important parts of the digestive tract of ruminants. Here digestion and absorption of ingested food takes place.

The *rumen* of this type of eaters is remarkably smaller and simpler and the turnover of food and the fermentation processes take place very quickly (Hofmann, 1973). Interestingly, the rumen lacks adhesions. This may lead to its contraction, thereby expelling gas. The surface of the mucosa is covered with rumen papillae that are abundant throughout the forestomach (Hofmann, 1968). Their function is to increase the size of the adsorbent surface (namely up to 22×) (Hofmann, 1989).

The *reticulum* of this type is relatively large, often greater than the abomasum (Hofmann, 1968). Its surface is covered by ridges and then shallow, but very extensive cells which can extend up to horny papillae. The dorsal part of the cap is covered by papillae, which are structurally similar to those in the rumen (Hofmann, 1973). *Ruminoreticular* fold is covered by the ruminal papillae which pass through the *reticulum* (Hofmann, 1989).

Omasum is small, flat and kidney-shaped. Its surface is small and the blades are often arranged in only one direction but individual leaflets are rigid, elongated and covered by horny papillae. *Omasum's* mucosal surface allows us to divide concentrate selectors into two groups, which are listed at the beginning of this chapter. Owing to the mucosal surface and its folded structure *omasum* is excellent fiber filter (Hofmann, 1989).

Abomasum is small, often even smaller than *reticulum* (Hofmann, 1973). It is defined with very thick glandural mucosa (Hofmann, 1968).

Ruminoreticulum in these species is small. This is because of the great absorptive surface of the mucosa in the dorsal rumen and reticulum front part (Hofmann, 1973). In this case we have to realize that concentrate selectors do not eat only the leaves and fruits. They eat grass or other fibrous plants. These may reach the value of 1 % (*Giraffa* spp.) to 67 % (*Strepiceros imberbis*) in the entire food content (Hofmann and Stewart, 1973). In ruminoreticulum of concentrate selectors, however, the fibrous plants are heavier than the rough parts of gastric juice and therefore are at the bottom (Hofmann, 1968). Liquids resulting from the digesting of food are exposed to a large absorbent surface in all parts of the stomach, but especially in the rumen and reticulum. Owing to the large absorption surface of the stomach the concentrate selectors also have much shorter intestine (Fig. 3 and 4) (Hofmann, 1989).

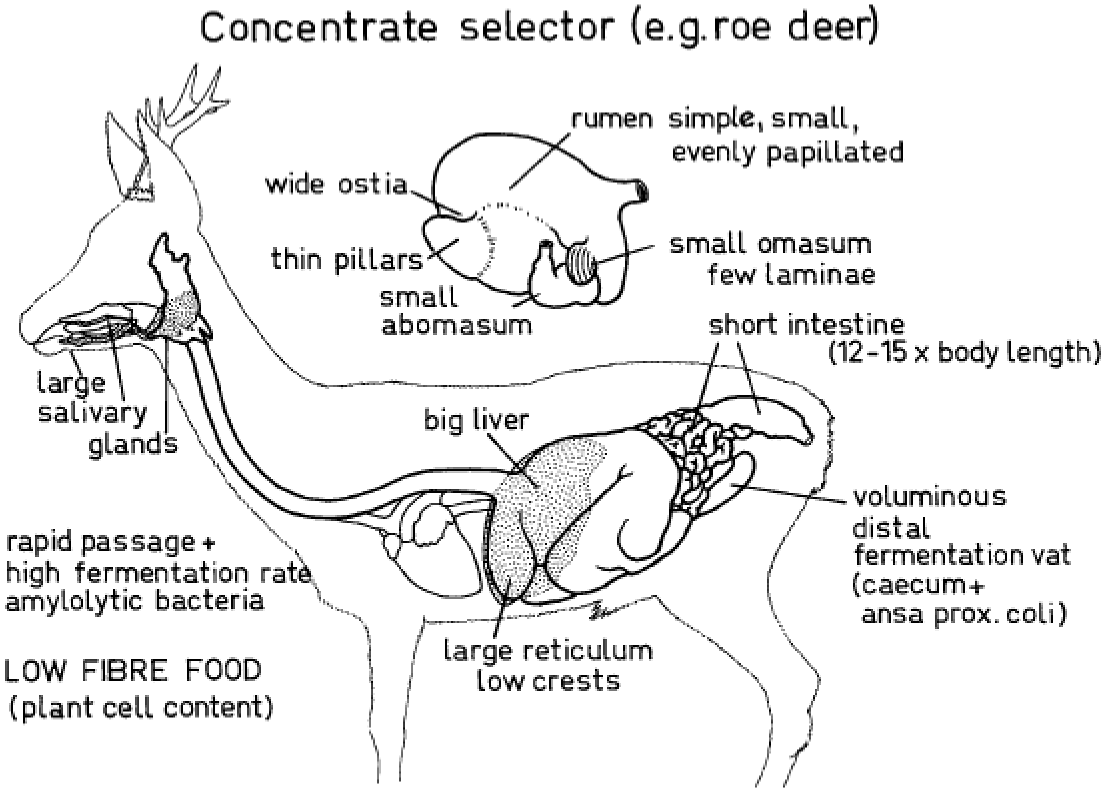


Fig. 6. Type example of a concentrate selector (roe deer) showing morphophysiological characteristics common to all ruminants belonging to this feeding type; from Hofmann 1985

Fig. 3: The anatomy of concentrate selectors (Hofmann, 1989)

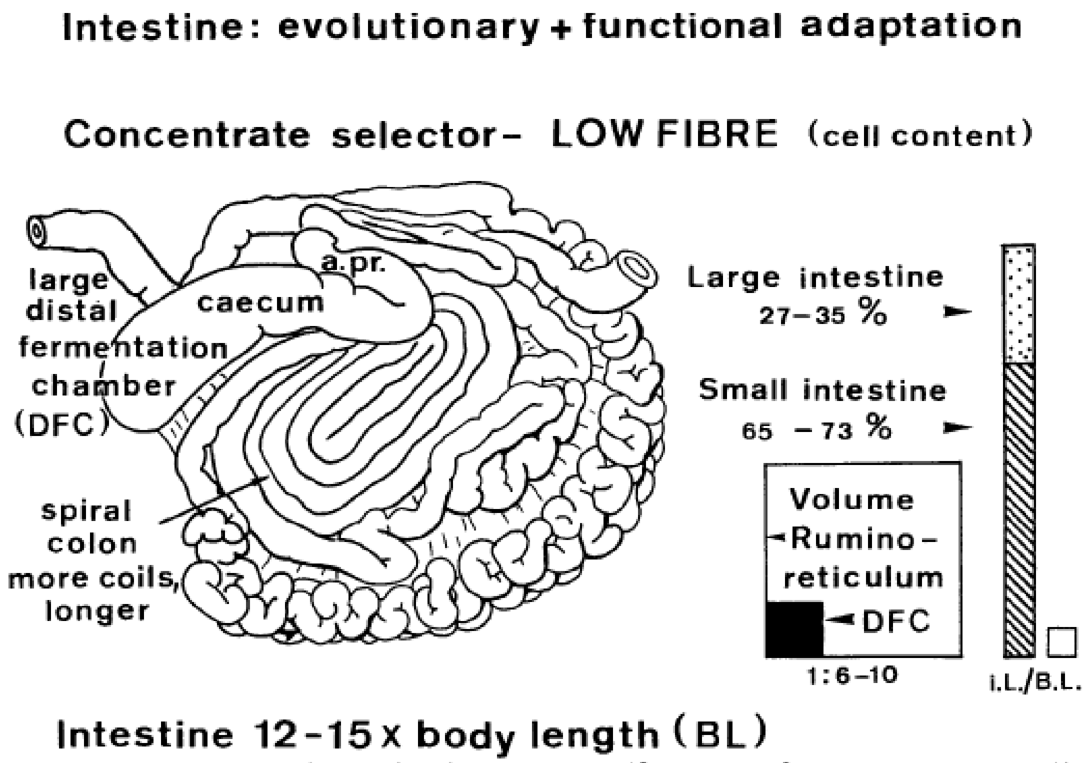


Fig. 14. Ruminant intestinal structure (from Hofmann 1985, modified)

Fig. 4: Intestine of concentrate selectors (Hofmann, 1989)

3.3. The grazer

In the literature can also be found under “Bulk and roughage eaters”(Hofmann and Stewart, 1973).

Of course, even here it is possible to divide this type into more subgroups. Division into the subgroups is possible on the grounds of presence and type of food the individual ruminants prefer to receive. Following groups will be discussed in this thesis: "Roughage grazers" (*Alcelaphus buselaphus* ssp. *cokii* for example), "Fresh grass grazers dependent upon water" (*Connochaetes taurinus*) and "Dry region grazers" (*Oryx beisa beisa*). (Hofmann and Stewart, 1973)

The main difference to concentrate selectors is the type of food. Grazers prefer monocots – grass. Grasses are high in fiber, but also dry matters (Hofmann and Stewart, 1973). They are also often rigid, sharp and otherwise protected against biting (Hofmann, 1989). It is thus clear that the morphological changes are necessary in the entire digestive tract (Hofmann, 1973). Due to the large amount of the fibrous feeds these animals also need to drink high amounts of water which is consumed in relatively short intervals (Hofmann, 1968).

The grazers´ lips are short, rigid and have almost no serous glands. Oral hole has much smaller chance to open minimize loss of grass during biting (Hofmann, 1989). Dental pattern is the same as in concentrate selectors (Hofmann, 1973).

Torus linguae are in comparison to the length of the tongue longer. But the movable part of the tongue is the shortest in all ruminants - only 28 % of the total length (Hofmann, 1989). It is used to tear off bundles of grass. The tongue in the grazers is very densely covered with taste buds. They use it to test the taste of various grasses (Hofmann, 1973).

The salivary glands are very small, forming only 0.18 % of the bodyweight. This is due to the size of their ruminoreticulum. Owing to the slow rate of turnover of food they do not need such a high saliva production to protect the pH in the *rumen* (Hofmann, 1989).

One of basic features for all ruminants whose main component of food is grass (or other fiber-rich components) is the large *rumen*. It extends to the pelvic inlet. Weight of the rumen is around 15 % of total body weight (empty weights around 3.5 %) (Hofmann, 1989). The arrangement of the papillae in the rumen is the same for all grazers: Papillae are arranged unevenly and dorsal part is completely unpapillated. The largest concentration of the papillae is in the folds, where the digest temporarily amasses and where fermentation processes may happen (Hofmann, 1973).

The top wall by the *rumen* is covered by the cornified papillae which increase absorbent capability (Hofmann, 1973); (Hofmann, 1989). Their task is to defend the mucosa from damage by rough parts of digested food. The digested gross part is swimming in the *rumen* juice. In the domestic species digest swims in the upper part of the *rumen* too (Hungate, 1966: "because of air caught within the hollow stem") (Hofmann, 1968).

The *reticulum* is relatively small (Hofmann, 1973). Its inner surface is surrounded with large crests, which may increase even quarterly subdivisions (Hofmann, 1968). The grooving is vertical. Food separation is considerably facilitated due to this surface relief (Hofmann, 1989).

The *omasum* is in this type of feeder large. It contains more than laminae with CS and has different mucosal relief as well (Sellers and Stevens, 1966 that relate the *omasum* of the cow offers one-third of the total epithelial area of the forestomachs) (Hofmann, 1973). The *omasum* also serves to absorb water and other soluble nutrients (for most concentrate selectors is it an insignificant share), (Hofmann and Stewart, 1973).

"Abomasum has increased capacity through numerous folds. Its size is directly proportional to the capacity of the rumen, which is maximally filled with food. (by Dirksen, 1962)" (Hofmann, 1973).

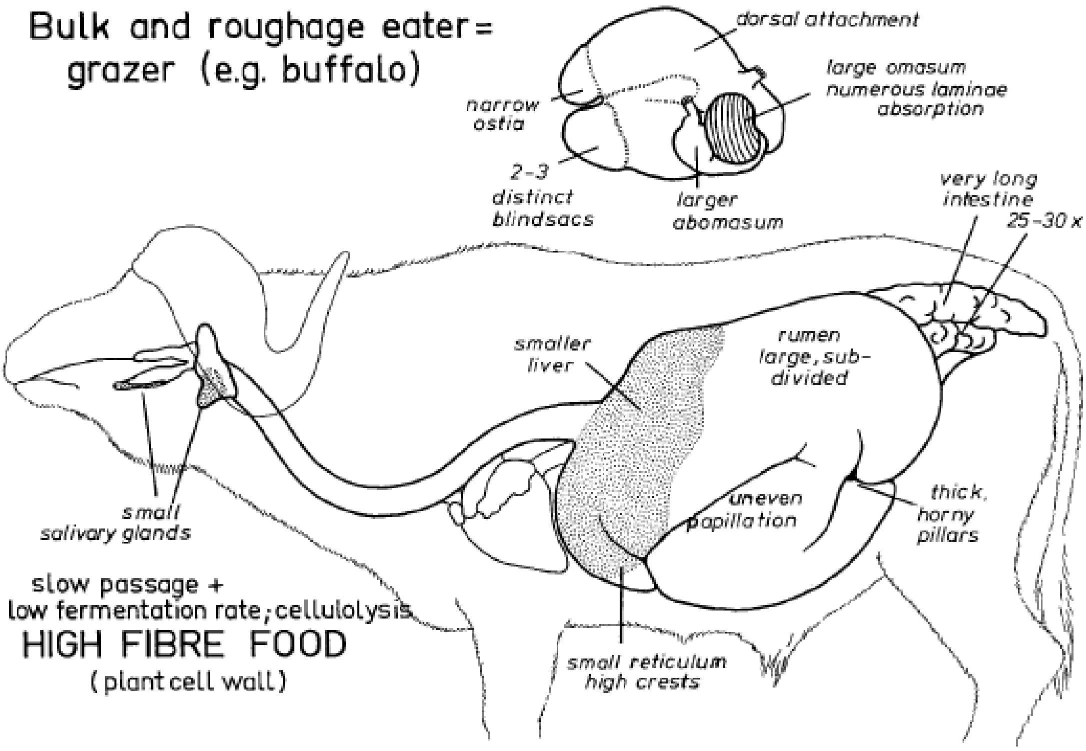


Fig. 7. Type example of a grass and roughage eater (buffalo); see legend of Fig. 6: from Hofmann 1985

Fig. 5: The anatomy of the grazer (Hofmann, 1989)

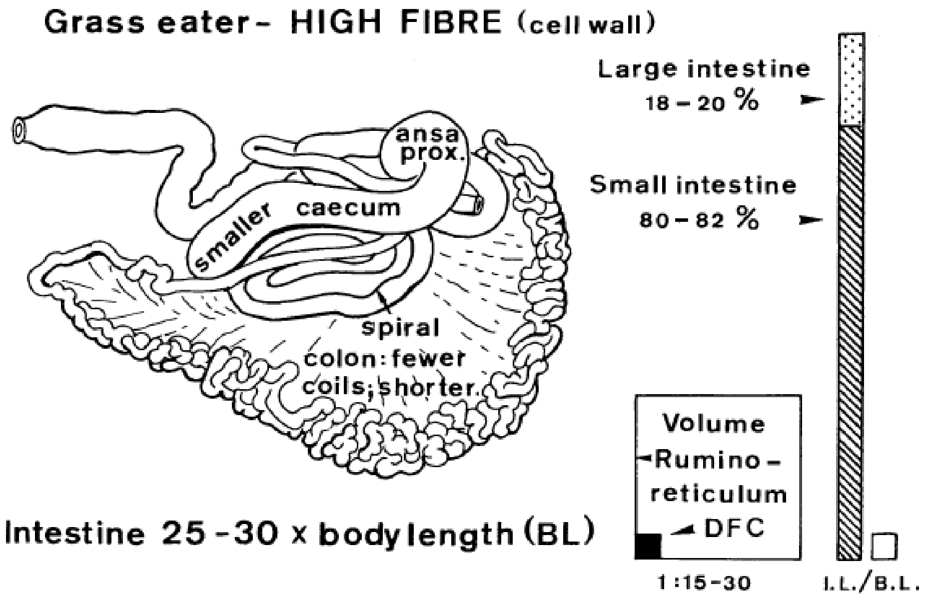


Fig. 14. Ruminant intestinal structure (from Hofmann 1985, modified)

Fig. 6: The intestine of a grazer (Hofmann, 1989)

3.4. The intermediate feeders

This group can also be found under "mixed feeders"(Hofmann and Stewart, 1973).

This group may be considered as a transitional type between the two groups described above. In the introduction it was mentioned that the ruminants have tremendous adaptability to environment which is definitely confirmed in this type of feeders. They are able to adapt to climate changes in dry and rain season but also to the vegetation changes (Hofmann and Stewart, 1973).

Their remarkably variable intake of monocotyledonous and dicotyledonous plants is dependent on the availability of food in a certain period. Mucous membrane of the stomach and forestomachs is adapted to the type of ingested food. However, changes due to changed food intake or seasonal changes may occur (Hofmann, 1968). Differences are already visible in the salivary glands (Fig. 7). But these changes can be observed largely on the deployment of the papillae in the *rumen* and on the laminae in the *omasum*. (Hofmann, 1973) Minor changes are also visible in the *abomasum* and *reticulum*. Changing mucosa allows increase or decrease of the absorption area due to seasonal changes (Fig. 8) (Hofmann, 1989).

We can divide this group into two subgroups: "Intermediate feeders preferring grasses (with only two representatives *Aepyceros melampus* and *Gazella thomsonii*) and "Intermediate feeders preferring forbs and shrub or tree foliage "(*Gazella granti* as an example) (Hofmann and Stewart, 1973).

Changes in the stomach surface may occur, depending on current habitat of the feeder. Individuals living in a forest will have similar stomach structure to the concentrate selectors, while the grazing individuals will have similar structure to the mucosa of the grazer (Hofmann and Stewart, 1973).

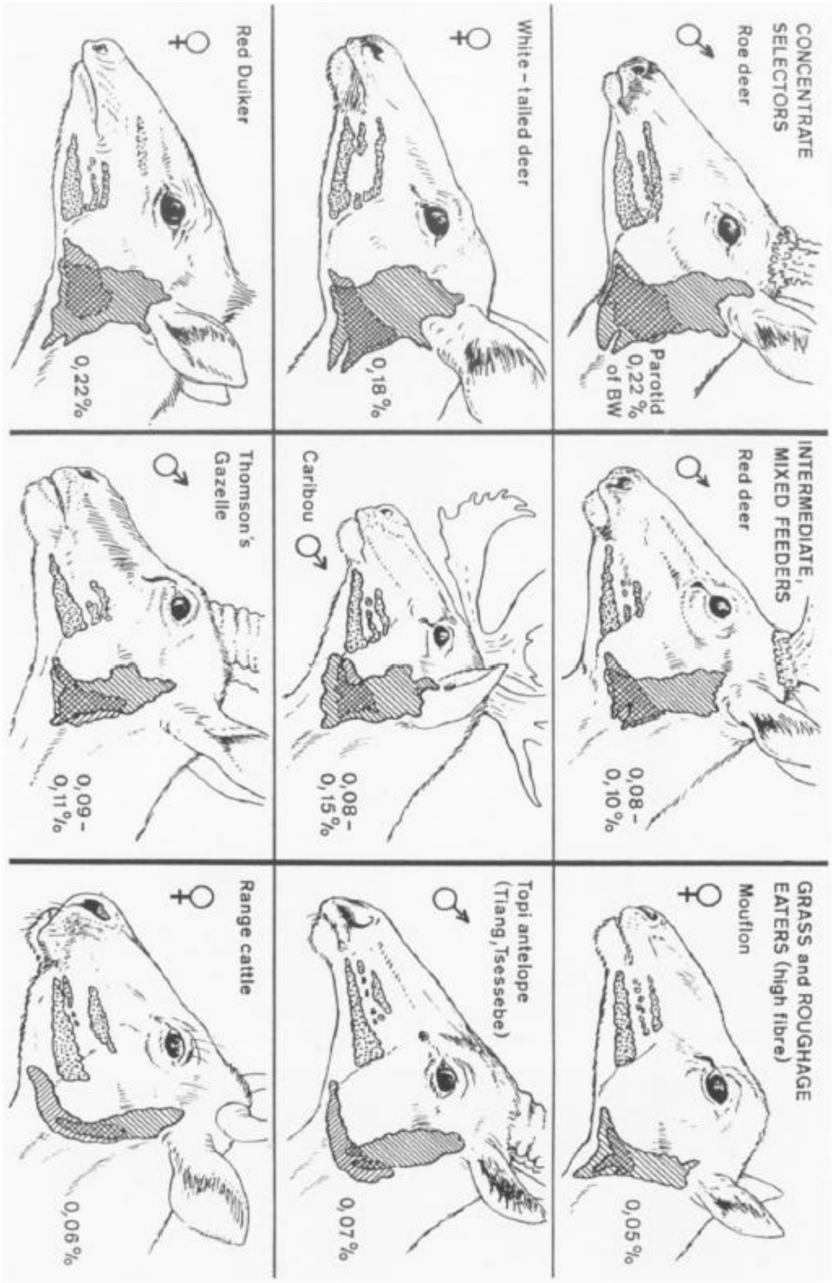


Fig. 8. Comparative topographic representation of the salivary glands (from left to right: buccal, mandibular, parotid) in 9 ruminant species of 3 feeding types and the relative weight of the parotid. All salivary glands (incl. sublingual, not shown) regress with increasing adaptation to plant cell wall digestion, most distinctly the parotid, for functional reasons. From Hofmann (1988)

Fig. 7: The differences between salivary glands in all feeding types (Hofmann, 1989)

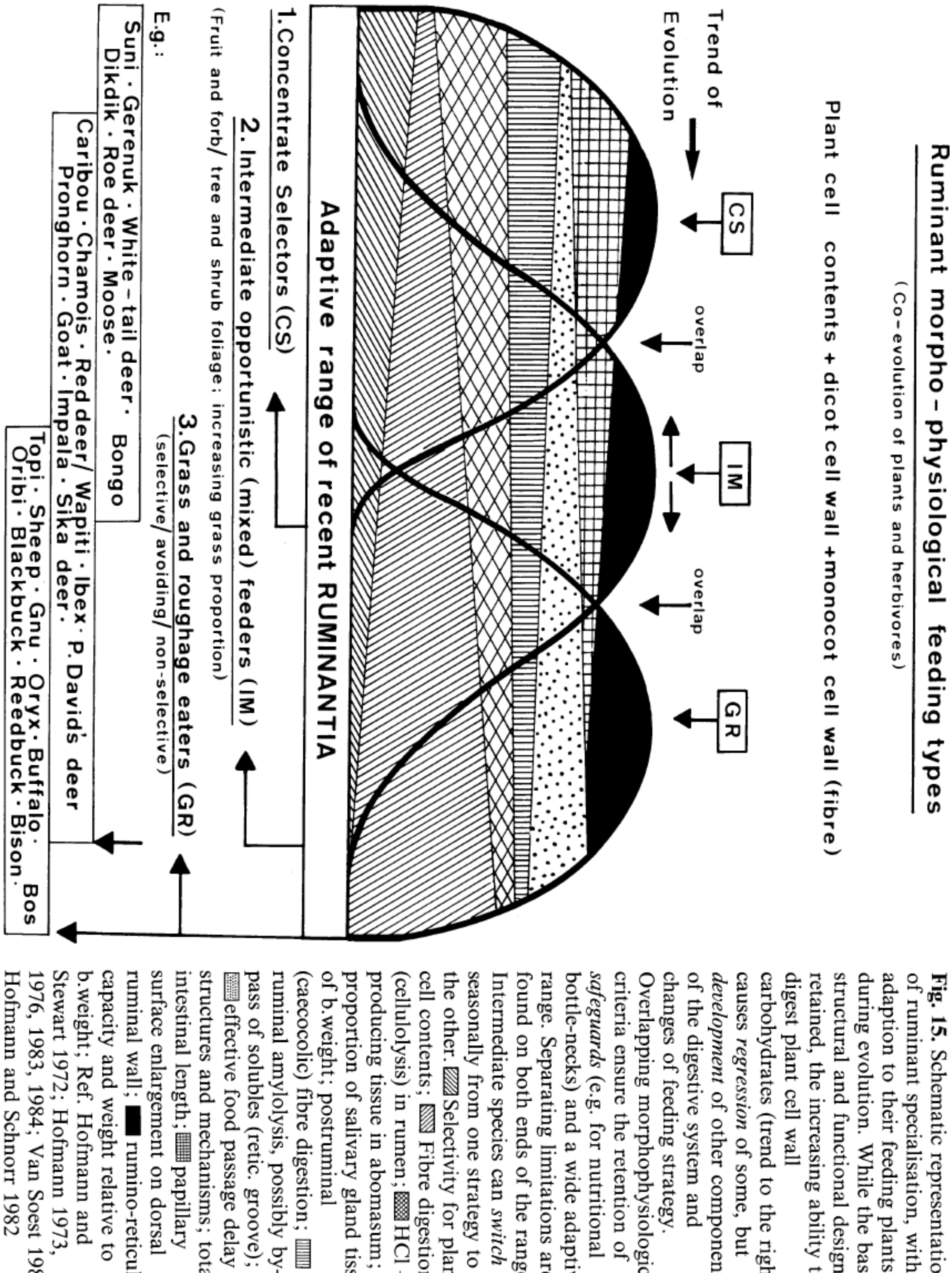


Fig. 8: The development of stomach by ruminants during the evolution (Hofmann, 1989)

4. Factors influencing ruminants food ingestion and digestion

Ruminants foraging strategy is simple - eat as much food as quickly as possible. After they succeed, they go to a quiet place. To digest the food received as effectively as possible, some basic conditions must be fulfilled. There they remain for few hours resting and chewing the food – digesting. Very important factor is the calm – animal needs be not disturbed during digestion.

However, this is only one of many conditions which must be fulfilled for proper digestion. It is also unique because it can be influenced by the animal. Other conditions are more difficult to be fulfilled.

For example, the acid and digestive juices in the stomachs have to stay in the correct concentration which will not disrupt the mucosal surface. This phenomenon can be influenced by the animals themselves.

The studies that examine and evaluate proper operation of the digestion can be subdivided into different areas of interest. These examining the processes of digestion and influences that affect digestion inside the animal are so-called "internal factors". The instigations from the environment are described as "external factors".

There is no possibility to determine clearly which factors are more important for the animal. Both groups are important for undistorted digestion and food intake.

4.1. Internal factors

Internal factors may influence overall health of the animal in large extend. Often these phenomena are associated with receiving and digesting food. Here we have to oversee the overall health of farmed/tested animals. However, it is important to note that this includes hormonal changes caused by pregnancy or growth.

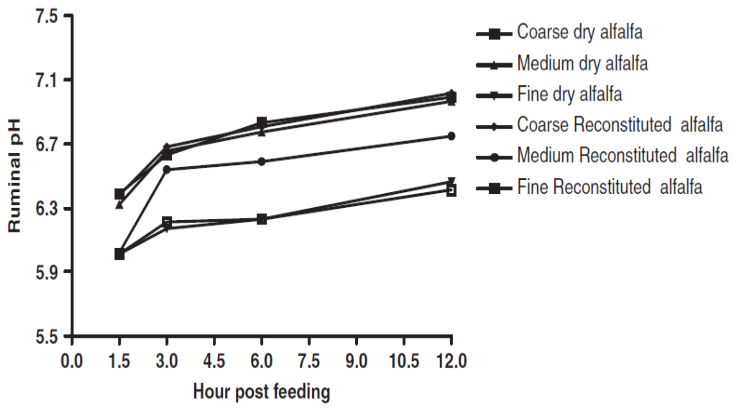
4.1.1. Food intake

The first internal factor which is necessary for the organism to function is food. In nature each animal is trying to find the best and most nutritious food. If the animal is captive, the breeder is trying to build the best ration. Balanced ratio of nutrients and vitamins gives the opportunity to the animal to make the best use of it. Feed divides into coarse and concentrated forage. Modifications may only be done with coarse forage, because concentrated forage already has predefined shape and size.

Very important coarse forage is alfalfa. It contains large amounts of proteins and energy. It is therefore suitable for growing animals that need to increase their weight but also for animals with great expenditure of energy, for example animals during lactation (Deyl, 2001).

Alfalfa is often administered to animals in the diet along with hay. For better and easier digestion water is also added. Yansari and Primohammad (2009) investigated the effects of adding water to the feed ration for Holstein cows. The alfalfa was cut to the size of 1.2 to 9.13 mm and the water at ambient temperature was added slowly to the hay during mixing to achieve theoretical and dry matter content of 350 g/kg (Yansari and Primohammad, 2009).

Ration, however, was also without water or with only lower concentration. It is important to note that in this case the feed ration was given ad libitum. Different length blades of alfalfa and the water resulted in different quantity of ingested food and the time spent with chewing. Interesting fact was to determine changes in gastric pH over 1.5 to 12 hours after feeding. However, pH was lower for ration with fine alfalfa than for ration with coarse alfalfa and that reconstitution had relatively little effect. In the current experiment, cows in all treatments had ruminal pH higher than 6.0 (Fig. 9). Lower ruminal pH, when cows were fed with fine particles, corresponds to lower total chewing activity and rumination time. When animals are fed adequate amounts of long forage based on peNDF (physically effective neutral detergent fiber), ruminal pH is buffered due to increased saliva flow (Yansari and Primohammad, 2009).



The values of ruminal pH over the time of post feeding in experimental cows fed dry and reconstituted three sizes of alfalfa as a part of rations.

Fig. 9: Level of ruminal pH after feeding with three sizes of alfalfa (Yansari and Primohammad, 2009)

In a study by Hosseinkhani et- al. (2007) cows were fed ad-libitum twice a day with alfalfa sized 5 to 20 mm. However, he claims that the particle size does not affect the pH in the stomach (but agrees that adding water reduces pH) (Hosseinkhani et al., 2007). Moreover, water addition to the TMR (total mixed ration) decreased rumen pH, referring to: the pH was in the range physiological for a healthy and normal rumen fermentation (Hosseinkhani et al., 2007). Explanation for this may be the effect of shortening the chewing time (the shorter particle size, the shorter time of chewing) and lesser saliva production. Saliva is important buffers for the environment of the stomach.

Yang et al. (2001) noted that the contribution of increased daily saliva output due to increased time of chewing (TC) on rumen pH is often overestimated. Although, reduced particle size may decrease TC, changes in total saliva production are small (approximately by 4%), when the animal rests its saliva secretion will increase (Yang, 2001).

Effect on food intake will also have the style in which animals are fed. If you feed a limited amount of food, the animal will spend more time in inactivity. Moreover, there is a lesser weight gain and therefore economic loss may be caused. Another change can be observed in comparing the various developmental stages of animals. Cows have a higher consumption time and intake rate compared to heifers, resulting in greater food consumption (Pazdiora et al., 2011).

Food intake depends not only on access to food, but also on the requirements of the animal species. It is noted that each animal prefers food through ad-libitum, but not everyone has access to it. The forage breeding method is also economically very demanding. Therefore, this method is predominantly seen in the experiments. However, one of the key items is the flavor. Owing to good developed flavor sense (described above) the ruminants have good ability to distinguish the taste of food. Abijaoude et al. (2000) described in his paper with goats that under influence of two feed mixtures with similar structures animals are able to distinguish one from the other. (Abijaoude et al., 2000) However, it seems that the feeding behavior of goats (chewing, eating speed, etc.) shall be adjusted to the basis of the type of food present (Abijaoude et al., 2000). Animals also choose the food that is able to provide them better nutritional value. It is good to take its content into account when drawing up ration (Abijaoude et al., 2000).

4.1.2. Chewing

Chewing is very important activity. During the process mechanical digestion of food takes place. Rumination time is reduced with the size of food portions (described above) (Fig. 10) and also with liquid content in the diet. However, at higher liquid content dry matter intake is reduced (Hosseinkhani et al., 2007).

Table 5: Time spent for eating, ruminating and total chewing

	Long hay		Short hay			Effect[1]		
	Dry	Wet	Dry	Wet	SEM	PS	DM	PS×DM
Eating time								
min d^{-1}	350.6	343.8	346.3	321.4	12.36	0.31	0.23	0.37
min kg^{-1} DM	14.96	14.52	14.84	14.45	0.82	0.19	0.17	0.55
min kg^{-1} total NDF	39.37	37.24	38.04	35.25	2.16	0.06	0.05	0.43
min kg^{-1} $peNDF_{1.18}$	47.57	42.83	48.84	44.07	2.73	0.43	0.02	0.52
Ruminating time								
min d^{-1}	465.5	463.3	401.3	413.8	22.89	0.02	0.92	0.85
min kg^{-1} DM	20.06	19.52	17.24	18.63	0.99	0.06	0.84	0.59
min kg^{-1} total NDF	52.77	50.06	44.19	45.44	3.19	<0.01	0.27	0.97
min kg^{-1} $peNDF_{1.18}$	63.76	57.58	56.74	56.82	3.97	0.06	0.11	0.90
Total chewing time								
min d^{-1}	816.3	806.9	747.5	735.0	50.98	0.03	0.25	0.46
min kg^{-1} DM	35.07	34.04	32.07	33.08	1.87	0.03	0.28	0.83
min kg^{-1} total NDF	92.14	87.29	82.24	80.69	4.71	<0.01	0.09	0.69
min kg^{-1} $peNDF_{1.18}$	111.3	100.4	105.6	100.9	5.93	0.09	0.03	0.82

[1]-Probability of the main effect of hay Particle Size (PS), TMR Dry Mater (DM) and the interaction of particle size and dry mater (PS×DM)

Fig. 10: Effects of the size of the food on the time spent with chewing in dairy cows (Hosseinkhani et al., 2007)

Great influence on animal chewing has sex and age. Younger individuals have higher chewing activity than older individuals to increase chewing efficiency (Li, 2013). It is caused by incomplete development of the digestive tract.

Chewing itself is not only related to body size. Chewing behavior, which also affects chewing effectiveness, compensates the reduction of possible tooth effectiveness. However food selectivity may also be related to body size. Considering feeding and metabolic rate abilities (e.g. picking out small items) smaller animals tend to select low quantities of high quality food, whereas larger animals prefer to choose the forage (Li, 2013).

An important role in chewing plays also the way of life in wild live animals. If the animal is solitary, the time it spends chewing is different than in case of animals in the herd. Also the role of gender and social status of the animal influence its chewing habits. "Harem holder" spends with food intake less time than females in the herd. Reason to this behavior is him willing to keep the attention of his group (Li, 2013).

Important influence on the frequency of rumination and time that animal spends with food intake has the form of food. If the animal is fed ad-libitum, it will take much larger amount of food than at a defined ration. The food intake will also take longer. However, in this case the cycle of rumination will shorten. Conversely, with plenty of fodder received the time between the rumination cycles will not change (Kaske et al., 2002).

Food intake, subsequent rumination and chewing have significant influence on hormonal changes caused by pregnancy. For example, in cows, there is a significant decline in rumination time on the day of calving. Rodenburg (2011) points in his study out that the length of rumination begins to shorten approximately five days before calving (Rodenburg, 2011). He also observed that during calving the rumination time will shorten from 350 to 220 minutes. This value corresponds to approximately half of the time spent with rumination which is typical for dry cows (Soriani, 2013). After the pregnancy cows show changes not only in behavior, but also in food intake and time spent with rumination. Primiparous cows experience more stress and therefore their rumination time shortens (Soriani, 2013).

In Bazeley's and Pinsent's study (1984) is reported that during the transitional period it is not good for the animals when it comes to sudden changes of the environment (Bazeley and Pinsent, 1984). Under this condition, the animals often change their feeding behavior, and due to this fact it can also be more susceptible to various diseases. Therefore in this period it is not reasonable to change the eating habits of the animals accommodated. These conditions may be considered to be stressful and this can affect the entire food intake and rumination (Soriani, 2013).

Chewing directly affects the digestibility. If the food is properly chewed, it comes to greater dilution which enables subsequent absorption of food in the stomach of the animal. Vega et al (2010) conducted a study to compare food intake and rumination in

Brahman grade cattle and crossbred water buffalo. Their study shows, inter alia, the fact that although the buffalo receives larger amounts of food thanks to the size of its masticatory muscles and longer time spent with chewing the digestibility of food received stayes at the same level as in cattle (Fig. 11 and 12) (Vega et al., 2010).

Good intensity in chewing may also affect the digestibility of food. Larger parts of food cannot pass through the *rumen* and the sediment at the bottom.

Table 5 Apparent digestibility of the diets for tropical grade Brahman cattle and crossbred water buffalo

Parameter	Species		SEM
	Cattle	Buffalo	
Apparent digestibility			
Dry matter	52.4	54.8	0.69
Organic matter	54.8	56.3	0.71
Crude protein	64.4	66.9	0.77
Ether extract	64.8	66.2	1.19
Neutral-detergent fiber	49.0	52.6	0.90
Acid detergent fiber	40.2	44.1	0.74
Total digestible nutrient, %	64.4	66.9	0.58

Fig. 11: Differences in food intake between Brahman and water buffalo (Vega et al, 2010)

Table 6 Diameter (µm) of the different muscles of mastication and regions of the tongue of crossbred water buffalo ($n = 3$) and tropical grade Brahman ($n = 3$) at the end of the 6 month experiment

Muscle location	Cattle	Buffalo
Digastricus muscle	0.439 ± 0.072^b	0.575 ± 0.091^a
Masseter muscle	0.419 ± 0.054^b	0.569 ± 0.101^a
Pterygoid muscle	0.378 ± 0.071^b	0.453 ± 0.091^a
Tongue (extensible)		
Tip	0.297 ± 0.055^b	0.319 ± 0.062^a
Middle	0.276 ± 0.073^b	0.356 ± 0.041^a
Base	0.311 ± 0.082^b	0.372 ± 0.042^a
Tongue (non-extensible region)	0.414 ± 0.057^a	0.280 ± 0.046^b

In rows, means with different superscript (^{a} and ^{b}) are significantly different at $P < 0.05$.

Fig. 12: Differences between muscles of mastication by Brahman and water buffalo (Vega et al., 2010)

Schwarm et al (2009) compared *Hexaprotodon liberiensis* with *Bos javanicus*. He refers that food intake of *Bos javanicus* is reduced in comparison with *Hexaprotodon liberiensis*. This is because the ruminoreticulum of *Bos javanicus* is smaller in comparison with Equids. However, due to higher chewing intensity the ruminants have better digestibility of neutral detergent fiber (Schwarm et al., 2009).

Domingue et al (1991) mentions the fact that the size of particles that come into the *rumen* may differ in dependence on the species. In his study he compared the foraging behavior of sheep and goats fed ad libitum. He pointed out that although the sheep fed faster than a goat, it spends less time with chewing. Because of this goats have much larger proportion of small parts in a bite when they swallowed than sheep. They also have higher saliva production. But he also refers to the fact that when ruminating the chewing takes longer in sheep (Domingue et al., 1991).

Previous studies showed that pressure changes during feeding and rumination were recorded with the help of two small, lightly inflated balloons, where one was placed at the reticulum and another held against the jaw (Balch, 1971); others determined chewing time as eating time plus rumination time (Bae et al., 1981). It is difficult to perform accurate measurements of chewing movements and chewing behavior of animals (Soriani, 2013).

Measurements of chewing frequency during rumination are probably one of the toughest. It is not about demands an attempt requires, but it is difficult to establish the resulting data. Previously, one of the methods was fixing mechanical gauges on the jaw of an animal. In this case the jaw movement results were recorded in a special computer program. However, the drawback of this method is that the entire chewing activity is recorded and the computer program cannot differentiate if the oral movements are a part of the rumination process or not, like for example the movements of the tongue, which can be a signal for boredom or licking. Probably the best way is to acquire a camera recording.

4.1.3 The rumen

It is probably one of the most important factors that influence food intake, subsequent processing and absorption of nutrients. Problems that may arise due to its poor function can completely hinder the absorption of nutrients from food. This in turn is the result of e.g. reduced daily additions, quantity of milked milk and inadequate health of the animal. If these problems occur in breeding, the breeder tries to return the animal to the original, healthy state as soon as possible. In these cases special medical treatment (prescription of pills or sampling of the stomach liquid) is often necessary. If the animal is treated with pills, it means temporary rest from breeding and economic losses for farmers. In the current extensive farming following saying is therefore often valid: a healthy stomach means healthy animals capable of producing.

For proper functioning of the stomach the symbiosis of the ruminant and its microflora in the *rumen* is one of the most important factors. These microorganisms are very sensitive to variations and changes in feed rations, and therefore switching to a different type of food must be performed gradually (as described above). We can simply say that "it is not necessary to feed the ruminant but the microbes".

Stomach microflora is specific to every species of ruminants. Therefore the different species can live in different condition, as it was described above. The ratio of microorganisms in the stomach is different within species. Higher ratio allows better digestibility of nutrients. Wanapat et al. (2003) described in their work that they put a part of ruminal fluid of a water buffalo into the rumen of Brahmin cattle (Wanapat et al., 2003). For the animal it resulted in higher digestibility of crude protein and ammonia concentration. Kennedy et al. (1992) and Kennedy (1995) points to the fact that a higher concentration of microbes in the stomach has a greater influence on the velocity of digestion, sedimentation and also on smaller-sized excreted parts (Kennedy, 1995; Kennedy et al., 1992; Vega et al., 2010). This was confirmed by Vega (Vega et al., 2010).

It is interesting to note that if the ration is reduced, the digestibility will increase. When the allocation of feed is reduced, also the speed of rumination reduces. Animals with reduced ration chew more slowly than animals fed ad libitum. The effect of this is that the chewed food is processed better. As a result we can also see better digestibility and faster absorption of nutrients. Due to intensed chewing we can observed a significantly greater production of saliva. (Galvani et al., 2010) It is useful to note that Putman et al. (1966) said that the production of saliva during chewing is similar among animals (Putnam et al., 1966).

Beauchemin et al. (2003) reported the result that long chewing has much better effect on gastric pH than the long time spent with food intake. However, in this study the animals were fed with a specific feed composition, which disagrees with the animal behavior during food intake (Beauchemin et al., 2003).

However, the pH of the stomach is one of the important indicators of animal's health. If the value falls under the optimum level (e.g. 6.0 in goats, Desnouyers et al. (2011)), it may cause unfolding disease called acidosis. This is the result of poor feeding and poor nutritional value of food (Gonzalez et al., 2012). But the average rumen pH can also be varied within one species. Various rumen patterns may affect the pH of the individual animal. Furthermore, the pH is not the only indicator of acidosis, as Dragomir et al. (2008) described in his study (Dragomir et al., 2008).

Measuring of the pH concentration should not be carried out only once a day. The pH changes can occur very quickly because of the time an animal spends waiting for food or feed (Desnoyers et al., 2011). The results may lead to false positives and therefore to exaggerated reaction of the breeder. This may induce stress in the animal, which may impede subsequent food intake and cause serious health complications.

During digestion in the rumen the production of organic acids takes place for which the microbes are responsible. These may cause acidification of the stomach. The quantity of acids depends on the amount and speed of the food received. The saliva reduces the acids. It depends also on the capacity of the rumen fluid. Acidosis, like any other disease, can have serious effects on food intake. Therefore, it is good to prevent it and ensure the best possible conditions for its prevention. The best prevention is already the diet itself. It is good to select individual components of food and their subsequent representation in the ration. It is also good to add some feed additives, such as buffers. It is also appropriate to modify feeding practices. A good effect on reducing the risk of acidosis has the reduction of the amount of food, feeding speed and increase of the amount of feed per day doses (Gonzalez et al., 2012). These adjustments do not only influence the prevention of acidosis, but also the quality of digestion (as described above).

It is important to mention that the food in the stomach is not completely digested. Parts of food that cannot be further digested in the rumen will settle on the bottom and pushed by ruminoreticulum to another part of the stomach. The study of deVega et al. (1996) says that the greatest effect on the throughput characteristics has the food. The size or rate of digestion has no such effect. For example, the legumes pass through the digestive tract faster than grass. But small-sized parts of food pass through as quickly as grasses and leguminous plants, regardless the status of the individual parts of the animal. This finding suggests the same kinetics of movement for all types of rumens. However, the greatest influence on the throughput of the rumen has the type of food and water (deVega and Poppi, 1997).

When feeding it is important to pay attention to the concentration of fatty acids which may contain different ingredients ration (main and supplementary parts of ration). Harvatine and Allen (2006) found that the addition of unsaturated fatty acids will decrease the intake of dry matter. As a consequence the wet weight of the rumen is reduced. We can also see a reduction in the amount of ingested food. Saturated fatty acids may increase the time of contemplation. But there is plurality in fluid intake per day. We can also see modifications of nutrient digestion and rumen kinetics. Due to saturated fatty acids the pH range may increase. However, it may probably be caused by different cleavage saturates during the experiment because they did not change the amount of food (Harvatine and Allen, 2006).

If the animal has increased energetic demands in a period, e.g. in the period of lactation, food intake automatically increases. Dado and Allen (1995) fed in their work cows during lactating (the 17th day of lactation) ad libitum which contained 25 and 35 % of neutral detergent fiber (NDF). It also increased rumen volume by 25 %. It reduced the dry matter intake of 35 % NDF. The increase in volume also increased the number of ruminating, chewing and NDF passage rate from the rumen. According to their study, additives, when added to the diet fiber, are more efficient when the animal has an increased volume of the stomach. Added volume also helps to reduce the pH drops after feeding. The high content of dietary fiber in early lactation reduces income because ruminoreticulum has such a large capacity. Increase in volume shows filling properties NDF (Dado and Allen, 1995).

The speed and ability passage of ruminoreticulum therefore depends on the type of ingested food. Chiofalo et al (1992) investigated the influence of feeding ration in sheep fed ad libitum. The rations were formed of hay and two silages with and without added additives. These rations were offered together to the sheep. He found that the animals prefer at different times of day different amounts of the selected food. This also corresponds to the chewing frequency and also to contractions of ruminoreticulum and volume of ingested food in it. With advanced time of the day the amount of feed intake decreases and this changes the number of contractions of ruminoreticulum. Food intake is linked to the volume of ruminoreticulum. On the basis of the total content of cell walls the ruminoreticulum was the largest when the animal ate hay (Chiofalo et al., 1992).

4.2. External factors

External factors include stimuli from the environment of the animal. To the best-known factors belongs the weather. The animal will behave at high ambient temperatures differently than at low temperatures. These factors include of course also the kind of housing. Sudden changes in housing or breeding groups may negatively affect the animal.

All such circumstances, and of course many others, may cause stress response in the animal. This can mean a threat to the health of the animal. One of the reactions to this stress is the change in eating habits. This subsequently affects the intake and processing of food. It leads to hardship of the animal.

Nowadays, when intensification of agricultural production is in full swing, stress prevention is one of the privileges of animal husbandry. When it comes to the reduction of food intake, it also comes to a reduction of the final product.

4.2.1. Weather

We can say that for the animal high temperatures are more dangerous than low temperatures.

Ogebe et al (1996) examined the effect of humid tropics on the Nigerian dwarf goats. He states the fact that with increasing temperature in the dry season the amount of food intake will decreases. In this fact the author refers to Brobeck (1948) (Brobeck, 1948) and Ragsdale et al. (1950) (Ragsdale, 1950) who found that the decrease in appetite and subsequent food intake restriction serves as thermoregulation (Ogebe et al., 1996).

And because of this the animal increases the intake of water. Ghosh, (1982) and NRC (1981) state that it serves to regulate body temperature (Ghosh, 1982; NRC, 1981). Interestingly, the water consumption increases in males more than in females. According to the author it can caused by various activities and greater aggression of the male. This may result in more evaporation. Unfortunately, this makes them, more vulnerable to thermal stress. The results also demonstrate increased rate of rumination. This is in contrast to the results Appleman and Delouche (1958). They found that with increasing temperature the rumination decreases (Appleman and Delouche, 1958). (This result may be influenced by the fact that Appleman and Delouche studied Anglo-Nubian goats) (Ogebe et al., 1996).

Very important influence on coping of heat stress has the breed. Dikmen (2013) observed the effects of the temperature on the breeds of Brown Swiss and Holstein cows. In the study he recorded the behavior of both breeds during the day. He pointed out the fact that the behavior of Brown Swiss is much less susceptible to thermal stress. Brown Swiss behavior changes in dependence of the temperature during the day. This allows them to take more food during the warmer parts of the day than it is possible for Holsteins. For higher temperatures, however, Brown Swiss showed shorter time spent with rumination in the parts of the day (Fig. 13). This probably saves them energy. Again, males have bigger changes in food intake than females due to higher temperatures (Dikmen, 2013).

Table 1. Behaviors (%) of Brown Swiss (BS) and Holstein (H) cattle

Hour	Group	Feeding	Drinking	Rumination	Standing	Resting	Locomotion	Other	p^x
06:00	BS	2.68	1.34	32.89	6.04	46.31	10.07	0.67	*
	H	4.79	0.68	17.12	7.53	60.96	6.85	2.05	
		NS	NS	**	NS	NS	NS	NS	
10:00	BS	11.11	2.08	15.28	29.17	6.25	34.03	2.08	NS
	H	15.56	4.44	9.63	28.15	11.85	29.63	0.74	
		NS	NS	NS	NS	NS	NS	NS	
13:00	BS	5.07	0.72	26.09	26.09	28.99	12.32	0.72	*
	H	2.22	1.48	36.30	11.85	26.67	20.74	0.74	
		NS	NS	NS	**	NS	NS	NS	
16:00	BS	31.47	1.40	1.40	16.08	5.59	42.66	1.40	***
	H	19.55	3.76	7.52	33.83	4.51	30.08	0.75	
		*	NS	*	**	NS	*	NS	
20:00	BS	17.36	2.08	4.17	13.89	7.64	52.78	2.08	**
	H	11.27	2.82	9.15	19.72	0.70	55.63	0.70	
		NS	NS	NS	NS	**	NS	NS	
23:00	BS	2.08	0.69	33.33	4.86	47.92	5.56	5.56	***
	H	0.70	0.70	16.78	0.70	78.32	0.70	2.10	
		NS	NS	**	*	**	*	NS	
Pooled	BS	11.60[a]	1.39	18.91	15.89	23.90[a]	26.22	2.09	**
	H	8.87[b]	2.28	16.07	16.67	31.18[b]	23.74	1.20	
p^y		*	NS	***	***	**	*	NS	

p values: * $p<0.05$, ** $p<0.01$, *** $p<0.0001$. NS: non-significant. [x]: p values show the differences of group by behavior within the observation hour. [y]: p values show the differences of group by time within the behavior type. [a,b]: Values with different superscripts in the same column differ statistically ($p<005$).

Fig. 13: Rumination activity during one day in Brown Swiss and Holstein (Dikmen, 2013)

Stafford et al (1993) examined the differences between rumino-reticular movements of red deer (*Cervus elaphus*) in summer and in winter in New Zealand. In his studies he comes to the result that the red deer has higher food intake and spends more time with rumination in summer than in winter. During summer feed intake was greater in the morning. However, the number of rumino-reticular contractions did not show significant changes during the season (Stafford et al., 1993). These small changes can occur due to climate change. Compared to the previously referred studies New Zealand is located in the temperate zone.

Li (2013) demonstrates the impact of rain on the time spent with rumination. Rain has a profound effect on rumination. When it is raining, the animal spends more time with rumination than in rainless day. (Fig. 14) The animals also spend more time with relaxation and thus saves energy. However, rain has no effect on the speed of the rumination (Li, 2013).

Table 1. Proportion of ruminating/bedding of Pére David's deer with respect to sex-age and rainfall in Dafeng Nature Reserve.

	Rainy day		Rainless day	
	Mean(SE)	**N**	**Mean(SE)**	**N**
Fawn	0.468(0.085)a	7	0.210(0.077)a	17
Juvenile Female	0.884(0.080)b	8	0.625(0.072)b	20
Juvenile Male	0.733(0.056)b	28	0.475(0.055)b	30
Adult Female	0.752(0.062)b	18	0.494(0.055)b	34
Stag	0.721(0.069)b	12	0.462(0.059)b	30
Harem holder	0.664(0.108)b	10	0.405(0.116)ab	2

Same letter in the same row denotes no significant difference at P>0.05.
doi:10.1371/journal.pone.0066261.t001

Fig. 14: Influence of rain on the rumination time in deer (Li, 2013)

4.2.2. Stabling and breeding

This factor has effects only on animals that are held in captivity. Animals living freely can influence these factors alone, for example with hiding from the sun in the shadow. In animals that are held in captivity this factor has an undeniable importance.

However, these factors are not influenced by the animal, but by the breeders and equipment of the breeding.

The study Hart et al (2013) focused on the changes in behavior and milk production in Holstein cows. He was interested in changing behavior by increasing the frequency of milking and the differences between primiparous and multiparous. Primiparous tend to intake smaller amounts of food even if the milking frequency increased. However, compared to primiparous with lesser milking frequency they had bigger food intake. Cows with lower milking frequency tended to faster food intake. But "parity of treatment x parity interaction had no effect on the total feeding time”. By bigger frequency of milking secondary peak of food intake was created. Cows with bigger milking frequency tend to higher food intake. Primiparous with a higher frequency of milking consume smaller portions, but they eat more often. This increases dry matter intake. These cows are more flexible to changes in feeding behavior. Connection of primiparous and multiparous with higher milking frequency to one group can thus be beneficial for the feeding behavior (and subsequent production) (Hart et al., 2013).

Very important parameter for the intake of food is animal health. Miguel-Pacheco, et al. (2014) examined the effect of lameness on changes in the behavior of cows milked by automatic milking system. These apparatus are primarily used for high production animals. Lame animals had reduced rumination time compared to healthy animals. In the case of cows with lame the frequency of rumination was greater in multiparous than in primaparous. Cows that were lactating over a longer period had a greater frequency of rumination than cows with shorter lactation period. Animals affected by lameness had also shorter feeding times. They also searched for food less frequently than healthy cows. Cows with lameness also attended the milking system much less in general. This may lead to a decline in production (Miguel-Pacheco et al., 2014).

Welfare of breeding is very important for overall health of the animals. Each animal should have the right to health, including food intake and proper conditions. One of these includes enough space. The following source on this topic is very interesting.

Bolinger et al (1997) studied the effects of self-locking stanchions on the behavior of Holstein cattle dairy cows in lactation. The actual use of this system was accompanied by no significant changes in the behavior of dairy cows, milked milk or changes in milk fat. However, there was a difference in food intake. Cows that were closed during the experiment then reduced the frequency of food intake. There was also a reduction in the frequency of rumination. These changes, however, have only a short-term effect that disappeared not later than within 24 hours. The author believes that these results may indicate the ability of cows to compensate the inability to move. But he also adds that it is necessary to conduct further research (Bolinger et al., 1997).

The overall welfare of animals is necessary for their proper functioning. Animal health significantly affects breeding economy. If the breeder can positively influence the food intake of the animals, he will achieve greater returns of animal products.

4.2.3. Oral stereotypy

The oral stereotypy in the animals is a serious problem. The most frequent reason for this is that the animals are bored. This may lead them to nibble things or equipment in their location. However, this at first sight innocent activity can have a serious effect on food intake. And it can also influence the health of the animals. Various licking or biting activities can lead to injuries in the oral cavity of the animal. Boredom and subsequent stereotypy also influence the feeding behavior of animals as such. The study of these issues is therefore very important.

Bored animals grow up with a lack of activities. In animals bred in captivity, however, the only activity is often only the food. Redbo and Nordblad (1997) studied the effect of feed rations and their changes on stereotypes in farmed cows of the Swedish Red and White Breed. The animals were tethered during the breeding and the entire study. The experiment was divided into three periods, during which there were the changes in the food system and feed rations. In the first and third period of the study the ration contained long straw, concentrate and silage. The second ration consisted of silage (with the same energy content as in the first and third periods). In the first period the animals had access to food ad libitum. In this observed period the incidence of stereotypes declined to minimum. In the second period, with limited access to food animals started to get bored and stereotypes increased. In the third period where the feeding regime was ad libitum again, occurrence of stereotypes decreased again. In every period also changes in animal behavior occured (Fig. 15). Food intake and rumination time was the shortest in the second period. Based on the results of this study the author recommends for animals kept in captivity feeding regime ad libitum to prevent the development of stereotypes. It's also a good system to prevent changes in food behavior (Redbo and Nordblad, 1997).

Table 3

Frequency of different behavioural categories as means per week (±SD) during the different periods and the reults from statistical analysis (univariate repeated measures ANOVA) (*** $P < 0.001$). Variation explained by a quadratic trend was estimated by a single degree-of-freedom polynomial contrast (2 order)

	Period			F value df = 6,282	Variation across time explained by a quadratic trend
	1	2	3		
Eating	35.2 (13.1)	15.2 (9.6)	42.1 (15.6)	36.6 ***	63%
Ruminating	87.9 (21.5)	24.8 (11.2)	81.7 (21.7)	120.0 ***	79%
Behavioural shift	65.9 (13.7)	97.9 (15.5)	59.8 (13.0)	63.8 ***	78%
Total lying	167.9 (25.2)	126.9 (25.2)	159.3 (23.5)	22.6 ***	68%
Standing	12.7 (8.8)	31.4 (14.2)	14.3 (10.3)	35.4 ***	74%
Lying inactive	69.1 (20.1)	83.9 (22.0)	68.7 (16.9)	7.9 ***	68%
Social behaviours	8.2 (4.4)	14.8 (6.3)	6.2 (3.3)	25.6 ***	80%
Grooming/scratching	10.1 (4.4)	13.2 (4.8)	8.7 (4.2)	9.6 ***	80%
Sniffing	7.1 (3.3)	8.6 (3.3)	3.2 (1.8)	20.0 ***	42%
Total licking/biting	7.4 (3.6)	30.1 (17.8)	9.0 (5.5)	44.4 ***	73%
Other	7.5 (2.9)	8.8 (2.6)	5.8 (2.7)	7.1 ***	54%

Fig. 15: Behavior change during changes of the feed ration (Redbo and Nordblad, 1997)

Previous year same results were observed in the behavior of cows during the lactation. Restriction of the amount of food containing high level of concentrate very negatively affects the overall welfare and promotes developed of stereotypes (Redbo et al., 1996).

Stereotyped behavior can be observed very well throughout the animal kingdom. In animals bred in captivity this problem is solved easier. The breed can be applied to various simple or more complex devices such as the scratching. The animal uses it and therefore does not develop any stereotypes. For exotic animals in captivity, for example in the zoos, solutions for these problems are more complex. Animals in these facilities should still be kept as in wild. Here is the only solution of these problems is the so called food "enrichment".

The task of enrichment is to increase the opportunities for natural animal behavior. His solution may involve eating or animal welfare.

During the study of the oral stereotypes Fernandez et al (2008) examined the impact of food enrichment on the behavior of giraffes. In the first experiment they tried to hide the caregiver only. This situation, however, did not record a reduction in stereotypes in observed animals. Another part of the experiment was conducted as different modifications of the feeders. They were prepared in the way that the animals spent more time trying to reach the food. Feeders were made out of buckets and either mobile or static. The results differed among individual animals observed. However, static feeders had almost no effects on reducing licking non-food items. Mobile brought a slight decrease of stereotypes. There was increase in the time spent ruminating but decreased food intake. The best results brought feeders made from mesh. Increased time spent ruminating reduced the number of stereotypes, thus allowing natural feeding behavior (trying to get the food) reduces the number of stereotypes in animals (Fernandez et al., 2008).

Deployment of enrichment at the zoo has therefore major impact on the reduction of stereotypes. However, as shown on the results of the study Fernandez et al (2008) conducted, the results may vary in individual animals. One type of enrichment affects one animal, while the other type affects the other. It is therefore necessary to take into account the individual needs of each and every animal.

Fig. 16: Enrichment for giraffes in ZOO Liberec, Czech Republic, photo by Ondřej Přibyl

5. Discussion

When writing this thesis I realised that most works used and cited here are directed on farming animals. It might be caused by increasing quality demands on these animals. Nevertheless I dare to say that conducting the research only into this direction is insufficient. In most cases the research is realised on highly cultivated animals (Yansari and Primohammad (2009) – research of Holstein milking cows, etc.). These works can be used in developed countries with specific location only (e. g. temperate zone). In developing countries these highly cultivated animals can be bread only in expensive conditions and it therefore makes the research useless.

It is also interesting to observe the incongruity of some scientific articles. For example Yansari and Primohammad (2009) compare the influence of the size of feeding particles on rumen pH. They claim that the size influences the chewing activity of the animal which increases the saliva production. Saliva works as a buffer and therefore decreases pH. On the contrary Hosseinkhami et al. (2007) states that water only can influence pH, but not the size of feeding particles.

In this thesis mostly those researches are cited that present the conclusion in form of statistical data. But these data were very often collected in very small samples (small number of testing animals). In the study of Fernandez et al. (2008) only 3 animals were observed, Dado, R. G., and M. S. Allen (1995) documented their work observing 12 cows. These two works are not unique. Researches with bigger samples, like e.g. Bolinger et al. (1997) with 64 observed animals, are rather a rarity.

Also the comparison of individual breeds or different types of ruminants is very interesting. This can be seen on the researches of Ogebe and Appleman and Delouche. Ogebe et al (1996) examined the influence of temperature on Nigerian dwarf goats and reached different conclusions than Appleman and Delouche (1958) who examined Anglo-Nubian goats. Ogebe et al. (1996) claims that the difference might be caused by the differences in the species. But it is not possible to find a comparison of the influence of temperature within one species – a comparison of a number of breeds. It is also very complicated to find a comparison of species/breeds in different thermal belts. Stafford et al., (1993) researched wild animals in New Zealand, but a comparison to a similar species (e.g. from the same order) in other thermal belts is not available. Possible insufficiency in this area opens the door to further researches on this topic.

Individual chapter is also the small number of sources targeted on wild or semi-wild animals, or animals kept in zoos. The work of Li, Z. Q. (2013) who researched wild-living Pere David's Deer is one of the few available. In connection with this topic the obvious demanding nature of this research must be mentioned in view of the life of these animals.

Most researches are also strictly targeted on a specific topic (e.g. the influence of weather on food intake etc.). Works dealing with wider area or observing several aspects can be seen as an exception. This can be also the point to continue on this thesis.

6. Conclusion

Further research on this topic could be targeted at groups consisting of statistically significant number of individuals, so that the results could be generalized. Another possible field of research is the research on wild/semi-wild animals, e.g. health resilience in connection with such factors that can be influenced by food intake and food processing. The results of the research on wild/semi-wild animals could be further used to optimize the food composition and other connected factors in the breeds of agricultural animals.

7. References

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