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Feeding Behaviour of the Bactrian Camel (*Camelus bactrianus*)

MASTER'S THESIS

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Declaration

I, Iva Pešková, hereby declare that I have done this thesis entitled Feeding Behaviour of the Bactrian Camel (*Camelus bactrianus*) independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague 22. 4. 2023

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Iva Pešková

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Abstract

The Bactrian camel (*Camelus bactrianus*) is a large ungulate herbivore, which is commonly used as a livestock animal in its native ranges across central Asia. Nowadays, its popularity is on the rise even in other parts of the world, thus the need for understanding the feeding behaviour of these animals is becoming more important. In this study, one camel farm and three zoos in the Czech Republic were chosen for the observation of the potential effect of different factors on the feeding behaviour of this species. The observation was carried out between June and September 2022 and took place for twelve days in Prague Zoo and six days in other institutions, overall covering the hours from 7.00 AM to 9.00 PM. Thirty animals in total were observed. The scan sampling method was used, where every five minutes the behaviour with other factors were recorded. Furthermore, a number of bites and chewing time were recorded during feeding or rumination and lastly, every defecation and urination was recorded during the time of the observation. Obtained data were later statistically analysed in the STATISTICA software. It was found that in total 31.89% of observations were of feeding and 11.65% of observations were of ruminating. The low frequency of rumination probably occurs due to the assumed higher frequency at night, as other studies suggest. The frequencies of behaviour were significantly affected by the institution, temperature, weather, part of the day, age and the sex of the animals ($p < 0.001$ – for all these factors). The average chewing time and the average number of bites were significantly lower during feeding than during rumination ($p < 0.01$). All the above-mentioned factors also significantly ($p < 0.05$) affected the chewing dynamics of observed camels, except for weather ($p > 0.05$). Defecation and urination frequency was not found to be affected by these factors ($p > 0.05$), but the results of this study are limited in this regard. In conclusion, many factors showed a potential effect on the feeding behaviour of the Bactrian camel, but further research is still necessary to fully understand the different variations in the feeding behaviour of these animals.

Keywords: Camelidae, rumination, digestion, two-humped camel, chewing, bite

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List of the abbreviations used in the thesis

FAO – Food and Agriculture Organization of the United Nations

FAOSTAT – Food and Agriculture Organization Corporate Statistical Database

HCl – Hydrochloric acid

IUCN – International Union for Conservation of Nature

MACR – The Ministry of Agriculture of the Czech Republic

NaCl – Sodium chloride

SE – Standard error of the mean

1. Introduction and Literature Review

1.1. Introduction

The Bactrian camel (*Camelus bactrianus*) is a commonly used livestock animal in regions of Inner, Central, and East Asia. Specifically in China, Mongolia, Kazakhstan, Kyrgyzstan, Turkmenistan, Afghanistan, the northern areas of Iran, India, Pakistan, and the eastern regions of Turkey (Dioli 2020). Today, however, herds of these animals can be found all over the world (Agnew 2018).

As the world faces higher rates of desertification due to climate change, these animals seem to be one of the viable options for sustainable milk and meat farming, thanks to their adaptations and resilience to harsh climatic conditions. These animals can also be highly efficient in the production of the above-mentioned products (Faye & Konuspayeva 2012). Additionally, they generally have lower methane emission output than other ruminants, which can also be an advantage in the future (Dittmann et al. 2014).

Although feeding and nutrition are an essential part of any animal production (Celi et al. 2017), camelids seem to be overlooked by scientists, and not much research has been done on this topic, especially in regions outside their traditional distribution (Al-Jassim & Veerasamy 2015).

1.2. Taxonomic classification and characterisation of camelids

The Bactrian camel belongs to the family Camelidae, which can be placed in the sub-order Tylopoda and the order Artiodactyla (McLean & Niehaus 2022). This family is further divided into two separate tribes – the Old World camelids (Camelini) and the New World camelids (Lamini) (Wheeler 2012; Scherer 2013).

The correct taxonomic order of the New World camelid tribe was long debated by the scientific community, but today the consensus is that these groups consist of two genera – *Lama* and *Vicugna* (McLean & Niehaus 2022).

Genus *Lama* is represented by two species. The first one is the guanaco (*Lama guanicoe*), which is the larger species of wild South American camelids. The second species of this genus is the llama (*Lama glama*) which is the larger domesticated New World camelid (Wheeler 2012).

Genus *Vicugna* also consists of two species, the wild one being the vicuña (*Vicugna vicugna*). This species went almost extinct due to overhunting for its high-quality fibre. The domesticated relative of the vicuña is the alpaca (*Vicugna pacos*) (Wheeler 2012).

The tribe Camelini or the Old World camelids consists of three species. The dromedary (*Camelus dromedarius*), the Bactrian camel (*Camelus bactrianus*), and the wild Bactrian camel (*Camelus ferus*) (MacKay et al. 2022, Ming et al. 2022).

The dromedary, known as the one-humped camel, is used today primarily as a dairy animal and its popularity is on the rise because of the suspected health benefits of its milk (Tibary & El Allali 2020). These animals create approximately 95% of the Old World camelids population around the world and their population size is still on the rise due to the intensification of their production systems (Sazmand et al. 2019). According to Sazmand et al. (2019), these populations are spread across forty-seven countries with the most important being Somalia, Sudan, Niger, Kenya, Chad, Mali, Mauritania, and Pakistan (Abri & Faye 2019). Dromedaries were also imported into Australia at the end of the 19th century, later being released into the wild and the population becoming feral. Today they are considered pests and are being captured for the growing Australian camel meat industry or trading with the states of the Arabian Peninsula (Burger & Faye 2019).

The domestic Bactrian camel can be found mainly in central Asian countries (Dioli 2020; Ming et al. 2016). Due to its similarity to the wild camel, it was long thought that the wild camel is an ancestor of the domesticated Bactrian camel (Faye 2022). Many genetic studies today show that these two animals are separate species (Ji et al. 2009, The Bactrian Camels Genome Sequencing and Analysis Consortium 2012, Mohandesan et al. 2017). According to the IUCN, the wild camel is marked as critically endangered, and its population is decreasing. Small populations can be found in China and Mongolia (Hare 2008). Their numbers are decreasing due to habitat fragmentation, climate change, overhunting (Yang et al. 2019), and even as a result of hybridization with domestic camels (Zhang 2019). According to Zhang et al. (2019), the inbred individual may be less resistant to climate conditions and thus endanger the entire population due to outbreeding depression, which is a fundamental problem because of the small numbers of wild individuals. Jemmett et al. (2022) also suggest that the name “wild Bactrian camel” should not be used since the word Bactrian refers to the potential place of domestication of *C. bactrianus* and thus has nothing to do with the species of *C. ferus*.

The Bactrian camel is a large ruminating herbivore, with many specific characteristics compared to more common livestock. Bactrian camels can weigh up to 1,520 kg (Bravo 2015) and they are generally stockier than their one-humped relatives. This is because of the area they inhabit – cold desserts and dry steppes (Yam & Khomeiri 2015). Shorter ears and thicker wool are also present in comparison to the dromedary (Bravo 2015). Another difference between the two species can be seen in males during the breeding season. Although males of both species exhibit obvious signs of a rut, only males of dromedaries show so-called “dulla” – extrusion of the soft palate (Nath et al. 2016).

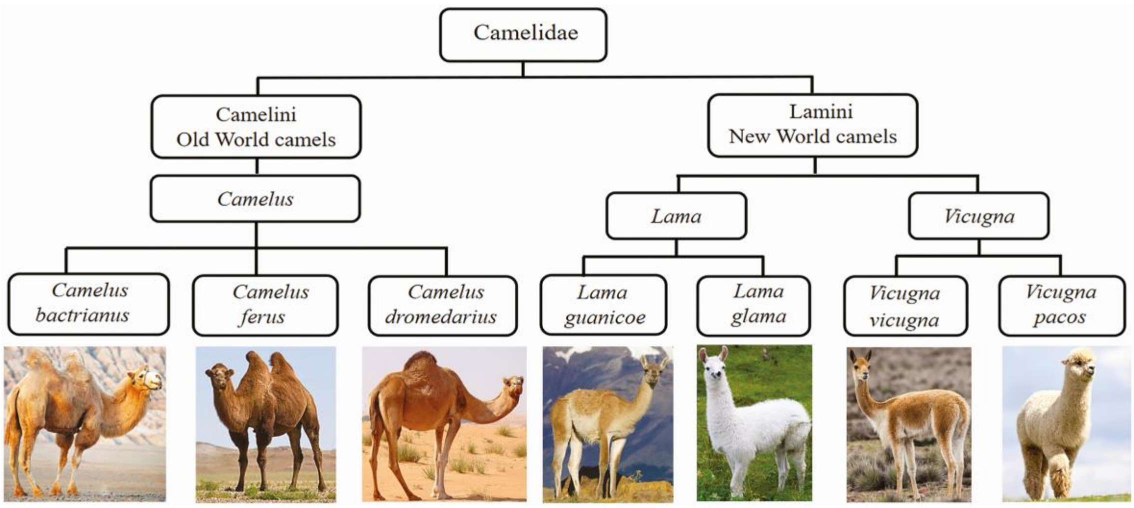

Figure 1: Taxonomy of the family Camelidae (Ming et al. 2022)

1.3. Utilization, and adaptations of camels

The Bactrian camel is an animal admirably adapted to arid and semi-arid conditions. Due to this fact, its importance as a livestock animal in these areas is indescribable (Ming et al. 2016). Despite the size of these animals, they were used for hundreds of years by the local communities because of their relatively docile nature. They were used as transport animals across the vast land of the Gobi Desert (Bai et al. 2021) and were also an important part of the trade along The Silk Route (Yam & Khomeiri 2015). Even though their historical importance as a transportation tool is indisputable, today they are mainly utilized for their meat, milk, or wool (Ming et al. 2016).

Camel meat is traditionally consumed in areas of camel's presence. In China, this meat is usually perceived as tough. The toughness of the meat can be explained by the age of the slaughtered animal as Si et al. (2022) mention. When slaughtered at the right age, the meat quality characteristics are similar to beef (Kadim et al. 2008). Camel meat is said to be lean, high in protein, and low in cholesterol which makes it a healthy source of protein (Kadim et al. 2014). The chemical composition of dromedary camel meat was described by Abdelhabi et al. (2012) as follows: 76–78% water, 19–22% protein, 2.9–3% fat, and 1.2% ash. Even though most research (even above mentioned studies – Kadim et al. 2008, Kadim et al. 2014, Abdelhabi et al. 2012) were done on *Camelus dromedarius*, Si et al. (2022) analysed these properties of Bactrian camel meat, and the chemical composition correlates with studies on dromedaries.

Camel milk was always an important source of nutrients in arid areas as it contains all the same nutrients as bovine milk. Most of the research is again focused primarily on the dromedary camel (Zhao et al. 2015). Zhao et al. (2015) also speculate that this is mainly due to the low milk yield of Bactrian camels. The observed yield of Bactrian camel ranges from 0.25 to 5.0 kg a day (Zhang et al. 2005; Park & Haenlein 2006). Dromedary camel milk consists of protein – 3.96%; lactose – 4.50%; fat – 5.32%; ash – 0.83%; total solids –14.52% (Zhao et al. 2015), but a study by Konuspayeva et al. (2009) suggests that Bactrian camel milk specifically is lower in lactose and higher in protein, fat and total solids than dromedary milk. Researchers suggest that camel milk can offer many health benefits including the prevention of diabetes, Crohn’s disease, immune disorders, cancer, and more (Kaskous 2016).

The wool of Old World camelids is generally of lower quality than the wool of New World camelids. Bactrian camels produce more and better quality wool than dromedary camels (Yam & Khomeiri 2015). The fine down (velli), sometimes called camel cashmere, is characterised by fluffiness, softness, smoothness, delicacy, and durability (Bai et al. 2021). The wool can then be used for mattrasses, quilts, and padded cloths (Yam & Khomeiri 2015).

Bactrian camels were utilised for the above-mentioned purposes thanks to their unique adaptations to their environment, where the husbandry of other livestock animals can be difficult (Bai et al. 2021).

The first adaptation worth mentioning is camel’s feet. This adaptation gave the name to the whole sub-order Tylopoda, in Greek meaning “padded feet” (König et al. 2014). As the name suggests, the whole sub-order has a unique feet structure. They are even toed with almost square feet that are covered in broad, flat, soft, leathery, and elastic pads (Geer 2008; Tabbaa 2012; Fesseha & Desta 2020). Two-finger nail-like toenails are located on each foot and a web can be found between these two toes (Geer 2008; Fesseha & Desta 2020). This feet-structure allows them to walk in terrains that other ruminants would not be able to. Primarily, it allows them to walk on the sand as it disperses their weight on a larger area (Fesseha & Desta 2020).

Similar pads can also be found on various parts of the body, such as the sternum, elbows, carpals, tarsals, and stifles (Geer 2008). These pads allow camels to rest on hard surfaces for extended periods of time (Khan et al. 2003).

Red blood cells (erythrocytes) also play a significant role in the adaptability of the Bactrian camel. Camel erythrocytes are elliptical unlike the biconcave shape of erythrocytes of many other mammals (Adili et al. 2013). The number of erythrocytes in camels is higher than in other mammals (Fowler 2010) and as Adili et al. (2013) mention the red blood cell count is higher in Bactrian camels than in dromedaries, most probably because Bactrian camel erythrocytes are smaller in size. Camel erythrocytes have a long axis that is oriented in the direction of blood flow. This characteristic makes it possible for blood to pass through small capillaries, which is important for keeping regular blood flow during dehydration when the viscosity of blood increases

(Fowler 2010). Erythrocytes of camelids are also resistant to osmotic lysis and deformation (Adili et al. 2013). This allows camels to drink substantial amounts of water in one session without having any osmotic problems as erythrocytes can swell up to 240% of their original size without bursting (Fowler 2010).

Kidneys also play an irreplaceable role in the camel's ability of water retention due to their ability to produce concentrated urine. The anatomy and structure of kidneys are almost identical in dromedaries and Bactrian camels (Li et al. 2020). The camel's kidneys are smooth, multilobar, and bean shaped. In general, kidneys must have a certain anatomical structure to be able to produce concentrated urine in the way camels do (Abdalla 2020; Li et al. 2020). Li et al. (2020) mention that the medullary/cortical thickness ratio is the most important characteristic in the ability to create concentrated urine. A high value of this ratio indicates higher osmotic pressure, which later produces more concentrated urine.

Another key adaptation of these animals is their fluctuating body temperature. This mechanism allows them to preserve water from not sweating in hot temperatures. Their body temperature can vary between 36.5° C to 42° C (Bravo 2015).

1.3.1. Metabolism and the digestive system of camels

The metabolism of the Bactrian camel is admirably adapted to the harsh conditions of its natural environment. In these environments, food sources can be scarce, so camels have two main strategies for dealing with famine periods (Guo et al. 2021).

The first strategy is the well-known storage of fat in the hump and abdomen. This fat serves as a reservoir of energy (Guo et al. 2019). When a shortage of feed occurs, this fat is broken down into energy and fatty acids are mobilised. The unique anatomy and placement of this subcutaneous fat storage are thought to be connected to thermoregulation. As the hump is placed further away from the rest of the body it allows for the heat to be dispersed (Zwick et al. 2018).

The other way of dealing with hunger is by slowing down their metabolic rate (Guo et al. 2021).

The mouth cavity can be seen as the start of the digestive tract. Camelids have unique lips. The upper lip is divided by a labial cleft. Both parts are independently movable thus helping them to investigate and pick vegetation (Fowler 2010). The lower lip hangs loose (Al-Ani 2004). The dental formula for camels is incisors 1/3, canines 1/1, premolars 3/2, molars 3/3 and it is identical in the dromedary and the Bactrian camel. The upper incisor is moved caudally, and the first upper and lower premolar is moved anteriorly, becoming caniniform (Bravo 2015). These caniniform teeth and canines are generally large in males (Martini et al. 2018). Camel's teeth are hypsodont, this can also be counted as an adaptation to the abrasive nature of the vegetation they feed on (Semprebon & Rivals 2010). They do not use their tongue to recognize feed, therefore when given mineral blocks, camels tend to mostly chew on them rather than lick them (Fowler 2010). Many salivary glands producing a large amount of saliva are present in camel's mouths, helping them to consume drier feed (Qureshi et al. 2019).

The stomach part of the digestive system of camelids is one of the main differentiations from taxonomic ruminants. The true ruminant stomach is described as having four chambers, whereas the camelid stomach only has three chambers (He et al. 2018). These chambers or compartments are named C-1, C-2, and C-3 and they are not analogous to the four compartments of typical ruminants (Wang et al. 2000; Bravo 2015). Therefore, camelids are sometimes described as pseudo-ruminants. The C-1 compartment is divided into cranial and caudal parts by a transversal muscular ridge (Sahoo 2020). It is the main location for fermentation and stratification of the feed, similar to the rumen in true ruminants. Compared to the typical ruminant rumen, the C-1 is not papillated, but it contains sacculated areas that have no analogical structure in true ruminants (Perez et al. 2016). There are two areas with these glandular sacs in the C-1 compartment. The first one is called the cranial glandular sac area and the caudal glandular sac area (Engelhardt et al. 2007). The C-2 compartment is conjoined to C-1 and is relatively small (Sahoo 2020) and it also has sacculated area, named the third glandular sac area. These unique glandular sacs are said to have a role in the digestion of cellulose, as camels are more effective in its digestion compared to other ruminants (Engelhardt et al. 2007). The C-2 compartment is said to be similar to the reticulum as the separation of feed particles according to their buoyancy takes place here (Perez et al. 2016). The C-3 compartment is a long, tube-like ventricle, which is attached to the C-2 (Sahoo 2020). It re-absorbs substantial amounts of fluid, similar to the omasum (Perez et al. 2016). This compartment can be separated into a proximal and a distal part (Sahoo 2020), where the distal part merges into the HCl-secreting part (hind stomach), without any visible separation from the outside (Vater et al. 2021).

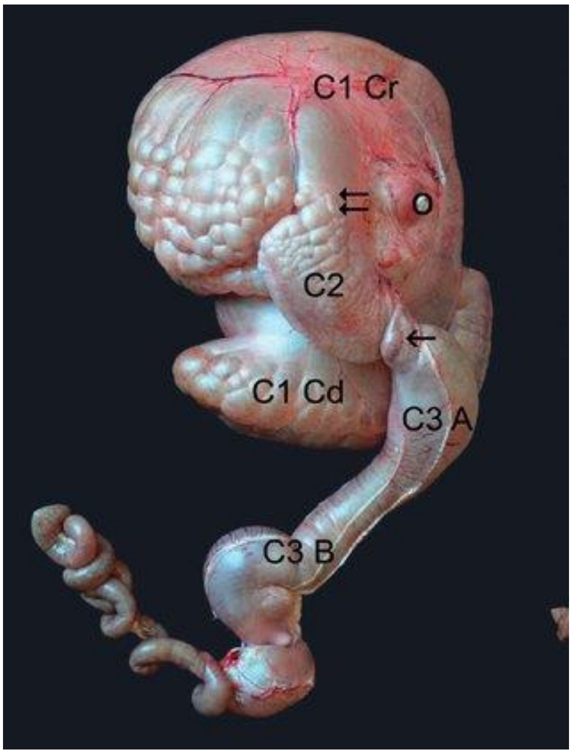

Figure 2: Camel stomach (Perez et al. 2018) - ■ C1 Cr: Cranial part of C-1 ■ C1 Cd: Caudal part of C-1 ■ C2 ■ C3A: Proximal part of C-3 ■ C3B: Distal part of C-3 ■ O: Ostium cardiacum ■ Double arrow: Position of the orifice between C1 and C2 ■ Arrow: Position of the orifice between C2 and C3A

The length of the small intestine is reported to be around 56 m (converted from 184.5 ft) in adult one-humped camels. This measurement is comparable to cattle, where the length of the small intestine is around 40 m (converted from 130 ft). The larger area of the small intestine is most probably correlated to better absorption of nutrients (Qureshi et al. 2019).

The length of the large intestine is also bigger than in other ruminants. The length in camels is reported to be 18 m (converted from 60.3 f) whereas in ruminants it is reported to be about 14 m (converted from 46 f). As the large intestine is the main area for the reabsorption of water, this length difference is thought to be connected to the camel’s ability to conserve water (Qureshi et al. 2019).

1.4. Feeding behaviour and dietary requirements of camels

Camels are foregut fermenters and browsers but can adapt to grazing conditions. Generally, camels are considered to be browse-dominant mixed feeders (Semprebon & Rivals 2010). Martini et al. (2018) suggest there are differences in the feeding behaviour of dromedaries and Bactrian camels. They base their assumptions on their findings of differences in cranial anatomy. Their research showed that the skull of the Bactrian camel is more adapted for grazing conditions than the anatomical features of the skull of dromedaries.

Figure 3: Bactrian camel browsing in Prague Zoo (Pešková 2022)

Camels can generally survive on a much lower-quality diet, due to their adaptation to harsh environments (He et al. 2018). They can consume a variety of fodder plants not excluding shrubs, thorny and salty bushes and even aromatic plants, which are usually avoided by other livestock (Sahoo 2020). Tolerance to the high salt content in vegetation is another speciality of camels. Their dietary intake of salt can be eight times higher than in sheep or cattle and despite that, these animals do not develop hypertension (Hasi et al. 2018). This tolerance is the reason these animals are willingly consuming salt-tolerant plants, such as species from families

Chenopodiaceae, *Compositae* and *Leguminosae* (He et al. 2018). It also allows them to drink salt water (Hasi et al. 2017).

They can sustain themselves on a diet that is very low in crude protein, this circles back to their ability to utilise urea present in the body more efficiently than other livestock (Qureshi et al. 2019).

Under traditional rearing systems camel's diet changes according to the season. They select a feed from many different types of vegetation (Al-Jassim 2019). As camels tend to browse more than other livestock, they are usually no competition for them. Additionally, their long necks and legs allow them to reach plant material that is not available to other livestock (Faraz et al. 2019). Khaskheli et al. (2020) mention that camels can consume up to 12.5 kg of dry matter a day and can move up to 70 km a day to find suitable vegetation. They also mention that daily intake can go up to 4% of their body weight. A standard daily intake is between 1% to 2% of body weight (Bravo 2015). Camels tend to cover a larger area when foraging rather than fully focusing on one place at a time. They tend to avoid feeding during the warmest hours of the day (Khaskheli et al. 2020) and according to Khademi (2017), camel calves start to fully forage at the age between one and three months.

Mengli et al. (2006) followed Bactrian camels in the Mongolian desert and found that even though camels were utilising a variety of species throughout the year, they mainly depended on the shrub *Haloxylon ammodendron*. They also mention that the animals tended to switch to more herbaceous species even when shrubs were readily available. Suggesting a bigger preference for these annual plants. On the other hand, they mention the potential problem of competition with other species that depend on these plants too. A remarkably similar phenomenon was described in a study by Abaturov et al. (2019). They followed free-ranging camels, and they report that when herbaceous plants were available, the camels preferred them. Especially in the spring when these grass-like plants made up almost 80% of the diet.

In general, camelids do not have any unique dietary requirements (Bravo 2015) and the requirements of all the camelid species are said to be similar (Fowler 2010). Fowler (2010) also mentions that not that many studies have been done to establish the nutritional requirements of camelids and many used guidelines are derived from studies done on cattle or sheep. Stating that due to the higher efficiency of camelids' digestion, these may not be correct.

Al-Jassim (2019) provides new calculations of dietary requirements for camels. These calculations were done for the dromedary, but due to the previously mentioned similarity of the camelid species (Fowler 2010), they may be helpful for the Bactrian camel. Daily metabolised energy requirements for maintenance, weight gain and milk production were calculated together with daily crude protein requirements for maintenance (see Appendix 1; 2; 3). More generally, Bravo (2015) states that a maintenance diet should consist of 10% to 14% crude protein and 50% to 55% of total digestible nutrients.

As camels are adapted to lower-quality feed, obesity is a fairly frequent problem in captivity due to overfeeding (Agnew 2018). The risk of obesity is increased when camels have unlimited access to feed (Bravo 2015) or are not allowed to move sufficiently (Fowler 2010).

1.5. Management of camels in captivity

As the popularity of camels grows, the number of animals in captivity all around the world increases too. In 2022 an estimated 38.5 individuals were all around the world, according to FOASTAT (2022). Camels were always moving, but usually in or to places where their adaptations would benefit the local population. In the Western world, camels were mostly limited to zoological gardens. Only in the last thirty years, camel farms are starting to appear across Europe (Faye 2022).

Even though camels are getting more popular, they are still considered a special animal in many Western countries (Faye 2022). For example, in the Czech Republic, private ownership of Bactrian camels is allowed, but the owner must follow certain regulations stated by the law. Potential owners must request permission from the local veterinary service (MACR 2021). Also, the Czech Ministry of Agriculture sets the minimal requirements for housing and other good practices for camel husbandry. This regulation states that the minimal size of pasture for one to three individuals must be minimally 150 m^2, with each additional animal, the enclosure must increase by 25 m^2. The presence of a roofed shelter is required, and it must allow the animals to hide from the rain and snow (MACR 2006). Even though Bravo (2015) states that animals are commonly seen standing or laying in a rain or snowstorm. Where Bravo (2015) and the legislation agree is the fact, that the shelter should provide sufficient protection against wind. It should not be heated, and every animal is supposed to have at least 4 m^2 of space. The terrain in the pasture should be natural soil or sand and objects for scratching should be available (MACR 2006).

As was previously mentioned, historically the majority of camels in the Western world were kept in zoos (Faye 2022) and most Bactrian camels in these zoos are of domestic origin (Agnew 2018). Research is generally not available regarding the topic of the management of these animals in zoos, but some articles focusing on different topics slightly touch on the subject.

A study done by Fowler and Santymire (2022) took place in Lincoln Park Zoo (Chicago, IL, USA) and the authors described local management of Bactrian camels as follows. All four observed animals (one male/three females) were housed together all the time. An outside enclosure and a barn were provided. The outside enclosure had an area of about 836.13 m^2 (converted from 9,000 ft^2) and was accessible only during the day. The exact hours that the camels were locked inside are not mentioned by the authors. Animals were given pellets (Mazuri 5ZF1 Wild Herbivore grain) twice a day and had the option to choose between grass, hay, or alfalfa (not specified if *ad libitum* or at a particular time). Enrichment was provided in the form of leafy green vegetables and browse.

An older study done by Rose et al. (2007) followed two Bactrian camels (male/female) at Twycross Zoo (Atherstone, UK). These animals had access to a grassed outside area, sanded area, hardstand and heated stable. Their movement was limited only during cleaning or veterinary procedures. They had access to grass hay *ad libitum* and were also fed by a mixture of cereals, cattle pellets and bread. During this study, the authors were testing enrichment of these animals and provided branches and logs.

Turnbull et al. (2012) in their research mention, that Bactrian camels observed by them at Southwick Zoo were given grass hay, Canadian alfalfa and trace minerals.

Another group of camels they followed was at Potter Park Zoo and this group was fed by grass hay with alfalfa and high starch pellets.

Connected to management in captivity is the development of stereotypical behaviour. This behaviour can develop in captive animals if their living conditions are sub-optimal. Constant, repetitive and apparently pointless behaviours can be labelled as stereotypy (Mason 1991; Padalino et al. 2014). This type of behaviour was already described in the dromedary camel. It is also mentioned that these behaviours can be associated with so-called feeding frustration, thus highlighting the importance of proper feeding management (Padalino et al. 2014; Aubé et al. 2017). Studies showing improvement after introducing different feeding enrichments have already been done in other species (Fernandez et al. 2008; Roberts et al. 2017; Ridge et al. 2020) and one study done on giraffes (*Giraffa camelopardalis*) also suggest that commented feeding and other guest programmes may lower the stereotypy (Orban et al. 2016).

Connected to all of this is animal welfare. In 2021 the first protocol for assessing camel welfare was published by Padalino & Menchetti (2020). They point out that research is extremely limited when it comes to camel welfare and create detailed protocols from the available literature. This protocol provides many tables with pictures and in-depth descriptions so that the conditions can be easily evaluated.

1.6. Importance of behavioural research

It is clearly visible from previous chapters, that behavioural research, especially considering feeding behaviour is limited when it comes to camels.

Research of behaviour connected to feeding is a topic well-mapped in cattle. The variation in frequencies of feeding and rumination can be a valuable tool for the detection of several diseases (Reynolds et al. 2019). Reduce feeding can be a sign of ruminal acidosis (Owens et al. 1998) and ketosis (Goldhawk et al. 2009), just for example. Reduced rumination can also be a sign of some metabolic disorders (DeVries et al. 2009) and even stress (Schirmann et al. 2011). Thus, as the camel industry is on the rise (Oselu et al. 2022), a similar finding can be a critical asset for correct animal husbandry and effective production.

Moreover, chewing and rumination activities are observed in cattle to non-invasively assess their health status. These measurements can detect deficiencies and assist in the adjustments of feed rations (Zehner et al. 2012). Today, technologies that can measure these data automatically, are being developed for the assessment of correct feeding practices of cattle (Borchers et al. 2016). Rumination is also monitored for the optimization of breeding. Reith et al. (2014) mention that when a dairy cow is in oestrus the time spent on rumination significantly decreases. Similar research could be particularly useful in camels, as fertility is generally considered low (Padalino et al. 2016).

The research on the frequency of defecation and urination was studied in livestock, primarily cattle (Aland et al. 2002; Lainez & Hsia 2004; Hirata et al. 2011; Lee et al. 2012). These studies can help to understand for example the differences in animals in different lactation stages, different housing systems, different feeding systems etc (Lainez & Hsia 2004) or once again detect health issues (Fowler 2010). This research is again limited in camels. Bhakat and Chaturvedi (2004) concluded only that camels defecate more in the night hours and Padalino et al. (2016) compared the defecation frequencies for females in and out of oestrus. To the best knowledge of the author, the topic of defecation and urination frequency was not further studied either in the Dromedary or in the Bactrian camel.

2. Aims of the Thesis

The main aim of this thesis was to develop previous research of the author (Pešková 2021) on the feeding behaviour of the Bactrian camel in the conditions of the Czech Republic. It was designed to describe if several factors (weather, sex, age, feed etc.) had a significant influence on feeding behaviour. Additionally, the previous research (Pešková 2021) formulated a hypothesis, that camels tend to ruminate more in the latter hours of the day, so this research tested this hypothesis on a larger sample of animals.

Another aim of this thesis was to evaluate if the above-mentioned factors had any significant influence on the time spent chewing and the number of bites per mouthful.

Lastly, this thesis aimed to briefly describe defecation and urination frequency in Bactrian camels and tried to evaluate the effect of different factors on these frequencies.

3. Methods

The research took place at three different zoos (Olomouc, Ostrava, Prague) and one camel farm (Záhostice) in the period from the 6th of June 2022 to the 9th of September 2022. A detailed description of each place and time of observations are explained in the following chapters.

Observations were done in six days in each institution, for three days in the morning hours – from 7.00 AM to 2.00 PM, and for three days in the afternoon/evening hours – from 2.00 PM to 9.00 PM (or 7.30 PM). See details in Chapters 3.1 - 3.4. The observations were done by using the scan sampling method where data were recorded every five minutes. The recorded data were as follows:

- Behaviours
    - Feeding = Feed intake, chewing and swallowing
        - The feed was also specified:
            - hay
            - green fodder = mix of cut green forage
            - salt = pure NaCl freely put into a trough
            - mineral block = salt + mineral mixes
            - pasture = feeding on grass growing in the enclosure
            - browse = feeding on bushes/trees in (or around) the enclosure
            - milk = calves suckling
            - concentrate = pelleted premixes
            - carrots = used as treats or during commented feedings
    - Ruminating = regurgitation, rechewing and swallowing
        - The feed was labelled as “mixed feed” due to the inability to distinguish between different feeds during the rumination process
    - Drinking
    - Other activities = behaviours not related to feeding
- The position in which the animal was during the data recording
    - Standing
    - Lying in sternal recumbency
    - Lying on the side
    - Walking
    - Running
- The position of the animal related to the sun
    - Sun = animal is in direct sunlight

- Shade = animal is either in shade during a sunny day or there is no direct sunlight
- Stable = animal is inside a building

During the whole research, the temperature [°C] was taken every ten minutes from the closest publicly available weather station and the general state of the weather was recorded – sunny, partially cloudy, cloudy, foggy, and rainy.

The weather was mostly cloudy (42.79% of the time) during the whole research. Followed by partially cloudy (24.04%), sunny (22.81%), rainy (8.51%) and foggy (1.84%). The average temperatures during these different weather states were as follows – sunny = 23.73°C; partially cloudy = 19.23°C; cloudy = 16.89°C; foggy= 19.48°C; rainy =14.98°C.

Different parts of the day were established according to the time as follows:

- morning – 7.00AM–10.00AM
- forenoon – 10.05AM–11.30AM
- noon – 11.35AM–1.00PM
- afternoon – 1.05 PM–4.00 PM
- early evening – 4.05 PM–7.30 PM
- evening – 7.35 PM–9.00 PM

Thirty animals were observed in total (see Appendix 4). All animals were divided into three age groups, based on the age of sexual maturity (Al-Qarawi et al. 2000; Choubisa 2013).

- calf – up to one year (n = 5)
- sub-adults – up to 5 years (n = 5)
- adults (n = 20)

Age of each animal was counted to the first day of observation. The age was not recalculated for the second observational period in Prague Zoo.

Body condition was also recorded in Appendix 4. This body condition was only visually evaluated by the author and is purely based on the appearance of the animal, without closer inspection.

Hay was the main feed across all institutions during observations (72.05% of all observed feeding), it was followed by pasture (9.07%) and green fodder (8.87%).

Additionally, during the whole observation, when an individual was feeding or ruminating in a well-visible place the number of chews and time of chewing [seconds] were recorded. Other factors such as position, feed, temperature etc. were recorded according to the previous explanations.

Furthermore, as the animals were being observed, their urination and defecation were recorded by the all occurrence sampling method. Every urination and defecation were recorded together with time, part of the day and the name of the animal. These data were not collected in Ostrava Zoo due to a big enclosure and worse conditions for such detailed observations.

3.1. Camel Farm Záhostice

The purpose of the farm is to educate the public about Bactrian camels and llamas. Visitors can book programmes with the animals. During these programmes, they get to pet, groom and ride the animals while the owner is lecturing them about husbandry, feeding and other topics relating to the animals. The farm is also full of educational signs for visitors to read on their own.

The observation at Camel Farm Záhostice took place from the 6th of June 2022 to the 11th of June 2022. For the first three days, the observation took place at the later hours (2.00 PM to 9.00 PM) and the next three days in the morning hours of the day (7.00 AM to 2.00 PM).

The temperature was taken from the weather station Tábor (Wanet s.r.o. 2022).

Nine animals were observed at this institution:

- Šajtan – 17 years old castrated male
- Khán – 14 years old castrated male
- Eda – 9 years old breeding male
- Sába – 11 years old lactating female
- Gejša – 10 years old lactating female
- Gobi – 8 years old lactating female
- Amra – 7 years old female
- Lenka – 0.25 years old female
- Farrid – 0.17 years old female

Two dromedaries and one new-born Bactrian camel were also present in the herd. These three animals were not a part of this study.

The animals had unlimited access to a pasture and a stable. The area of the stable was approximately 87.5 m^2 and the accessible pasture area was around 2,400 m^2. The pasture was enclosed by an electric fence and was practically completely covered by grazable grass. Two automatic drinkers accessible all the time were in the stable. A feeding trough was placed lengthwise along the feed rails inside the stable, its length being circa 16 m with a depth of around 22 cm.

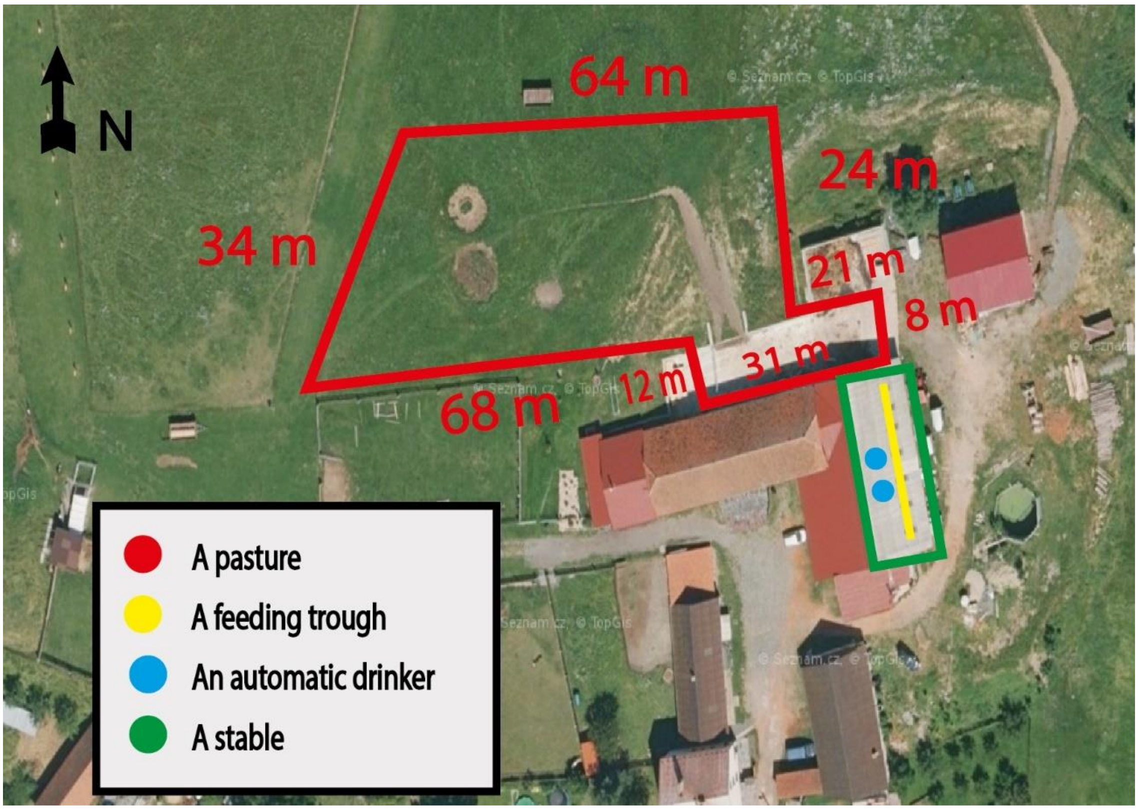

Figure 4: Map of Camel farm Záhostice (Pešková 2023).

The animals were fed hay inside the stable every day. The hay was put into the trough till the trough was full, there was no specific measurement. Furthermore, the animals were given a bucket of concentrated pellets (pellets for livestock produced by local company ZZN Pelhřimov) either into the trough or by the guests during the programme. There were around 1.5 kg of pellets for each animal per day. The time of feeding depended every day on the visitors, but the pellets were always given before the hay and the feeding took place no later than 4.45 PM.

Since visitors can book visits to this farm, the animals are sometimes taken out of the herd to participate in educational programmes. These programmes do not have any specific timing and it purely depends on the agreement with the owner. During my observation time, only one program interfered with the observation. It took place on the 11th of June from 10.20 AM to 2.00 PM and the two castrated males (Šajtan, Khán) were taken away from the herd, so they were not included in data collection at that time.

Cleaning of the stables was done while the animals were freely moving, and they were not manipulated with in any way.

Loose salt (pure NaCl) was put into the feeding trough (4 kg) on the first day of the research. Three mineral blocks were also available all the time for the animals. These blocks were loosely placed in the trough.

3.2. Olomouc Zoo

The observation at Olomouc Zoo took place from the 16th of July 2022 to the 21st of July 2022. The observation took place at the later hours (2.00 PM to 9.00 PM) for the first three days and in the morning hours of the day (7.00 AM to 2.00 PM) for the next three days.

The temperatures were taken from a weather station Olomouc Droždín (Wanet s.r.o. 2022).

Four animals were observed at this institution:

- Lorenzo – 5 years old breeding male
- Eliška – 27 years old female, has arthrosis (can barely stand up) – medicated
- Tereza – 12 years old female
- Masafi – 3 years old female

The animals had unlimited access to an outdoor enclosure and a small stable. The accessible area of the stable was around 28 m^2, and the outdoor enclosure had an area of around 1,250 m^2. A few patches with grazable grass were in the outside enclosure. One automatic drinker was placed outside the stable and was available all the time. The feeding area for hay was placed under an open-sided shelter, feeding area for cut forage was located on stones placed at the edge of the enclosure. Two feeding troughs were also located in the enclosure, but only one of them was used and only for feeding concentrated pellets during a commented feeding.

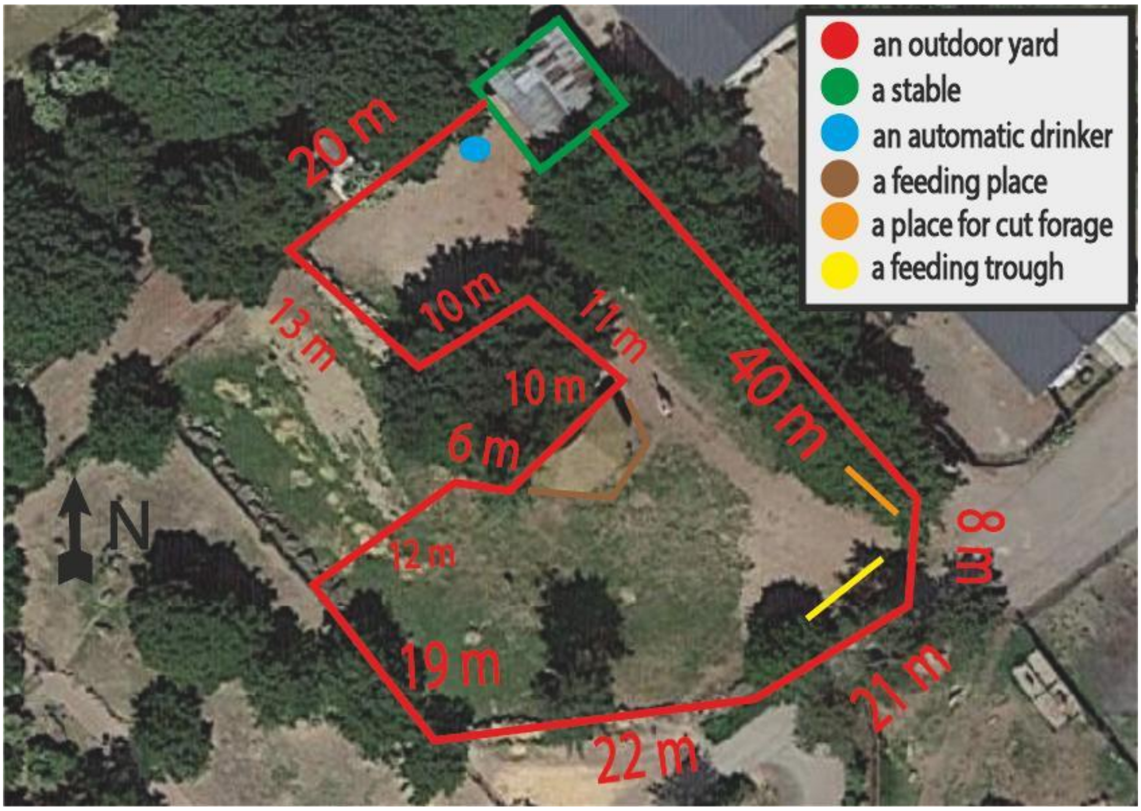

Figure 5: Map of the enclosure at Olomouc Zoo (Pešková 2023).

Animals in the Olomouc Zoo received hay *ad libitum* at the previously mentioned feeding shelter and also in a small amount in the stable. They were fed cut forage – mainly consisting of cut alfalfa, every day around 8:30 AM. This forage was given to them on the rocks mentioned above and they were given two to three large scoops grabbed with a pitchfork. They were given concentrated pellets and oat flakes as a part of an event for visitors called "commented feeding" around noon every day. For each animal, there was 0.5 kg of pellets for ruminants and 0.4 kg of oat flakes. On some days, the animals were also given a bunch of cut branches as a form of adding diversity to their diet.

Cleaning of the enclosure took place every day in the morning hours and the animals were not manipulated with. The zookeepers were cleaning while the animals freely moved around the enclosure.

Two mineral blocks were hung on a rope from the ceiling of the feeding shelter.

3.3. Ostrava Zoo

The observation at Ostrava Zoo took place from the 23rd of August 2022 to the 28th of August 2022. For the first three days, the observation took place at the later hours (2.00 PM to 7.30 PM = shortened due to the zoo management) and the next three days in the morning hours of the day (7.00 AM to 2.00 PM).

The temperatures were taken from a weather station Bohumín which was located closer than any other weather station in Ostrava (Wanet s.r.o. 2022).

Ten animals were observed at this institution:

- Youri – 11.3 years old breeding male
- Spiša – 18.5 years old female
- Polly – 15.17 years old female
- Sněženka – 9.42 years old lactating female
- Flo – 8.5 years old female
- Gioja – 8.25 years old female
- Katniss – 8.3 years old female
- Muf – 1.42 years old male
- Hubert – 0.42 years old male
- Sarah – 0.3 years old female

In Ostrava Zoo, camels have an outdoor enclosure and a stable. The outdoor enclosure in this zoo was the largest one observed, with an area of circa 5,500 m^2. Nearly the whole outside enclosure was covered by grazable grass. The stable provided an area of 200 m^2 with 80 m^2 accessible to the animals. An automatic drinker was placed inside the stable as well as in the outside enclosure, so the water was available all the time. Camels shared this enclosure with a herd of Mongolian sheep (*Ovis orientalis aries*) – circa ten individuals of sheep. Both, the outdoor enclosure and the stable, are available nearly the entire day with a few exceptions. Animals naturally spent the night in the stable even though the whole enclosure was open during the night. Animals were locked inside the stable every day around 9.00 AM and a zookeeper cleaned the whole outside enclosure. The herd was let out of the stable after the cleaning and the stable was cleaned. Once again, the animals were locked inside the stable around 2.00 PM when they were fed concentrated pellets. They were let out of the stable after that and the animals were closed just in the enclosure to stay visible to visitors. The stable was opened around 6.15 PM every day and stayed open during the night.

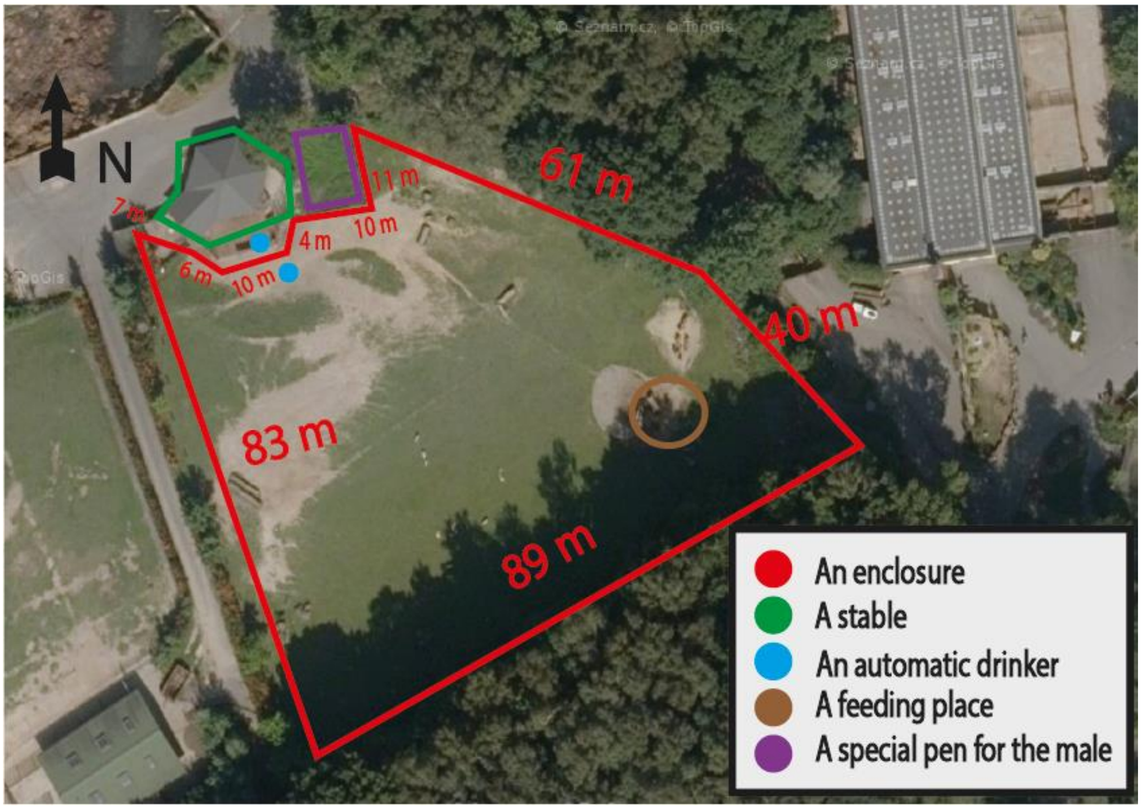

Figure 6: Map of the enclosure at Ostrava Zoo (Pešková 2023).

Camels at Zoo Ostrava were fed by hay twice a day. They were given a huge wheelbarrow of hay which filled the whole feeding place each time. The hay was always placed into the feeding place during the cleaning of the enclosure when camels were locked away. The first feeding took place around 9.00 AM and the second one around 3.00 PM. The animals went straight to the feed after being let out of the stable. They were also given concentrated pellets on a daily basis. Feeding of the pellets took place inside the stable each day between 2.00 to 3.00 PM. During this feeding, females and youth were separated from the breeding male which was placed in a separate little outside pen (circa 92 m^2), so the male did not distract the females. There were 1.5 kg of commercial pellets for ruminants for each animal per day. These pellets were put into buckets placed in the stable. Additionally, on the 25th of August at 3.00 PM commented feeding took place. Only females and youth participated, and they were given alfalfa cubes.

Inside the stable, there were two salt blocks placed on the floor.

3.4. Prague Zoo

The observation was done in two periods in Prague Zoo: 1) At the beginning of summer from the 4th of July 2022 to the 9th of July, when the morning observation (7.00 AM to 2.00 PM) took place for the first three days and the afternoon/evening observation (2.00 PM to 9.00 PM) was done for the next three days; 2) During the late summer from the 14th of September to the 19th of September. The observation was done in the later hours (2.00 PM to 7.30 PM) for the first three days. The time was shortened due to the earlier sunset and the onset of darkness in the enclosure. Further observations took place in the morning (7.00 AM to 2.00 PM) for the next three days.

The temperatures were taken from a weather station Praha – Libeň (Wanet s.r.o. 2022).

Seven animals were observed at this institution:

- Ibrahim – 8.3 years old breeding male
- Sofia – 12.3 years old female
- Sara – 5.3 years old female
- Morgana – 9.17 years old female
- Fidorka – 3.3 years old lactating female
- Margotka – 1.17 years old female
- Hynek – 0.25 years old male

Camels in Prague Zoo had only an outdoor enclosure available during both observations. The stable was closed, and the animals could not enter it. The area of the enclosure is approximately 2,500 m^2. The enclosure was mainly covered by dirt, sand and rocks, only places with grazable grass were along the fences. The feeding place for forages was situated in the front part of the enclosure, close to visitors. Feed was usually placed there, the exception being when it was raining or there was rain forecasted. In that case, the feed was placed in a manger hung on a wall of the stable where it was partially covered from the rain. There was one automatic drinker available all the time. A feeding trough was also placed in the enclosure but was only used for feeding pellets. Its length is circa 4 m with a depth of around 20 cm. The area for commented feeding was also located in the front part of the enclosure.

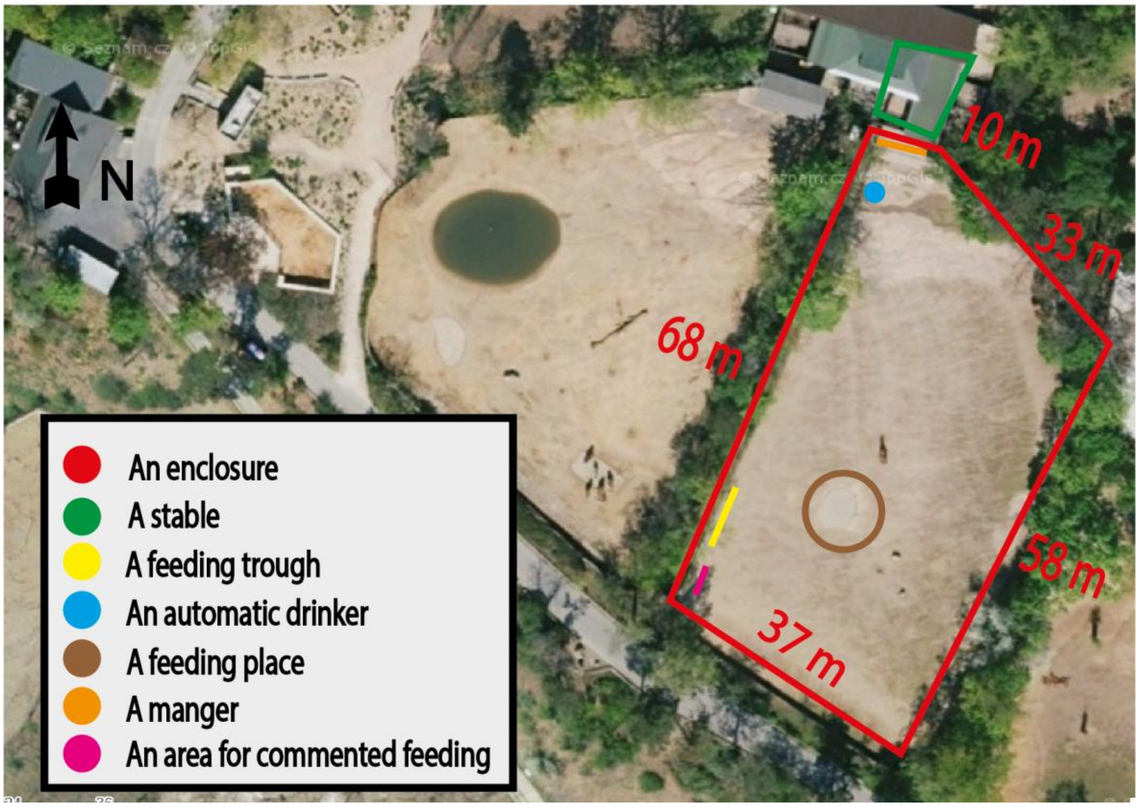

Figure 7: Map of the enclosure at Prague Zoo (Pešková 2023).

Camels in Prague Zoo were fed a few times a day. Each time they were brought a wheelbarrow of hay or cut green forage. They were given three/four wheelbarrows each day. The first one was usually given before 7.00 AM, then the rest was brought in randomly depending on the fullness of the feeding place. However, no feed was brought later than 3.30 PM, because the shift of the zookeepers ended at that time. They were fed only by hay for six days in July. During the observation in September, they were fed by cut green forage except for the day of the 18th of September and the first feeding on the 19th of September when hay was brought to them. Camels in Prague Zoo were also fed with concentrated pellets on a daily basis. The pellets were fed every day before the first hay was brought. There were 2 kg of pellets for each animal per day. Occasionally, they were given a bucket of carrots as a treat from the zookeepers, or they were also given a bucket of carrots when visitors bought commented feeding which took place at 1.30 PM. Commented feeding was observable only during the morning observations and took place on 5 of those 6 days (3 times in July + 2 times in September).

The zookeepers did not manipulate with the animals in any way and cleaning of the enclosure took place with the animals freely walking in the enclosure.

A mineral block was hung on a wall next to the manger. The block itself was put in a “cage” so the animals had to play with it to lick it.

3.5. Data analysis

All collected data were organised into three Excel sheets. The first one was for the records of scan sampling, the second one is for the number of bites and chewing times and the third one is for urination and defecation. All data were analysed in the statistical software STATISTICA (TIBCO Software Inc., version 14). All data collected from scan-sampling and chewing were assumed to be normally distributed (due to a large quantity); thus, only parametrical tests were used.

Frequency tables were the main used analysis in the scan sampling dataset. Frequency tables were then followed by a calculation of Pearson’s chi-squared test to see if the differences were statistically significant. This method was used to establish if there are differences in the frequencies of behaviours dependent on different factors, those being the institution, weather, part of the day, age group and sex of the animals. A frequency table followed by Pearson’s chi-square test was also used to determine if the presence of sun and shade changed the frequency of the behaviour, but for this analysis, only records with weather marked as sunny and partially cloudy were chosen, as those are the only records where animals had the choice between direct sun and shade. It was also used to see if the occurrence of positions differed for distinct behaviours. One-way ANOVA followed by Tukey HSD test was used to calculate if there was a difference between the average temperatures for every behaviour.

One-way ANOVA and Student’s T-test were the two most used analyses for the number of bites and chewing times since they contained quantitative data. Student’s T-test for independent groups was used to determine if the average number of bites and average chewing times in seconds significantly differed for feeding and rumination. Additionally, the difference in the average number of bites and average chewing time during feeding was compared based on the type of feed, also done by Student’s T-test for independent groups. Averages for feeding and rumination were then compared, using one-way ANOVA followed by Tukey HSD test, based on different factors, those being institution, part of the day, age category, sex and health status of the animal. The relationship between temperature and the number of bites, as well as chewing time, was tested using a Linear regression model.

Lastly, the urination and defecation data were analysed by frequency table and followed by Pearson’s chi-squared test. This analysis was done to find the frequencies of defecating/urinating in different parts of the day. Furthermore, these data were tested for normality due to their lower amount. The Kolmogorov-Smirnov and the Shapiro-Wilk tests of normality were used, and all confirmed the normal distribution of these data ($p > 0.05$), thus parametrical tests were also used for these data. One-way ANOVA was used to determine if the institution, body condition and age group affected the average daily frequency of defection and the average daily frequency of urination. The analysis of feed/water intake was not suitable for this research, as the retention time of camels can be up to 72 hours (Qureshi et al. 2019).

The significance level was accepted at a p-value lower than 0.05 for all analyses.

4. Results

4.1. Feeding behaviour – scan-sampling data

4.1.1. General description of the scan-sampling data

Altogether, 17,952 records were collected over 201 hours of observations. From these records, 9,992 of them were of other activities not related to feeding. 5,724 of those records were of feeding, 2,092 of rumination and 108 of drinking. 36 of those records were marked as "programme" due to animals being taken away at Camel Farm Záhostice.

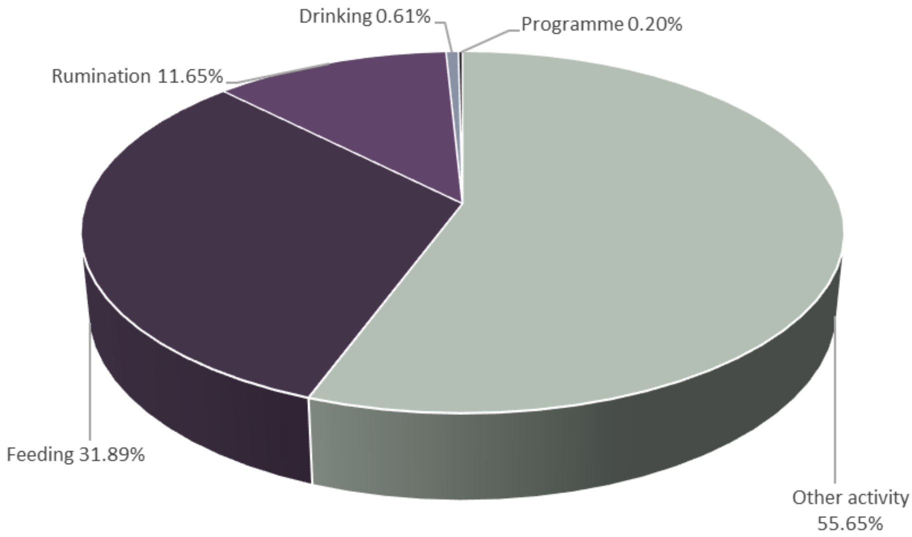

Figure 8: Percentage distribution of behaviour (Pešková 2023).

4.1.2. Factors affecting feeding behaviour

A statistically significant difference was found in the distribution of behaviour in the four **different institutions** (Pearson's chi-squared test: df =12, $p < 0.001$). An interesting result can be seen in Table 1 – Prague camels had the highest frequency of feeding (37.80%) compared to camels in Záhostice, Olomouc and Ostrava (28.26%; 24.71% and 29.98% respectively). On the other hand, their time investment into rumination (6.55%) was visibly lower than that of camels in Záhostice, Olomouc and Ostrava (16.95%; 12.75% and 13.40% respectively).

Table 1: Percentage distribution of behaviour in different institutions (Pešková 2023).

	Other activity [%]	Feeding [%]	Rumination [%]	Drinking [%]
Camel Farm Záhostice	53.18	28.26	16.95	0.83
Prague Zoo	55.00	37.80	6.55	0.65
Olomouc Zoo	61.96	24.71	12.75	0.59
Ostrava Zoo	56.29	29.98	13.40	0.33

A significant difference was found between **positions** during different behaviours (Pearson's chi-squared test: df=12, $p < 0.001$). Altogether, animals were observed mostly standing (63.25%). Standing was also the preferred position for feeding (in 96.30% of cases of feeding). On the other hand, rumination mainly took place while the animals were lying in sternal recumbency – 68.93% of all observed ruminations. Drinking was omitted from the following table as it logically took place while standing in 100% of collected records. The rest of these results are shown in Table 2. A statistically significant difference can also be seen between positions when considering only feeding and ruminating (Pearson's chi-squared test: df =3, $p < 0.001$).

Table 2: Frequencies of positions (Pešková 2023).

	Standing [%]	Lying on sternum [%]	Lying on the side [%]	Walking [%]	Running [%]
All behaviours	63.25	27.22	8.04	1.48	0.01
Feeding	96.30	3.02	0.19	0.68	0.00
Rumination	30.16	68.93	0.00	0.72	0.00

Results suggest that **temperature** significantly influenced the behaviour of camels (ANOVA: $F(3,17912)=23.728$; $p < 0.001$). The average (±SE) temperature during feeding was significantly lower than during rumination (Tukey HSD test; $p < 0.001$; 18.42±0.07°C vs. 18.96±0.11°C, respectively). The average (±SE) temperature during feeding was also significantly lower than the average (±SE) temperature during other activities (Tukey HSD test; $p < 0.001$; 18.42±0.07°C vs. 19.15±0.05°C, respectively). These differences can be seen in Figure 9.

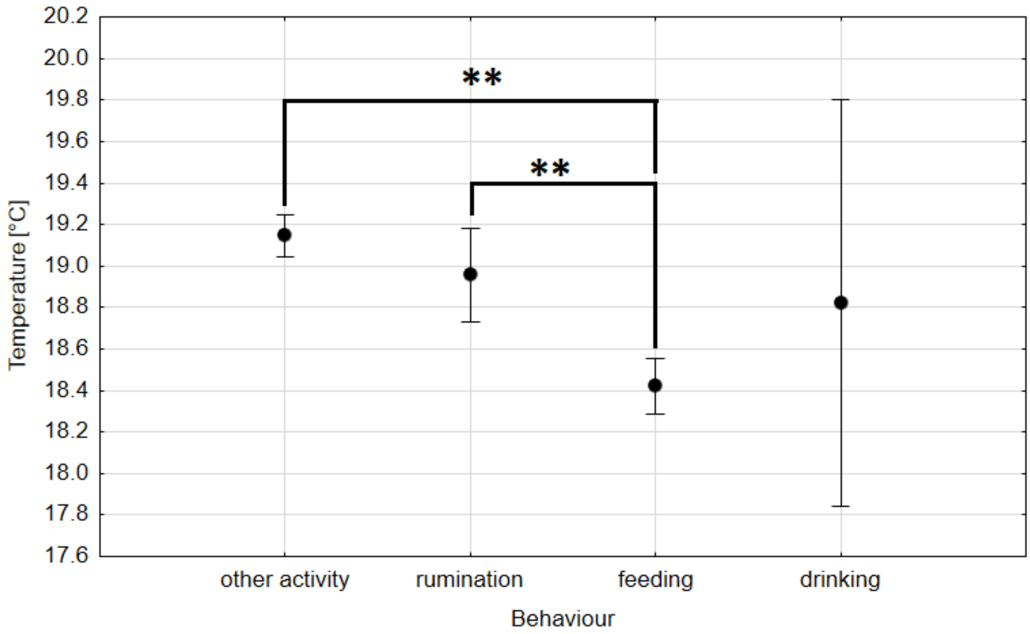

Figure 9: Average temperatures during different behaviours; vertical bars denote a 0.95 confidence interval; ** indicates a $p < 0.001$ (Pešková 2023).

This research implies that the frequencies of different behaviours were influenced by **the weather** (Pearson's chi-squared test: df=12, $p < 0.001$). As seen in Figure 10, feeding was more prevalent during rainy and foggy weather (40.52% and 41.82% out of all activities, respectively). In comparison, animals spent the least amount of time by feeding during sunny weather (23.12%). On the other hand, rumination was observed the most during sunny weather (15.51% out of all activities). Activities not related to feeding behaviour were also observed the most during sunny weather (60.73%).

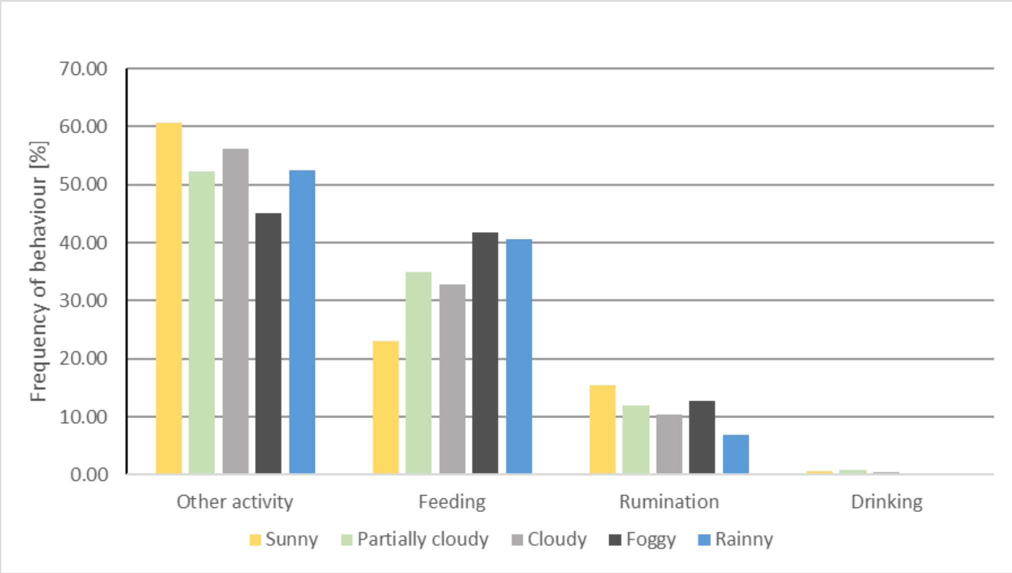

Figure 10: Frequencies of behaviour in different weather (Pešková 2023).

A difference was found between the frequencies of behaviour and the **presence of sun or shade** (Pearson's chi-squared test: df=3, $p < 0.001$). When given the choice animals spent a slightly bigger part of the time in the shade (51.32%). Rumination and drinking were also observed mostly in the shade (57.24% and 63.64%, respectively). On the other hand, feeding was observed more in direct sunlight (53.41%) as shown in Table 3.

Table 3: Frequencies of behaviour dependent on the sun (Pešková 2023).

	Shade [%]	Sun [%]
The total frequency of occurrence	51.32	48.68
Feeding	46.59	53.41
Rumination	57.24	42.76
Drinking	63.64	36.36

A statistically significant difference was also found in the frequencies of different behaviours in **different parts of the day** (Pearson's chi-squared test: df=15, $p < 0.001$). Table 4 shows that the least number of behaviours connected to feeding were observed in the evening and during noon (35.74% and 31%, respectively).

The morning was part of the day with the highest frequency of behaviours connected to feeding (52.42%).

Table 4: Frequencies of behaviours in different parts of the day (Pešková 2023).

	Other activity	Feeding	Rumination	Drinking
Morning	47.58	38.59	13.03	0.80
Forenoon	50.56	38.39	10.09	0.96
Noon	68.32	12.36	19.07	0.25
Afternoon	55.06	34.39	9.89	0.66
Early evening	58.45	32.30	8.79	0.45
Evening	64.26	20.46	15.00	0.28

When other activities were omitted from the analysis, a significant difference was found between the frequencies of feeding behaviour in different parts of the day (Pearson's chi-squared test: df=10, $p < 0.001$). As shown in Figure 11, feeding itself was the main feeding behaviour in every part of the day except at noon (19.07%). Feeding was observed the most during the forenoon and early evening (77.64% and 77.75%, respectively). During noon, the animals were mainly observed ruminating (60.19%). Rumination was also observed more frequently in the evening (41.97%).

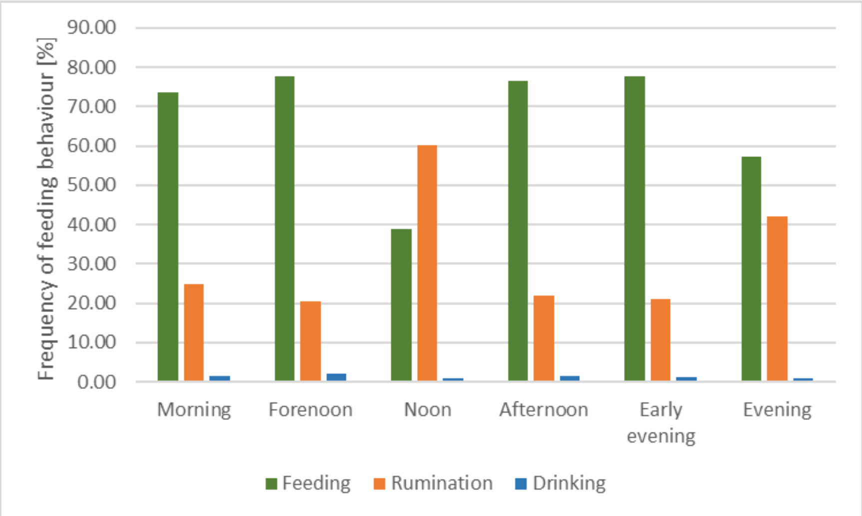

Figure 11: Frequency of feeding behaviour in different parts of the day (Pešková 2023).

A statistically significant difference was found when comparing behaviour frequencies based on **age groups of animals** (Pearson's chi-squared test: df=6, $p < 0.001$). Sub-adult animals were feeding the most often (42.72%) and, contrarily, ruminating the least often (42.72% and 8.95%, respectively). All of the frequencies for other age groups can be seen in Table 5.

Table 5: Frequencies of behaviour based on age group (Pešková 2023).

	Other activity	Feeding	Rumination	Drinking
Adults	57.80	28.80	12.79	0.60
Sub-adults	47.42	42.72	8.95	0.91
Calves	57.42	31.92	10.42	0.24

When these age groups were divided into **different sexes**, a significant difference was also found (Pearson's chi-squared test: df=18, $p < 0.001$). As seen in Figure 12, sub-adult females were feeding most frequently, followed by sub-adult males (44.92% and 37.16%, respectively). Sub-adult females were also the group that ruminated least frequently during the observation (6.96%). On the contrary, rumination was most frequently observed in castrated males (20.43%).

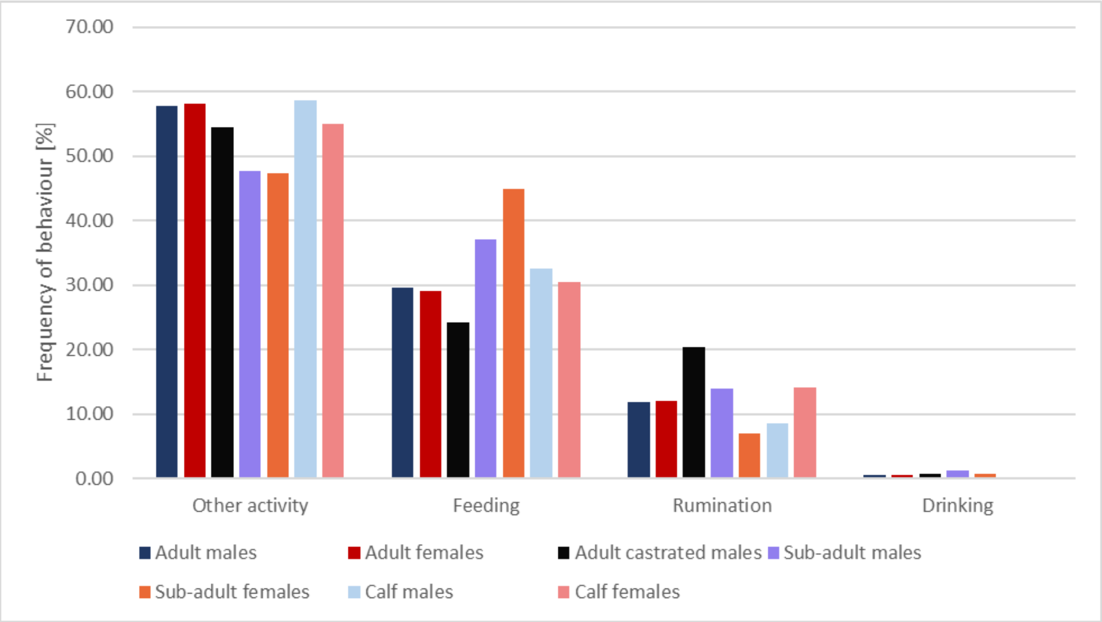

Figure 12: Frequencies of behaviour divided by age group and sex (Pešková 2023).

Likewise, a statistically significant difference was found between the frequencies of behaviour (Pearson's chi-squared test: df=6, $p < 0.001$), when only adult animals were considered.

4.2. The number of bites and chewing time

637 records of the number of bites and chewing time were recorded during the observation. Out of these, 444 records were of feeding and 193 records were of ruminating.

4.2.1. General description of the number of bites and chewing time

While feeding, the average (±SE) the number of bites was 19.77 (±0.38) and the average (±SE) chewing time was 18.73 (±0.37) seconds. During rumination, the average (±SE) number of bites was 30.65 (±0.72) and the average (±SE) chewing time was 30.33 (±0.64) seconds. These results are visualised in following Figure 13. The average number of bites and the average chewing time during feeding were significantly lower than during rumination (t-test, df=635, $p < 0.001$ for both). By a simple calculation (average number of bites/average chewing time), the average chewing speed was obtained. The average speed during feeding was 1.06 bites per second and during rumination, it was 1.01 bites per second. Out of these, the average chewing rate could be obtained by multiplication by sixty. After this calculation, the average chewing rate of 63.3 bites per minute for feeding and 60.6 bites per minute for ruminating was calculated.

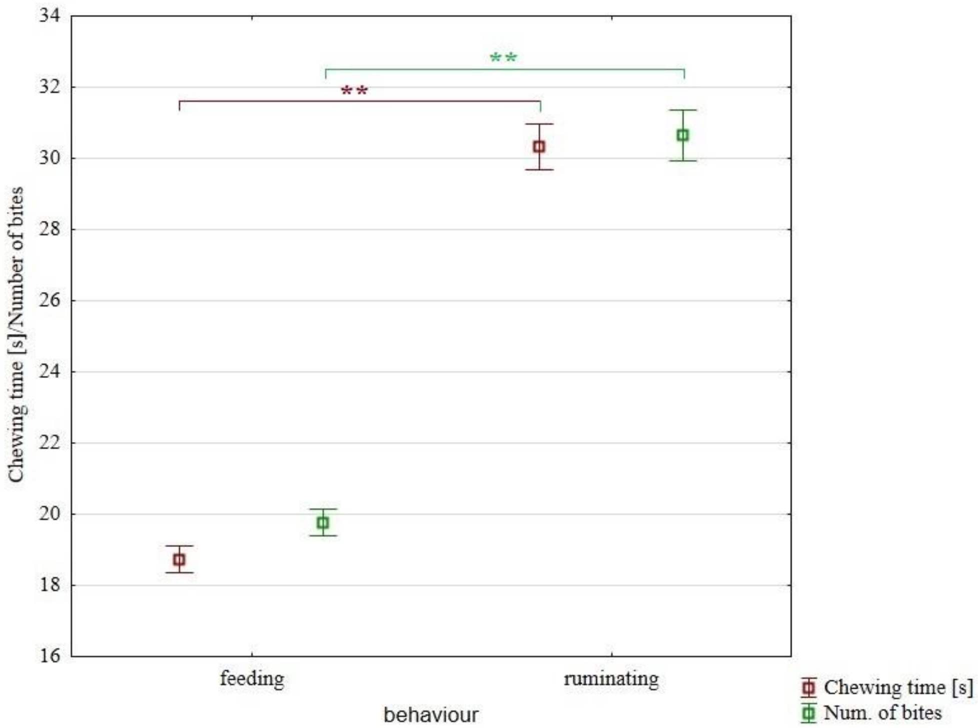

Figure 13: Average number of bites and chewing time; vertical bars denote ±SE; ** indicates a p < 0.001 (Pešková 2023).

4.2.2. Factors affecting the number of bites and chewing time

The number of bites and chewing time during feeding were also compared based on a **different feed**. The average (±SE) number of bites was higher when animals were fed by hay compared to green fodder (20.06 ±0.42 vs. 18.09±0.70, respectively), but no significant difference was detected between these two averages (t-test, df=442, $p > 0.05$), even though a difference is clearly visible in Figure 14. However, the average (±SE) chewing time was significantly higher when hay was fed rather than when green fodder was fed (t-test, df=442, $p < 0.05$; 19.17±0.42 vs. 16.25±0.71, respectively).

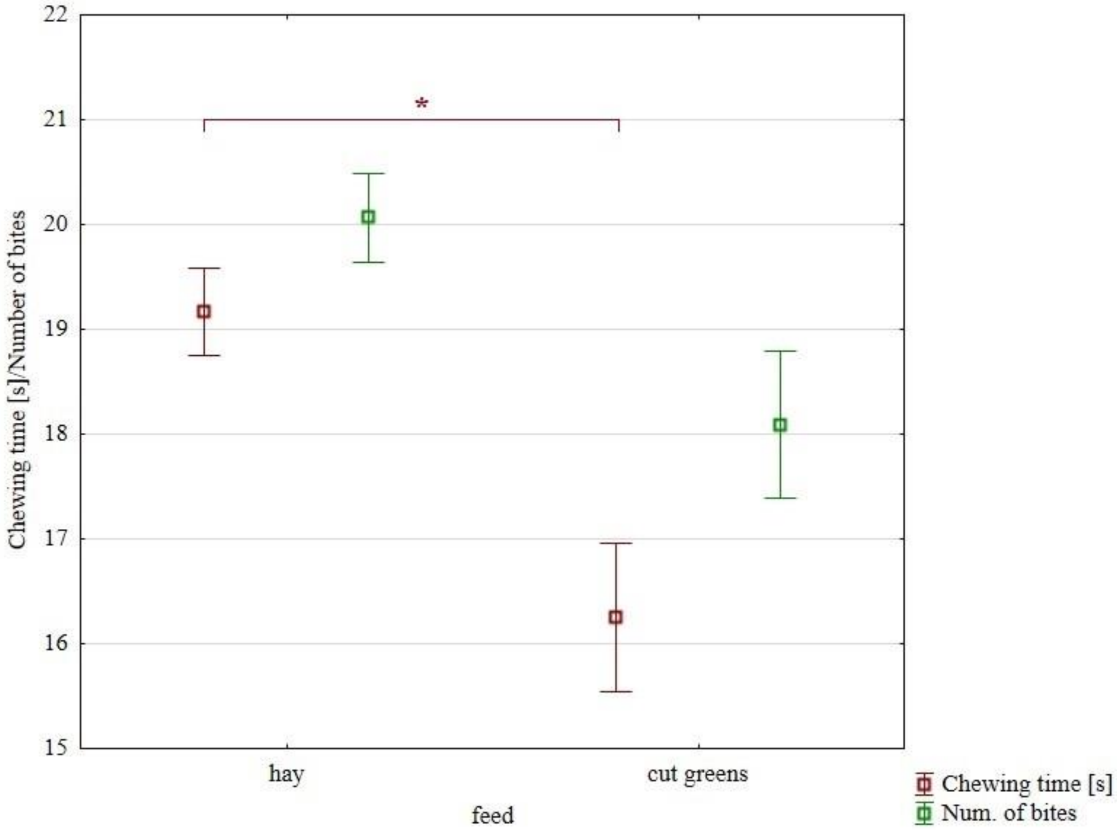

Figure 14: Average number of bites and chewing time for different feed; vertical bars denote ±SE; * indicates a p-value <0.05 (Pešková 2023).

The average (±SE) the number of bites and the average (±SE) chewing time were also compared based on the four **different institutions**. As for feeding, a statistically significant difference was found between the average (±SE) number of bites as well as between the average (±SE) chewing time in seconds (ANOVA, $F(3.440) = 4.1403$, $p < 0.05$ and ANOVA, $F(3.440) = 5.4004$, $p < 0.05$, respectively). As seen in Figure 15, the average (±SE) number of bites was significantly lower in Prague Zoo than in Camel Farm Záhostice (Tukey HSD test, $p < 0.05$; 18.66±0.56 vs. 21.91±1.19, respectively). The average (±SE) chewing time in Prague Zoo was also significantly lower, but in this case opposed to the average (±SE) chewing time in Ostrava Zoo (Tukey HSD test, $p < 0.05$; 17.34±0.55 vs. 20.67±0.62 seconds, respectively). The average (±SE) number of bites and average (±SE) chewing time for rumination were not statistically different across institutions (ANOVA, $F(3,189) = 1.4333$, $p > 0.05$ and ANOVA, $F(3.189) = 1.4722$, $p > 0.05$).

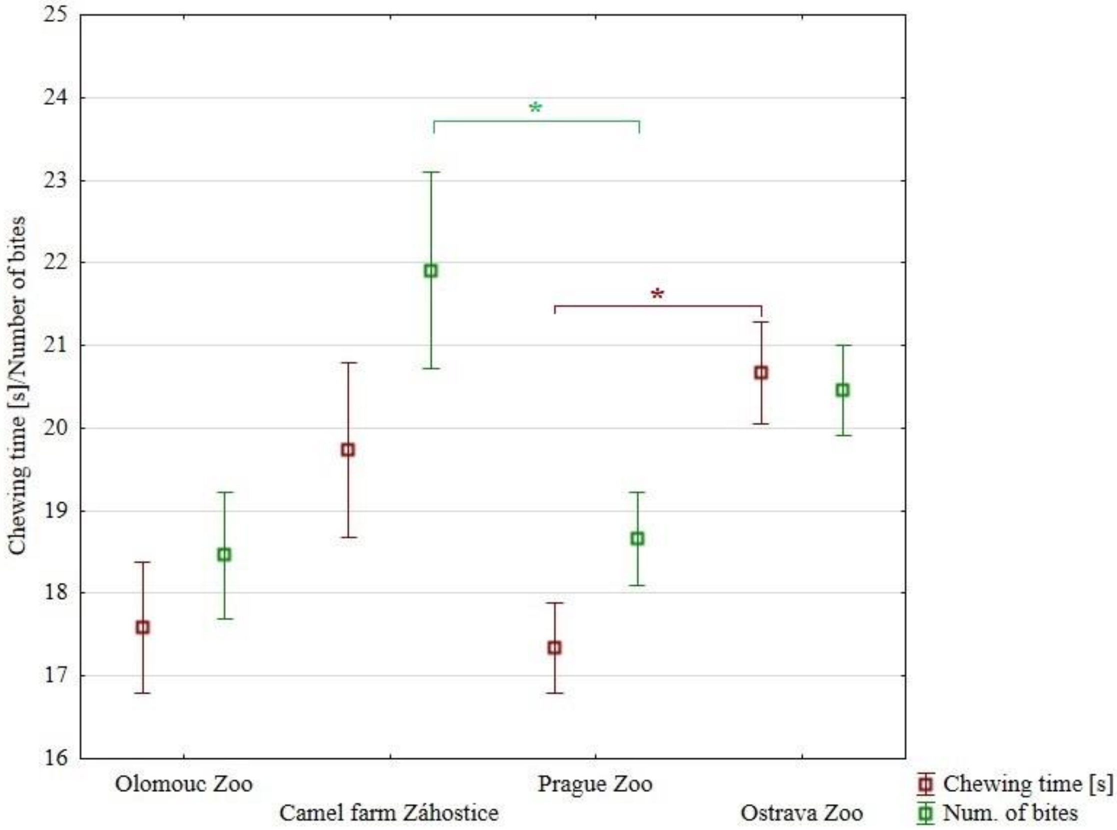

Figure 15: Average number of bites and chewing time for feeding in different institutions; vertical bars denote ±SE; * indicates a p-value < 0.05 (Pešková 2023).

When the average (±SE) the number of bites and the average (±SE) chewing time were compared in **different parts of the day**, no statistically significant difference was found for feeding (ANOVA, $F(5,438) = 1.2650$, $p > 0.05$ and ANOVA, $F(5,438) = 2.0418$, $p > 0.05$, respectively). On the other hand, a statistically significant difference was found when rumination was considered for the average (±SE) number of bites and average (±SE) chewing time (ANOVA, $F(5,187) = 4.3498$, $p < 0.05$ and ANOVA, $F(5,187) = 7.7415$, $p < 0.001$, respectively). The average (±SE) number of bites was significantly higher in the evening than in the morning (Tukey HSD test, $p < 0.001$; 40.62±3.99 vs. 28.09±1.20, respectively). The average (±SE) number of bites was also significantly higher when compared to the average (±SE) in the afternoon (Tukey HSD test, $p < 0.05$; 40.62±3.99 vs. 29.32±1.32). Averages for chewing time were statistically significantly different across more parts of the day. The average (±SE) chewing time in the evening (40.87±3.60 seconds) was significantly lower than those in the morning, noon, afternoon and early evening

(Tukey HSD test, p < 0.001 – evening vs. morning, afternoon; Tukey HSD test, p < 0.05 – evening vs. noon, early evening; 27.21±0.99, 31.18±1.07, 29.13±1.25, 31.71±1.85 seconds, respectively). Furthermore, the average (±SE) chewing time in the morning was significantly lower than the one in the forenoon (Tukey HSD test, p < 0.05; 27.21±0.99 vs. 35.55±1.85 seconds, respectively). All of these results, including statistical differences, are shown in Figure 16.

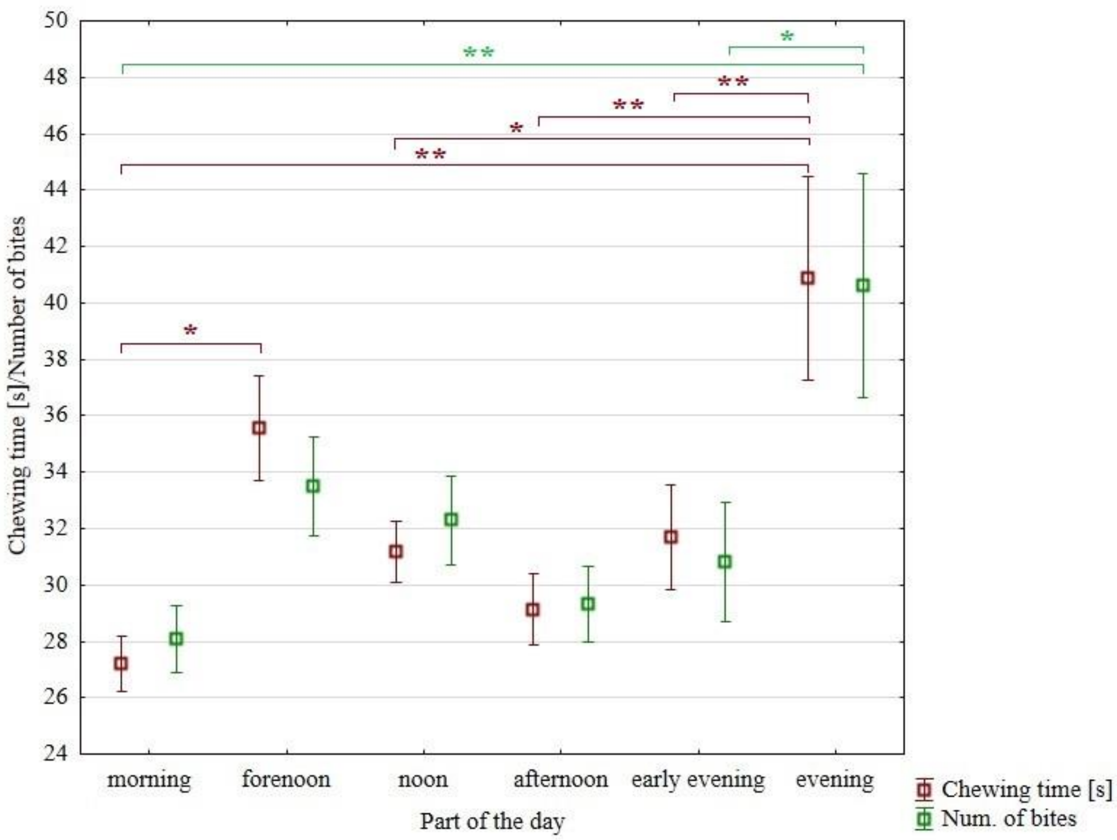

Figure 16: Average number of bites and chewing time for rumination in different parts of the day; vertical bars denote ±SE; * indicates a p-value < 0.05; ** indicates a p-value < 0.001 (Pešková 2023).

When the comparison of the average (±SE) the number of bites and the average (±SE) chewing time for feeding and rumination was based on **different weather**, no statistically significant difference was observed in either category (n. of bites, feeding – ANOVA, F(4,439) = 1.2411, p > 0.05; n. of bites, rumination – ANOVA, F(4,188) = 0.7738, p > 0.05; chewing time, feeding – ANOVA, F(4,439) = 2.2060, p > 0.05; chewing time, rumination – ANOVA, F(4,188) = 0.6380, p > 0.05).

A statistically significant difference in the average (±SE) number of bites was not observed between **age groups** during feeding (ANOVA, $F(2,441) = 0.2152$, $p > 0.05$). During rumination, a statistically significant difference was found (ANOVA, $F(2,190) = 4.9496$, $p < 0.05$), furthermore post host testing showed that sub-adult animals had significantly higher average (±SE) number of bites than adult animals (Tukey HSD test, $p < 0.05$; 35.11±1.64 vs. 29.41±0.75, respectively). This difference is visualised in Figure 17.

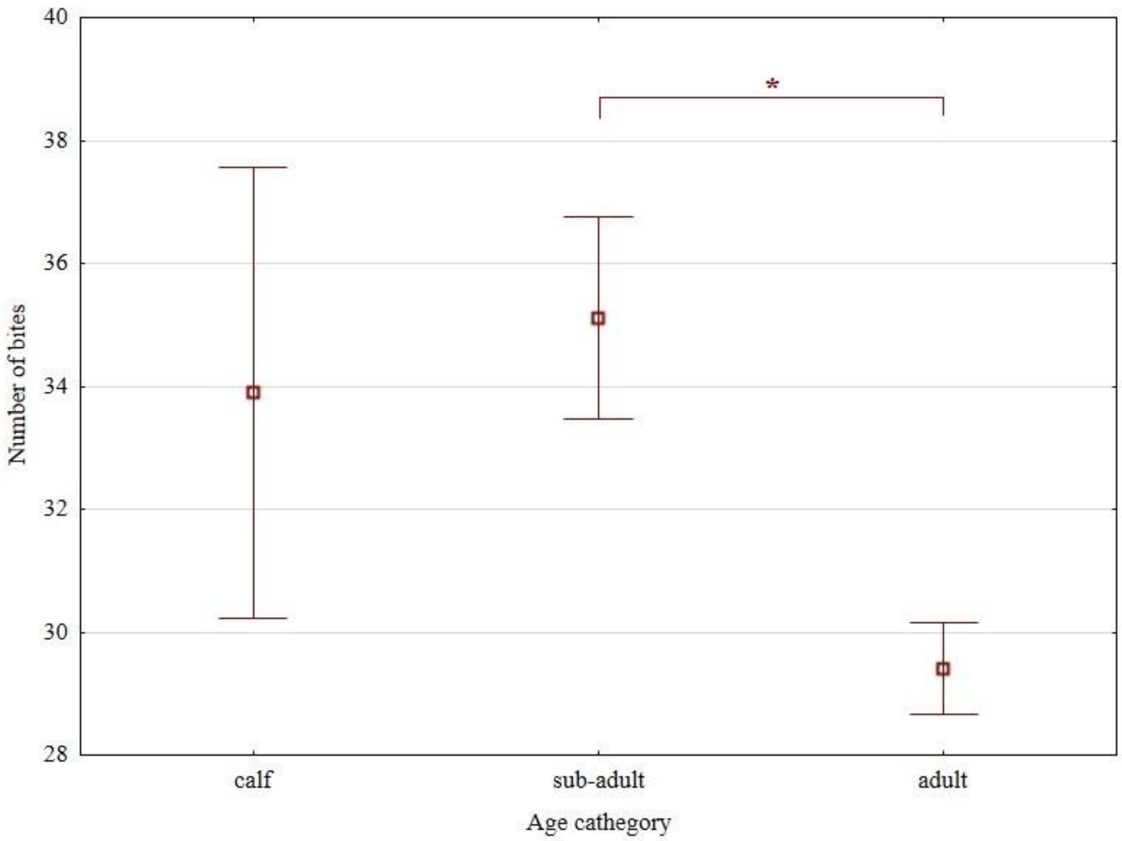

Figure 17: Average number of bites during rumination in different age groups; vertical bars denote ±SE; * indicates a p-value < 0.05 (Pešková 2023).

The same analysis was done for average chewing time (±SE). As for feeding, a statistically significant difference was found (ANOVA, $F(2,441) = 3.3683$, $p < 0.05$), but post-hoc testing did not reveal between which groups (Tukey HSD test, $p > 0.05$ – for all pairs). On the other hand, from Figure 18, a trend is clearly visible, suggesting that the older the animal is the longer it tends to chew. Considering rumination, a statistically significant difference was also found (ANOVA, $F(2,190) = 6.8384$, p < 0.05). The average (±SE) chewing time of calves was significantly lower than the averages (±SE) of sub-adult and adult animals (Tukey HSD test, $p < 0.001$ – calves vs. sub-adults; Tukey HSD test, $p < 0.05$ – calves vs. adults; 23.89±2.03 vs. 33.19±1.51, 30.64±0.72 seconds, respectively). and are visualised in Figure 19.

The average chewing rate was also calculated for later comparison purposes. The average number of bites was divided by the average chewing time for each age group and was also multiplied by sixty to get the chewing rate for one minute. Chewing rates during feeding were as follows: calves 79.2 bites per minute, sub-adults 66.6 bites per minute and adults 61.8 bites per minute. The chewing rate during rumination was – calves 85.2 bites per minute, sub-adults 69 bites per minute and adults 52.8 bites per minute.

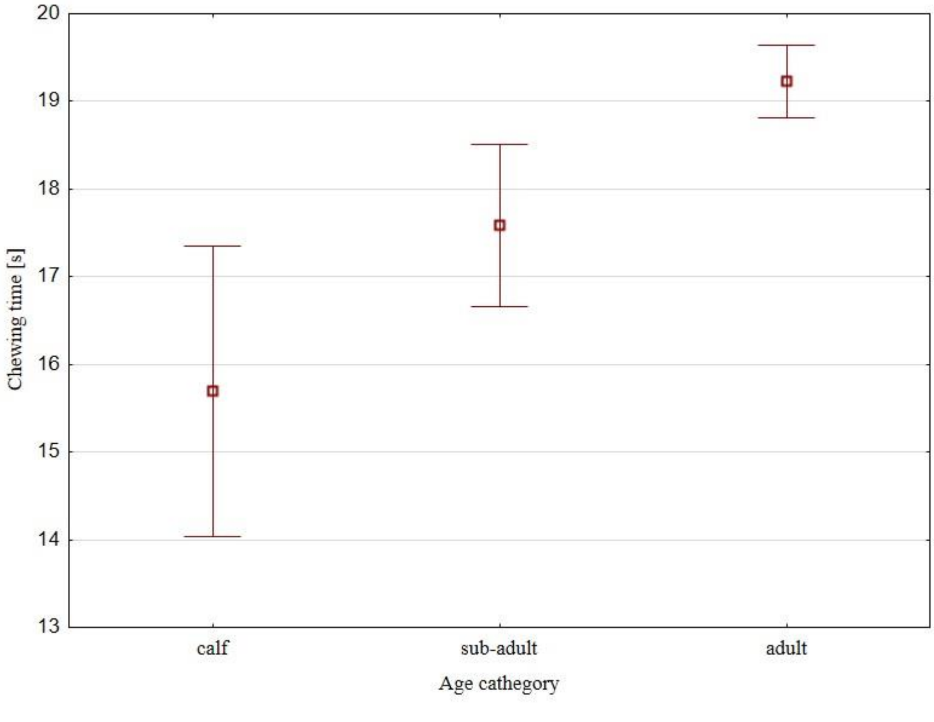

Figure 18: Average chewing time during feeding in different age groups; vertical bars denote ±SE (Pešková 2023).

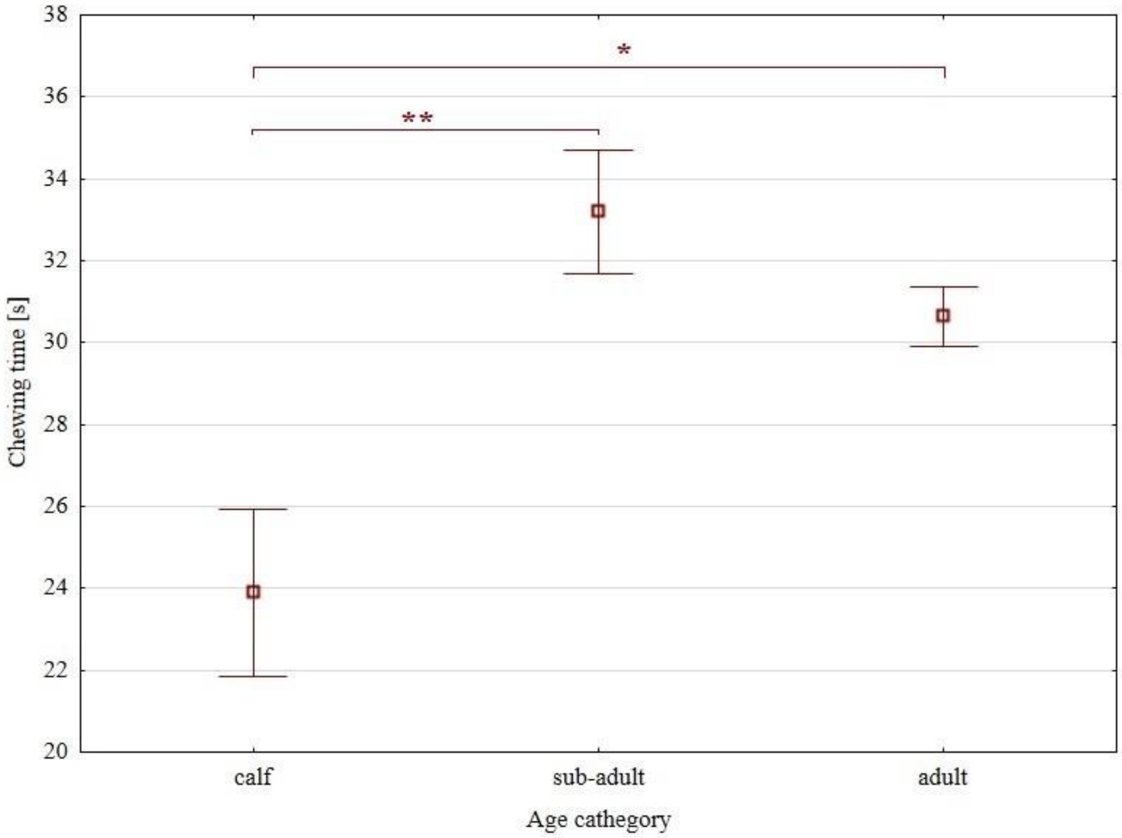

Figure 19: Average chewing time during rumination in different age groups; vertical bars denote ±SE; * indicates a p-value < 0.05; ** indicates a p-value < 0.001 (Pešková 2023).

When the **sex of the animals** was considered together with the age group, more statistically significant differences were found. Considering feeding, a significant difference was found in the average (±SE) the number of bites and also between the average (±SE) chewing times (ANOVA, $F(6,437) = 2.9772$, $p < 0.05$ and ANOVA, $F(6,473) = 4.3245$, $p < 0.001$, respectively). Adult females, on average, made significantly fewer bites than adult males during feeding (Tukey HSD test, $p < 0.05$; 18.69±0.41 vs. 22.60±1.14, respectively). The average (±SE) chewing time of adult females was also significantly lower than that of adult males during feeding (Tukey HSD test, $p < 0.05$; 18.15±0.43 vs. 22.23±1.11 seconds, respectively). This analysis also showed that sub-adult females spent on average (±SE) less time chewing than adult males (Tukey HSD test, $p < 0.05$; 17.64±1.12 vs. 22.23±1.11 seconds, respectively). These differences can be seen in Figure 20. When talking, about rumination statistically significant differences were also found in the average number of bites (±SE) and average chewing time (±SE) (ANOVA, $F(6,186) = 4.8297$, $p < 0.001$ and ANOVA, F(6,186) = 4.1004, p < 0.001, respectively). The average (±SE) the number of bites of calf females was significantly lower than the average (±SE) of adult males and castrated adult males (Tukey HSD test, p < 0.001 – calf female vs. adult male; Tukey HSD test, p < 0.05 – calf female vs. castrated adult male; 40.13±5.89 vs. 24.61±1.19, 26.00±1.65, respectively). The average (±SE) the number of bites of adult males was also significantly lower than the average (±SE) number of bites of sub-adult females (35.75±1.97) (Tukey HSD test, p < 0.001; 24.61±1.19 vs. 35.75±1.97). Taking average (±SE) chewing times for rumination into account, the average (±SE) of adult females was significantly higher than the average (±SE) of adult males (Tukey HSD test, p < 0.05; 31.86±0.98 vs. 26.47±1.11 seconds, respectively). Furthermore, the average (±SE) chewing time of calf males was significantly lower than the averages (±SE) of sub-adult and adult females (Tukey HSD test, p < 0.05 – for both; 22.60±2.50 vs. 32.78±1.55, 31.86±0.89 seconds, respectively). Figure 21 visualises all the results related to rumination in this analysis.

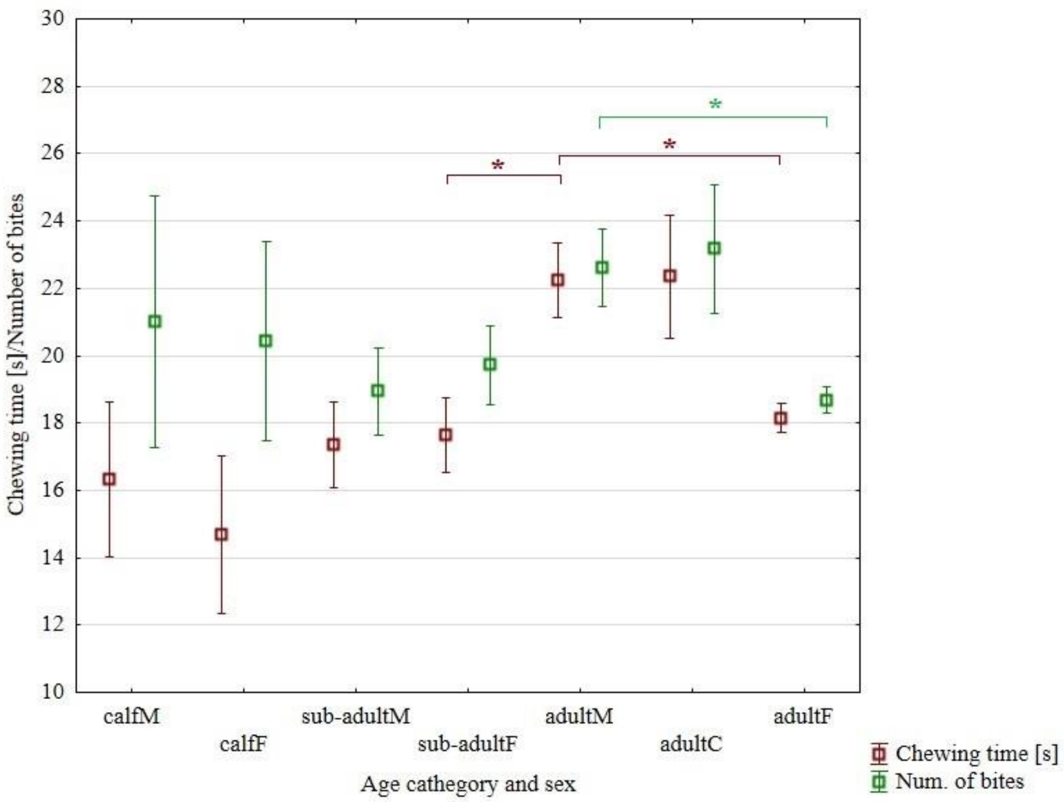

Figure 20: Average number of bites and chewing time for feeding based a sex and age group; vertical bars denote ±SE; * indicates a p-value < 0.05; ** indicates a p-value < 0.001 (Pešková 2023).

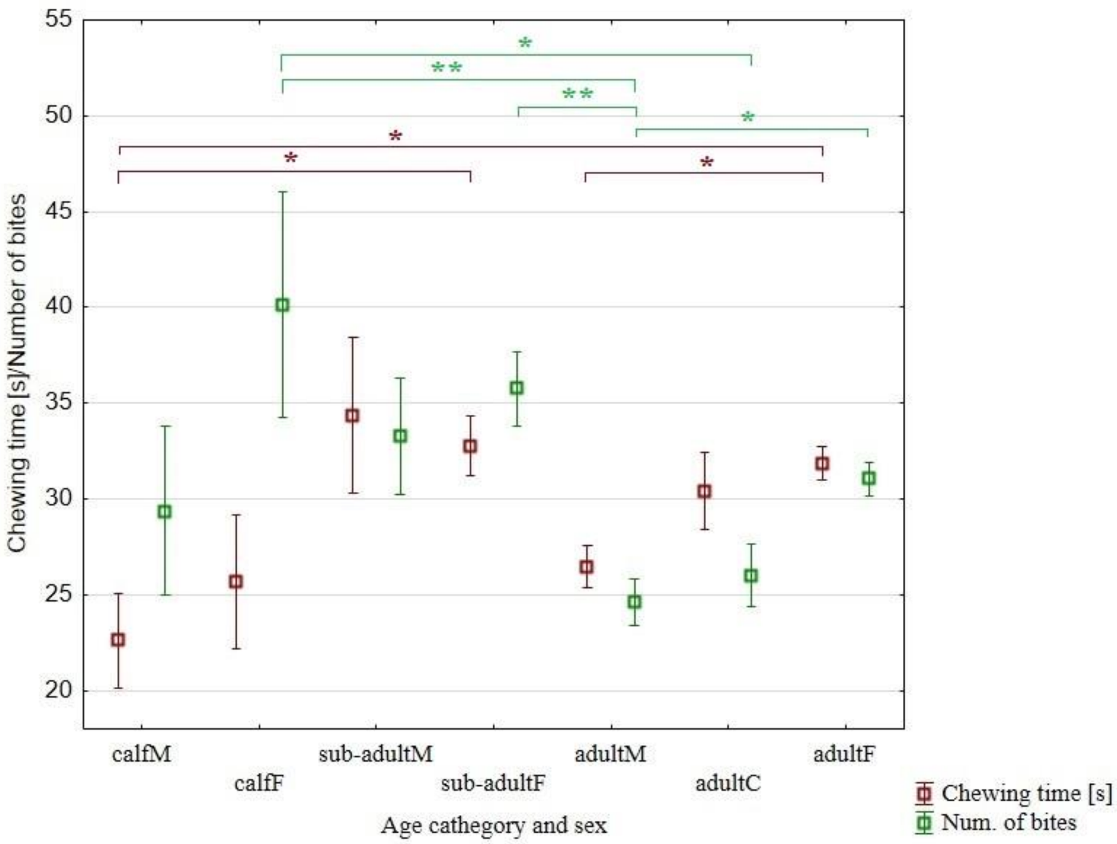

Figure 21: Average number of bites and chewing time for rumination based on different sex and age group; vertical bars denote ±SE; * indicates a p-value < 0.05; ** indicates a p-value < 0.001 (Pešková 2023).

The health status of the animals was also considered. As for rumination, there was no statistically significant difference found for the average (±SE) the number of bites, neither was it found for the average (±SE) chewing time (ANOVA, $F(3,189) = 1.6123$ $p > 0.05$ and ANOVA, $F(3,189) = 1.4008$, $p > 0.05$, respectively). However, a significant difference was found in the average (±SE) the number of bites as well as in the average (±SE) chewing time (ANOVA, $F(3,440) = 15.914$, $p < 0.001$ and ANOVA, $F(3,440) = 11.176$, $p < 0.001$, respectively), when feeding was considered. As shown in Figure 22, the averages (±SE) of animals with diarrhoea were significantly higher than in all the other groups (Tukey HSD test, $p < 0.001$ – for all pairs). The average (±SE) number of bites for animals with diarrhoea was 37.75, compared to healthy animals, lactating animals and one animal with arthrosis (37.75±3.29 vs.19.60±0.40, 19.24±0.91, 15.56±1.31, respectively). A similar trend can be seen in the average (±SE) chewing time; animals with diarrhoea were chewing

33.94 (±2.94) seconds on average, compared to healthy animals, lactating animals and the animal with arthrosis (18.51±0.39, 18.44±0.90, 16.47±1.55 seconds, respectively).

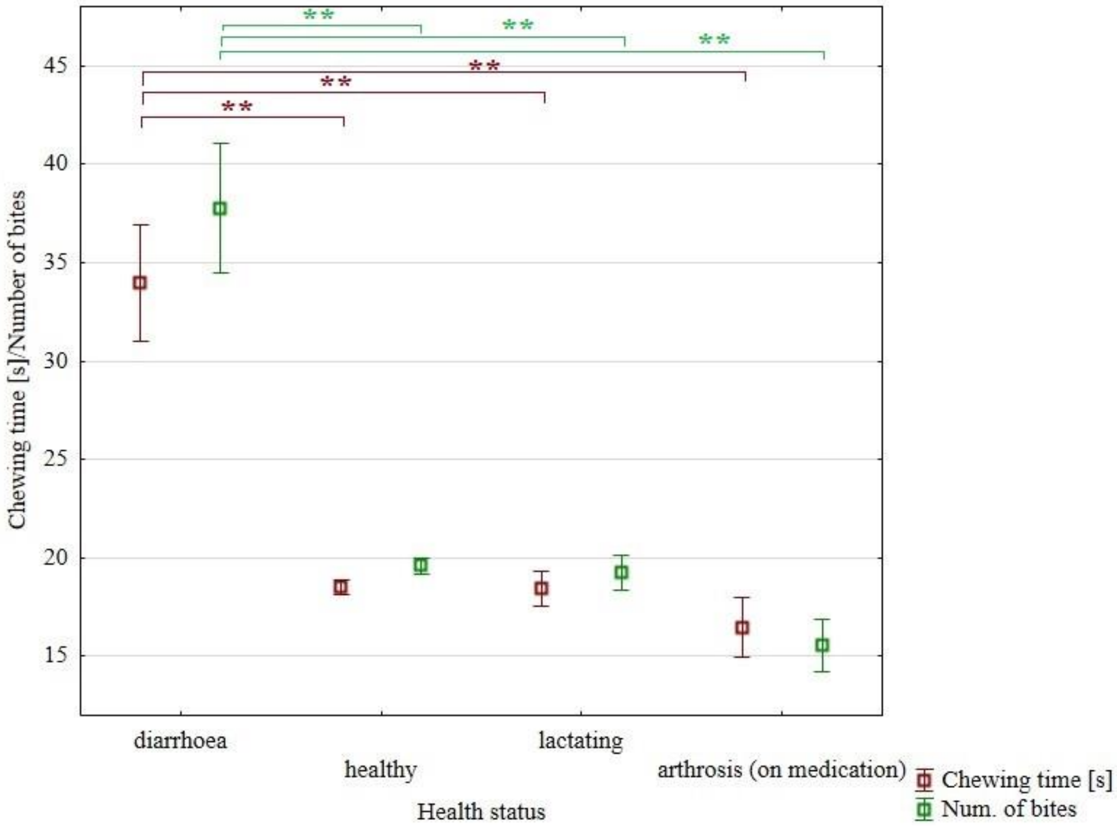

Figure 22: Average number of bites and chewing time for feeding based on health status; vertical bars denote ±SE; ** indicates a p-value < 0.001 (Pešková 2023).

No statistically significant relationship was found between the number of bites and **temperature** for feeding (Linear regression, $p > 0.05$), nor for rumination (Linear regression, $p > 0.05$). The same can be said for the chewing time during feeding (Linear regression, $p > 0.05$). On the other hand, a positive relationship can be seen between temperature and chewing time during rumination (Linear regression, $p < 0.05$, $r = 0.1920$), showing that when the temperature is increasing, the time of chewing slightly increases too, as seen in Figure 23.

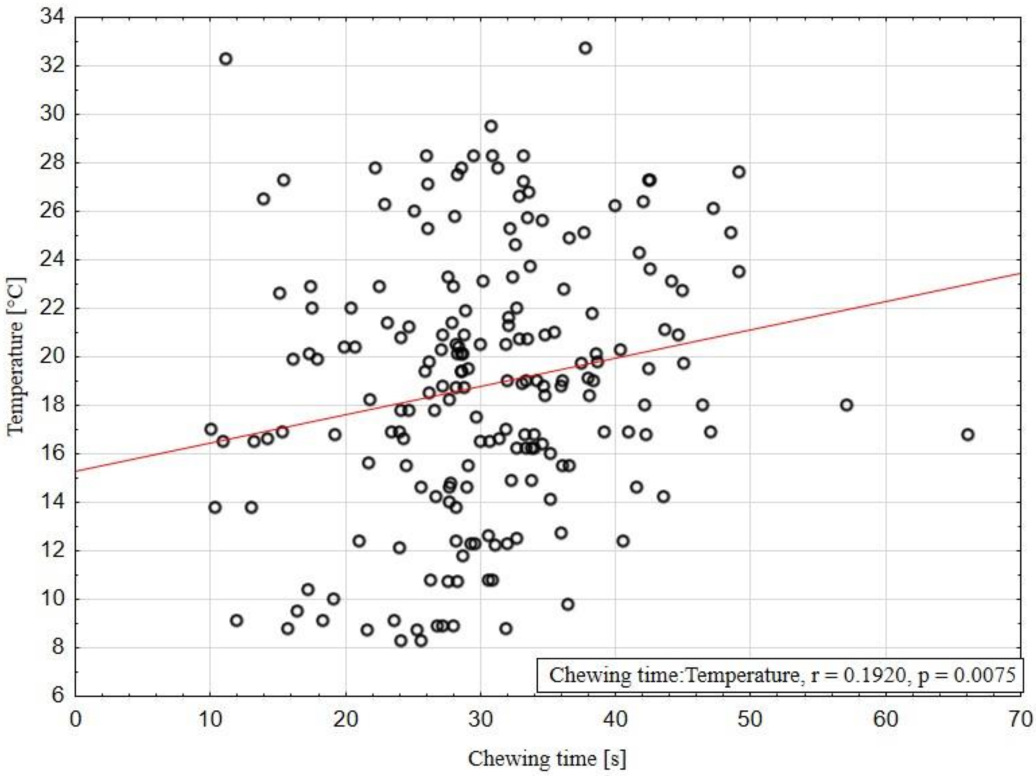

Figure 23: Relationship between temperature and chewing time during rumination (Pešková 2023).

4.3. Defecation and urination

Lastly, 157 records of defecation and 231 records of urination were collected.

The number of observed urinations ranged from 1 to 6 in one animal per the 7 hours of observation a day, observed defecations were in the same range of 1 to 6 in one animal per the 7 hours of observation a day.

Results show that there was not a statistically significant difference in defecation/urination in different **parts of the day** (Pearson's chi-squared test: df =5, $p > 0.05$). The different frequencies can be seen in Table 6.

Table 6: Frequencies of defecation/urination in different parts of the day (Pešková 2023).

	morning [%]	forenoon [%]	noon [%]	afternoon [%]	early evening [%]	evening [%]
urine	68.47	28.58	20.24	44.65	54.18	14.88
faeces	46.53	19.42	13.76	30.35	36.82	10.12

Furthermore, the urination and defecation frequency for each animal was calculated – the total number of defecations/urinations of each animal dived by the number of observation days. Overall, the average (±SE) daily frequency of defecation was 1.37 (±0.13) and the average (±SE) daily frequency of urination was 0.9 (±0.12).

The results suggest that neither the average (±SE) daily frequency of defecation nor the average (±SE) daily frequency of urination were affected by the different **institutions** (ANOVA, $F(2,17) = 2.4431$, $p > 0.05$ and ANOVA, $F(2,17) = 2.2449$, $p > 0.05$, respectively).

No significant difference in the average (±SE) daily frequency of defecation and the average (±SE) daily frequency of urination was found between different **body conditions** of the animals (ANOVA, $F(3,16) = 1.9034$, $p > 0.05$ and ANOVA, $F(3,16) = 2.1034$, $p > 0.05$, respectively).

Even though a significant difference was not found in the average (±SE) daily frequency of defecation or in the average (±SE) daily frequency of urination for different **age groups** (ANOVA, $F(2,17) = 3.5247$, $p > 0.05$ and ANOVA, $F(2,17) = 1.0458$, respectively), Figure 24 clearly shows that older animals (sub-adults and adults) had a higher average (±SE) daily frequency of defecation than younger ones (calves) (1.00±0.17 and 1.02±0.14 vs. 0.22±0.55, respectively). Furthermore, the p-value of this analysis was remarkably close to the given level of significance ($p = 0.05241$).

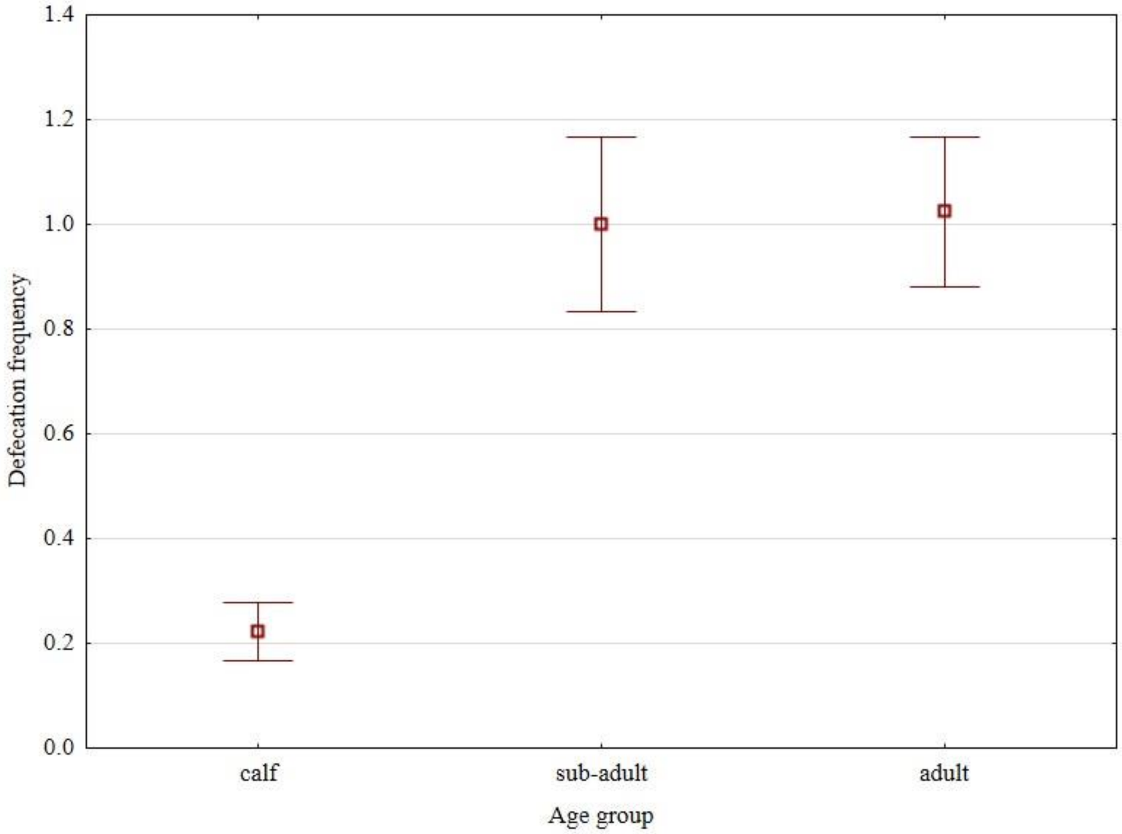

Figure 24: The average daily frequency of defecation in different age groups; vertical bars denote ±SE (Pešková 2023).

5. Discussion

5.1. Feeding behaviour

In comparison with a study by Chaibou (2005), where Dromedary camels on pasture spent 61% of the time feeding, camels in this study spent only 31.89% of the time feeding which is significantly lower. One possible explanation is that during Caribou's research camels were not fed at one feeding place but were freely foraging, walking up to 30 km per day. A similar number can be found in a study by O'Connor et al. (2015); they followed Dromedary camels that were allowed to graze freely in the savannah. These animals spent 71.1% of the day feeding. My result can be compared to the result of Aubé et al. (2017), who studied box-housed camels with restricted movement and regular feeding. These camels spent 30% of the day feeding. These results can be explained by the fact that when camels are feeding in natural areas with almost no restriction of movement, they can cover a large area of land while foraging (Khaskheli et al. 2020). Whereas when they are fed at once at one location there is limited movement, which reduces the time needed for feeding. In my study, camels were observed ruminating for 11.05%. Khan et al. (1998) observed a rumination frequency of 31.7% in camels that were allowed to graze for eight hours a day and were also observed for the entire 24-hour period. This leads to the important fact, that camels are supposed to have their peak rumination activity during the night hours (Kaske et al. 1989; Iqbal & Khan 2001 Kassilly 2002; Dereje & Udén 2005) when my research did not take place. This is also supported by the finding of Aubé et al. (2017), who mentioned that 21% of all observed rumination took place at night. However, lower frequencies of rumination can also be seen in camels that were fed *ad libitum* by hay – 22% (Cahill & McBride 1995).

5.1.1. Factors affecting feeding behaviour

This study found that there was a significant difference between the frequencies of behaviours in different institutions. The biggest difference was seen in the herd from Prague Zoo. This herd spent the most time feeding (37.80% of the time of observation), but on the other hand, spent the least amount of time ruminating (6.55%). This short amount of time spent ruminating may suggest that the fibre content of feed could be lower than in feed from other institutions. However, it does not explain the high frequency of feeding as with lower fibre content, the ingestion should also be shorter (Engelhardt et al. 2006). The herd in Prague Zoo was the only herd that was fed only by green fodder, which is lower in fibre than hay (Carley 2019), so this may be a key factor. It can also be assumed that a substantial portion of rumination took place at night when the observation did not take place. As was previously described, the peak of rumination is between 1.00 AM and 7.00 AM (Kaske et al. 1989; Iqbal & Khan 2001). Even though the description of stereotypical behaviour was not the aim of the study, these behaviours were clearly seen in two female camels in this group. This can be linked to the findings of Padalino et al. (2014) and Aubé et al. (2017), who studied stereotypy in dromedaries and concluded that the lack of pasture, can lead to abnormalities in feeding behaviours. The availability of pasture was very limited in the enclosure in Prague Zoo and thus this may be one of the reasons why the herd in Prague Zoo differed from the other institutions.

The preferred position during feeding was standing. The animals were standing 96.30% of the time while feeding during this research. This result agrees with the result of Stolzl et al. (2015), who observed sheep and llamas and concluded that feeding took place mostly while standing and it is also the standard feeding position for ruminants. Laying in sternal recumbency was the preferred position for rumination in camels (68.93% of the observed rumination) in this research, followed by standing (30.16%). These results were identical to research by Acatincăi et al. (2010), who observed cattle and concluded that cows tended to ruminate while lying for 63.4% of all ruminations and while standing for 36.5% of all ruminations. Camels generally tend to ruminate while they are resting (Aubé et al. 2017) and the preferred position for resting is lying in the sternal recumbency (El-Allali 2022), so these findings agree with my results.

Feeding behaviour was observed to take place during the average temperature of 18.42°C, which was the lowest temperature compared to other behaviour. This result can be simply explained by the fact that camels tend to avoid feeding during the warmest hours of the day (Khaskheli et al. 2020). Other ruminants also avoid feeding during elevated temperatures, as digestion is one of the biggest sources of heat for them (Berihulay et al. 2019). Connected to this result is also the result showing that feeding took up the least amount of time during the sunny weather. The average temperature during the sunny weather was 23.73°C, which is higher than the other states of the weather (from 14.89°C to 19.48°C). On the other hand, the highest frequencies of feeding were observed during foggy and rainy weather. Rainy weather had the lowest average temperature (14.98°C), so this also correlates with the preference for feeding in cooler temperatures. As Bravo (2015) mentions, camels do not mind standing outside in the rain. And in this research, most of the observations of rainy weather were collected in Prague Zoo (1,316 out of 1,525 records), where the animals did not have any shelter available, thus suggesting that rain is not a limiting factor for feeding in camels. During foggy weather, the average temperature was higher (19.48°C), and the frequency of feeding was the highest out of all the different weathers (41.82% of the time of foggy weather), but it is important to mention, that this weather was observed only for two hours in one morning right after the new feed was put into the enclosure, thus explaining the high frequency of feeding.

Rumination was mostly observed most during sunny weather (15.51% of this sunny weather) and the average temperature for rumination (18.96°C) was higher than for feeding. Rumination is generally said to be decreasing with increasing temperature in cattle (Chaiwong et al. 2010; Soriani et al. 2013), but my results show the contrary. This can be explained by the fact that the largest part of rumination in my study was observed during noon (60.19% of all activities) and an assumption can be made that in this part of the day, the temperatures are generally higher. As previously mentioned, the largest rumination activity can be expected in the night, suggesting that this would lower the average temperature for rumination if the observation took place over a 24-hour period. Another possible explanation can be the fact that as camels are well adapted to higher temperatures than cattle (Bravo 2015), the ambient temperature does not affect them this way.

Another result connected to the weather is the distribution of behaviour dependent on direct sunlight. Zappaterra et al. (2021) studied this in dromedary camels and concluded that the animals had a visible preference for shade. General preference for shaded areas was also described in other species (Holcomb & Stull 2016; Ratnakaran et al. 2016) and even though camels are known to have better thermoregulation than other species, heat stress can still occur (Norton et al. 2014), thus shade seeking behaviour can be compared to other species. This agrees with my results, which show that animals chose shaded areas 51.32% of the time when the sun was shining. A larger portion of feeding (53.41%%) took place under direct sunlight, this can be simply due to the fact that most of the feeding places were placed in an open area with great visibility to the visitors, thus not having any cover to provide shade over the feeding place. However, it was observed that camels preferred to feed in shaded areas (Zappaterra et al. 2017), so providing shade over the feeding place may be considered a good husbandry practice. In the already mentioned study (Zappaterra et al. 2017), camels were observed to ruminate more in the shade, this agrees with my results that show that 57.24%% of rumination was observed in shaded areas.

Feeding itself was the most prevalent behaviour connected to feeding behaviours during all of the different parts of the day, except for noon, when it was overtaken by rumination. This result can circle back to the fact that camels tend to avoid feeding during the hottest part of the day (Khaskheli et al. 2020), which can be generally assumed is noon. However, it is especially important to acknowledge the fact that this result may be largely affected by the feeding regimes of the different institutions, as feed was given at particular times – except for Zoo Olomouc where hay was available *ad libitum*, but other feeds were still given at set times. Camels that are given feed at set times are said to consume most of the given feed in the first two hours after the feed is provided (Bhakat & Ghorui 2011), so it can be assumed that this fact is the main reason for the distribution of feeding in this study. Rumination was most prevalent during noon (19.07% of all behaviours). This can be attributed to the fact that camels tend to ruminate while they are resting (Zappaterra et al. 2021) and as feeding frequencies during noon were the lowest (12.36%) and behaviours not connected to feeding behaviour were the highest (68.32%), it can be assumed that the animals were resting during this part of the day, thus ruminating more. However, this finding is not in agreement with the fact that rumination is supposed to be decreased in higher temperatures (Chaiwong et al. 2010; Soriani et al. 2013) – again it is assumed that noon is generally the hottest part of the day. A study by Engelhard et al. (2006) also mentions that rumination was frequently observed around the midday hours. results also show the increased frequency of rumination in the evening (15.00% of all behaviours), thus maybe suggesting that rumination would be more prevalent with the onset of night, which would agree with the findings of other authors (Kaske et al. 1989; Iqbal & Khan 2001 Kassilly 2002; Bhakat & Chaturvedi 2004; Dereje & Udén 2005).

When mentioning different age groups of the observed animals, sub-adult animals were feeding the most (42.72% of the time). Dereje and Udén (2005) describe the fact that younger camels tended to browse for longer periods of time than the adult animal. On the other hand, it is important to mention that they followed a freely grazing herd and the authors claimed that the younger animals needed to feed for longer times as they needed to find more delicate plants. Camels in my study all got the same feed, so this problem should be largely erased. But on the other hand, Nelson et al. (2015) more generally mention that younger camels tend to feed for longer periods. Sub-adult animals tended to ruminate the least amount of time (8.95%) which is not corresponding to the general fact that rumination is supposed to increase with age (Wang et al. 2022), thus suggesting that calves should be the ones ruminating the least. This discrepancy in the results can be attributed to the fact the number of followed calves and sub-adults was relatively low (five calves and five sub-adults). It can be assumed that with higher numbers of these animals, the results could be different as even in this study the difference in the frequency between the two groups was rather small – the frequency was only higher by 1.42% in calves.

My result show that castrated males were the ones that ruminated the most (20.43% of the time) out of the other sexes. Castration is known to have several effects on the behaviour and physiological state of animals (Devant et al. 2012), but in a study by Silva et al. (2019), there was no difference found in the time spent on rumination between castrated and uncastrated goats. Dereje and Udén (2005) also mention that the frequencies of behaviours are more dependent on the age rather than the sex of the animal. Also, it is crucial to mention that in my study only two out of the thirty observed animals were castrated, thus the data may be skewed.

5.2. Number of bites and chewing time

The average number of bites for cattle was reported to be between 17-40 bites per mouthful (Gill et al. 1966). The average in my study was 19.77 bites. Another similarity with the above-mentioned study by Gill et al. (1966) is the fact that the number of bites was significantly lower when the animals were fed by herbaceous plants than when they were fed by hay. This trend can be seen in my results too. It is also in agreement with Fowler (2010) and Jalali et al. (2012) who mention that the number of bites and the time needed for feeding is largely dependent on the type and quality of the feed. This trend can be explained by the simple fact that hay contains more fibre than green fodder (Carley 2019) and thus needs more time to be mechanically processed (Beauchemin & Yang 2005). My results show that the average bite rate during feeding is 63.6 bites per minute, in comparison to study on cattle, which observed the bite rate between 47.5-59.4 bites per minute (Gibb et al. 1997) and a study observing goats, which showed the bite rate between 59.3-63.2 bites per minute (Hulbert et al. 1998).

Engelhard et al. (2006) concluded that rumination patterns in camelids are remarkably similar to other ruminants. Lindgren (2009) stated that the average number of bites for cattle was between 30-60 bites lasting around 40 seconds. Our findings were similar, showing that the average number of bites was 30.65 bites and lasted 30.33 seconds on average. The average number of bites is also in the range of bites for the vicuna, which was reported to be between 25-35 bites (Fowler 2010). Dromedary camels were recorded to have an average bite rate of 63 bites per minute during rumination (Engelhard et al. 2006), this result is close to my observation of bite rate for rumination – 60.6 bites per minute.

The statistically significant difference in the average number of bites and average chewing time between feeding and rumination can be explained by a well-known trend that is described in ruminants saying that the chewing process during rumination is much slower and consistent than during feeding (Beauchemin 2018). This agrees with my result showing that the average chewing time during feeding was 18.73 seconds compared to the average chewing time during rumination of 30.33 seconds. This finding can also be supported by the fact that these two chewings serve different functions during the process of ingestion (Baumont et al. 2006).

5.2.1. Factors affecting number of bites and chewing time

When different institutions were considered, results from Prague Zoo differed from the rest again. The average chewing time and the average number of bites differed significantly compared to other institutions. This difference can be again explained by the fact that this herd was the only one being fed only by green fodder for a longer period of time, thus being fed lower fibre content and thus leading to a lower average number of bites and average chewing time because of it.

The average number of bites and chewing time differed in different parts of the day according to our research. The one part of the day that was the most different was the evening. During the evening, the averages tended to be the highest out of the entire day (40.62 bites and 40.87 seconds). These results agree with the statement that longer rumination periods tend to appear later in the day rather than when rumination is observed after and in between meals (Welch & Hooper 1988).

My results suggest that older animals tended to chew one mouthful longer than younger animals, this finding is in contrast to a study by Ali et al. (1990), who stated that older buffalos tended to chew for a slightly shorter time than the younger ones. My results do not show statistically significant differences; thus, these results should be taken critically. On the other hand, when the average results were recalculated for the average chewing rate (average number of bites/average chewing time) these results agreed with the assumption of Li (2013), who stated that smaller individuals have higher chewing rates to increase chewing efficiency. This assumption was based on the Jarman-Bell principle and agrees with my results for both feeding and rumination. The effect of age on chewing was also studied in giraffes (*Giraffa camelopardalis*) and this study concluded that older animals tend to make fewer bites than younger ones (Slepica 2018), which agrees with the results of my study.

Blanchard and Fritz (2008) stated that sex did not influence the number of chews or the duration when studying impalas (*Aepyceros melampus*). This statement does not agree with our findings that show that during feeding males tended to chew for a longer time and make more bites than females. The opposite was seen during rumination when males tended to chew for a shorter time and make fewer bites than females. The lack of effect of the sex in the study by Blanchard and Fritz (2008) is explained by a little sexual dimorphism in their animals of interest. Differences in the sexes of Dromedary camels were previously described and it was concluded that sexual dimorphism exists in camels – bulls tend to have higher body weight (Tandoh & Gwaza 2017). This could be one of the reasons for observed differences as other studies suggest that difference in body size changes feeding and rumination patterns (Blanchard & Fritz 2008).

Animals with diarrhoea were chewing longer and making more bites than animals in any other health state. No studies considering this trend in camels were found. However, it can be assumed that animals with diarrhoea needed to chew their feed more, to compensate for the faster passage rate and worse absorption of the nutrients (Fowler 2010). As Dufreneix et al. (2019) mention, bigger particles had a higher chance to leave the rumen less degraded when studying cattle.

Results of this study suggest that with increasing temperatures the animals tended to chew slower during rumination– chewing time rising with temperature, whereas the number of bites stayed the same. It can be speculated that this mechanism could be another way of thermoregulation, as it is known in other ruminants that during higher temperatures, they reduce their movement to reduce heat production (Blackshaw & Blackshaw 1994). Another explanation could be the fact that during higher temperatures feed intake generally decreases (Berihulay et al. 2019), thus more through chewing may provide a way how to utilise the lower amount of feed more efficiently, as it was previously mentioned that smaller particles have higher degradability (Dufreneix et al. 2019).

5.3. Defecation and urination

In general, defecation and urination of animals are affected by many factors, such as feed intake, water intake, diet digestibility and physiological state of the animal (Hirata et al. 2011). Most of these factors were not part of my study. According to my best knowledge, no study was focused on urination or defecation in camels, so I cannot compare my results with other studies on camels.

However, Hirata et al. (2011) stated that the average number of urinations per cow of domestic cattle is between 2-16 in 24 hours and the average number of defecations is between 2-20 in 24 hours. The number of defecations/urinations per animal per one observation day in my study is much lower (1-6 per animal per day in both urination and defecation). This can be due to the fact that every day the observation took place only for 7 hours; thus, it can be expected that a number of defecations/urinations was missing from the data set. Another factor which can play some role is the fact that camels are generally much better at managing their body waste to preserve water and utilise available nutrients (Fowler 2010), thus defecating and urinating fewer times than cattle.

In this study, the frequency of defecation/urination during different parts of the day was observed. The frequency of either defecation or urination did not differ in various parts of the day, but it is also important to mention again that this study was done only for 7 hours a day, thus many records of urination/defecation are missing. Nevertheless, my result showed that the lowest frequencies of elimination behaviours were observed during noon (defecation – 13.76% of all defecations; urination – 20.24% of all urinations) and evening (defecation – 10.12%, urination – 14.88%). Additionally, feeding behaviours had the two lowest frequencies (noon – 31.68%, evening – 35.74% of all activities) and behaviour not connected to feeding had the two highest frequencies (noon – 68.32%, evening – 64.26% of all activities) in these two parts of the day. Assuming that behaviour not connected to feeding includes resting time, a comparison of these results can be made to a study by Aland et al. (2002), who studied cattle and observed that these animals had the lowest frequency of elimination behaviours during times of rest. Also, the lowest frequencies of urination/defecation in the evening may suggest a trend described by Hirata et al. (2011) in cattle, saying that the larger portion of these elimination behaviours takes place during the day rather than at night.

This study suggests that younger animals had a lower average frequency of defecation than older animals. This result is inconsistent with other studies done in cattle, which suggest that age does not affect elimination frequency (Aland et al. 2002; Villettaz Robichaud et al. 2011), but even my results did not confirm the significance of the result, however, the p-value was close to the level of significance. On the other hand, the frequency of defecation tends to vary largely even between individuals in both young and older animals (Villettaz Robichaud et al. 2011; Vaughan et al. 2014), thus my results may be skewed due to the comparatively small number of younger animals (calves – 3; sub-adults – 3).

6. Conclusions

This study clearly shows that the feeding behaviour of Bactrian camel is affected by different factors, such as management, weather, sex and age of the animal. However, it can be assumed that one of the largest effects was the management itself, as it clearly determined when the animals were feeding, thus affecting the distribution of feeding behaviour throughout the day. On the other hand, results suggest that despite the management, the animals were still affected by natural factors, such as the temperature. Even though the management was not changing with the weather, it is clearly visible that camels tend to avoid feeding during higher temperatures.

Rumination was mostly observed when the animals were resting, and the feeding frequency was the lowest. Higher frequencies were also observed in the evening hours, thus it can be assumed that the frequencies would grow further into the night, as other studies suggest. More extensive research, which is carried out for the whole 24-hour period, is needed for the confirmation of this assumption.

Factors observed in this study showed a potential effect on the chewing of camels. An expected difference was seen between the characteristics of chewing during feeding and rumination, as these two serve different purposes. Nevertheless, the difference was also seen in different age groups, sexes, parts of the day and different weather. Research focused solely on chewing dynamics is needed to fully understand the specifics of the Bactrian camel.

This study suggests that the defecation and urination frequencies are not affected by any factors that were observed. But these data were limited and as there is practically no research discussing this topic in camels, the results should be taken critically. Studies that solely focus on this issue are necessary to be able to understand these frequencies in camels.

In conclusion, the feeding behaviour of the Bactrian camels is still a very understudied topic, especially in the conditions of the Western world. The correct understanding of this behaviour is the foundation for good husbandry practices of these animals and their welfare. And as their numbers grow, the research should be following the same trend.

7. References

Abaturov BD, Kazmin VD, Dzhapova RR, Ayusheva EC, Dzhapova VV, Nokhaeva DV, Kolesnikov MP, Minoranskiy VA, Kuznetsov YE. 2018. Forage Resources, Nutrition, and Food Supply of Free-Grazing Camels (*Camelus bactrianus*) in a Pasture within the Natural Steppe Zone. Biology Bulletin **45**:961-972.

Abdalla MA. 2020. Anatomical features in the kidney involved in water conservation through urine concentration in dromedaries (*Camelus dromedarius*). Heliyon (e03139) DOI: 10.1016/j.heliyon.2019.e03139.

Abdelhadi O. Babiker S, Picard B, Jurie C, Jailler R, Hocquette J, Faye B. 2012. Effect of season on contractile and metabolic properties of desert camel muscle (*Camelus dromedarius*). Meat Science **90**:139-144.

Abri MA, Faye B. 2019. Genetic improvement in dromedary camels: challenges and opportunities. Frontiers in genetics (e167) DOI: 10.3389/fgene.2019.00167.

Acatincăi S, Gavojdian D, Stanciu G, Cziszter LT, Tripon I, Baul S. 2010. Study regarding rumination behaviour in cattle–position adopted by cows during rumination process. Scientific Papers Animal Science and Biotechnologies **43**:199-202.

Adili N, Melizi M, Bennoune O. 2013. The Influence of Age, Sex and Altitude on the Morphometry of Red Blood Cells in Dromedary Camel. Journal of Animal Science Advances **3**:33-36.

Agnew D. 2018. Chapter 7 – Camelidae. Pages 185-202 in Terio KA, McAloose D, St. Leger J, editors. Pathology of Wildlife and Zoo Animals. Elsevier Books, Amsterdam.

Aland A, Lidfors L, Ekesbo I. 2002. Diurnal distribution of dairy cow defecation and urination. Applied Animal Behavioural Science **78**:43-54.

Al-Ani F. 2004. Camel: management and diseases. Dar Ammar book Publisher, Amman.

Ali A, Raza SH, Ghaffar A. 1990. Eating and rumination in relation to age of lactating buffalo. Applied Animal Behaviour Science **28**:273-279.

Al-Jassim RA, Veerasamy S V. 2015. Review paper: Climate change and camel production: impact and contribution. Journal of Camelid Science **8**:1-17.

Al-Jassim RA. 2019. Metabolisable energy and protein requirements of the Arabian camel (*Camelus dromedarius*). Journal of Camelid Science **12**:33-45.

Al-Qarawi AA, Abdel-Rahman HA, El-Belely MS, El-Mougy SA. 2000. Age-related changes in plasma testosterone concentrations and genital organs content of bulk and trace elements in the male dromedary camel. Animal Reproduction Science **62**:297-307.

Aubé L, Fatnassi M, Monaco D, Khorchani T, Lacalandra GM, Hammadi, Padalino B. 2017. Daily rhythms of behavioral and hormonal patterns in male dromedary camels housed in boxes. PeerJ (e3074) DOI: 10.7717/peerj.3074.

Bai J, Wu RTD, Dao LM, Bao D, Zhang Q, Tian XH. 2021. Study on Change of Wool Fineness with Age of Alxa Bactrian Camel. Pakistan Journal of Zoology **53**:1599-1601.

Baumont R, Doreau M, Ingrand S, Veissier I. 2006. Feeding and mastication behaviour in ruminants. Pages 241-262 in Bels V, editor. Feeding in domestic vertebrates: from structure to behaviour. CAB International, Paris, France.

Beauchemin KA, Yang WZ. 2005. Effects of Physically Effective Fiber on Intake, Chewing Activity, and Ruminal Acidosis for Dairy Cows Fed Diets Based on Corn Silage. Journal of Dairy Science **88**:2117-2129.

Beauchemin KA. 2018. Invited review: Current perspectives on eating and rumination activity in dairy cows. Journal of Dairy Science **101**:4762–4784.

Berihulay H, Abied A, He X, Jiang L, Ma Y. 2019. Adaptation Mechanisms of Small Ruminants to Environmental Heat Stress. Animals (e75) DOI: 10.3390/ani9030075.

Bhakat C, Chaturvedi D. 2004. Studies on behavioural pattern of adult camel in different systems of management. Journal of Dairying, Foods and Home Sciences **23**:192-196.

Bhakat C, Ghorui SK. 2011. Camel management from birth to production. Pages 44-51 in Training Manual for short course on "Camel health and management". 19-28th April '10. Publisher-Director. National Research Centre on Camel, India.

Blackshaw JK, Blackshaw AW. 1994. Heat stress in cattle and the effect of shade on production and behaviour: a review. Australian Journal of Experimental Agriculture **34**:285-295.

Blanchard, P. Fritz H. 2008. Seasonal variation in rumination parameters of free–ranging impalas Aepyceros melampus. Wildlife Biology **14**:372–337.

Borchers MR, Chang YM, Tsai IC, Wadsworth BA, Bewley JM. 2016. A validation of technologies monitoring dairy cow feeding, ruminating, and lying behaviors. Journal of Dairy Science **99**:7458-7466.

Bravo PW. 2015. Chapter 60 – Camelidae. Pages 592-602 in Miller RE, Fowler ME, editors. Fowler's zoo and wild animal medicine, Volume 8. W. B. Saunders, Philadephia.

Burger P, Faye B. 2019. Old World camels in a modern world – a balancing act between conservation and genetic improvement. Animal Genetics **50**:596-612.

Cahill L, McBride B. 1995. Effect of level of intake on digestion, rate of passage and chewing dynamics in hay-fed Bactrian camels. Proceedings of the Nutrition Advisory Group **1**:3-35.

Carley D. 2019. Into the Winter – Feeding and Nutrition for the Colder Months. Thunderbrook Equestrian Limited, Griston. Available from https://thunderbrook.co.uk/into-the-winter-feeding-and-nutrition-for-the-colder-months/#:~:text=Per%20kilo%2C%20hay%20contains%20a,the%20longer%20it%20is%20stored (accessed March 2023).

Celi P, Cowieson AJ, Fru-Nji F, Steinert RE, Kluenter AM, Verlhac V. 2017. Gastrointestinal functionality in animal nutrition and health: new opportunities for sustainable animal production. Animal Feed Sciences and Technology **234**:88-100.

Chaibou M. 2005. Productivité zootechnique du désert: Le cas du bassin laitier d’Agadez au Niger [Ph.D. Thesis]. Université Montpellier, Montpellier.

Chaiwong V, Kaewma, S, Yano T, Rojanasthien, S. 2010. Relationship between ambient temperature and humidity on respiratory rate and rumination of lactating dairy cows in dairy farms in ChiangMai and Lumphun provinces. In Proceedings of the 48th Kasetsart University Annual Conference, Kasetsart, 3-5th March, 2010. Kasetsart University, Bangkok.

Choubisa SL. 2013. Why desert camels are least afflicted with osteo-dental fluorosis?. Current Science **105**:1671-1672.

Dereje M, Udén P. 2005. The browsing dromedary camel I. Behaviour, plant preference and qualityof forage selected. Animal Feed Science and Technology **121**:297-308.

Devant M, Martini S, Bach A. 2012. Devant, M., Marti, S., & Bach, A. (2012). Effects of castration on eating pattern and physical activity of Holstein bulls fed high-concentrate rations under commercial conditions. Journal of Animal Science **90**:4505-4513.

DeVries TJ, Beauchemin KA, Dohme F, Schwartzkopf-Genswein KS. Repeated ruminal acidosis challenges in lactating dairy cows at high and low risk for developing acidosis: Feeding, ruminating, and lying behavior. Journal of Dairy Science **92**:5067-5078.

Dioli M. 2020. Dromedary (*Camelus dromedarius*) and Bactrian camel (*Camelus bactrianus*) crossbreeding husbandry practices in Turkey and Kazakhstan: An in-depth review. Pastoralism (e2041-7136) DOI:10.1186/s13570-020-0159-3.

Dittmann MT, Runge U, Lang RA, Moser D, Galeffi C, Kreuzer M, Clauss M. 2014. Methane Emission by Camelids. PLOS One (e94363) DOI: 10.1371/journal.pone.0094363.

Dufreneix F, Faverdin P, Peyraud JL. 2019. Influence of particle size and density on mean retention time in the rumen of dairy cows. Journal of Dairy Science **102**:3010-3022.

El-Allali K, Beniaich Y, Farsi H, M′ hani MEM, Jabal MS, Piro M, Achaâban MR, Ouassat M, Challet E, Besson M, Mounach J. 2022. Sleep pattern in the dromedary camel: a behavioral and polysomnography study. Sleep (ezsac101) DOI: 10.1093/sleep/zsac101.

Engelhardt W, Dycker, CH, Lechner-Doll M. 2007. Absorption of 284 short-chain fatty acids, sodium and water from the forestomach of camels. Journal of Comparative Physiology B **177**:631–640.

Engelhardt W, Haarmeyer P, Kaske M, Lechner-Doll M. 2006. Chewing activities and oesophageal motility during feed intake, rumination and eructation in camels. Journal of Comparative Physiology B **176**:117–124.

FAOSTAT. 2022. Data. FAO, Rome. Available from https://www.fao.org/faostat/en/#data (accessed December 2022).

Faraz A, Waheed A, Mirza RH, Ishaq HM. 2019. The Camel - A Short Communication on Classification and Attributes. Journal of Fisheries & Livestock Production (e289) DOI: 10.4172/2332-2608.1000289.

Faye B, Konuspayeva G. 2012. The encounter between Bactrian and Dromedary camels in Central Asia. Page 27-33 in Knoll EM, Burger PA, editors. Camels in Asia and North-Africa-Interdisciplinary Perspectives on their Past and Present Significance. Austrian Academy of Sciences Press, Wien.

Faye B. 2022. Is the camel conquering the world? Animal Frontiers: the Review Magazine of Animal Agriculture **12**:8-16.

Fernandez LT, Bashaw MJ, Sartor RL, Bouwens NR, Maki TS. 2008. Tongue twisters: feeding enrichment to reduce oral stereotypy in giraffe. Zoobiology **27**:200-212.

Fesseha H, Desta W. 2020. Dromedary camel and its adaptation mechanisms to desert environment: A review. International Journal of Zoology Studies **5**:23-28.

Fowler ME, Santymire RM. 2022. Characterizing zoo-housed Bactrian camel (Camelus bactrianus) reproduction using gonadal steroid metabolite analysis in feces. Domestic Animal Endocrinology (e106721) DOI: 10.1016/j.domaniend.2022.106721.

Fowler ME. 2010. Feeding and Nutrition. Pages 17-58 in Fowler ME, editor. Medicine and surgery of Camelids 3rd edition. Wiley-Blackwell, Oxford.

Fowler ME. 2010. Hemic and Lymphatic Systems. Pages 407-422 in Fowler ME, editor. Medicine and surgery of Camelids 3rd edition. Wiley-Blackwell, Oxford.

Geer AVD. 2008. Camelus bactrianus, the Bactrian camel. Page 171-174 in Geer AVD, editor. Animals in Stone – Indian Mammals Sculptured Through Time. Brill, Leiden.

Gibb MJ, Huckle CA, Nuthall R. 1997. Measurement of intake rate, bite mass and bite rate by grazing lactating dairy cows and the effect of time of day. In British Grassland Society Fifth Research Conference. Seale Hayne Faculty of Agriculture and Land Use, University of Plymouth.

Gill J, Campling RC, Westgarth DR. 1966. A study of chewing during eating in the cow. British Journal of Nutrition **20**:13-23.

Goldhawk C, Chapinal N, Veira DM, Weary DM, von Keyserlingk MAG. Prepartum feeding behavior is an early indicator of subclinical ketosis. Journal of Dairy Science **92**:4971-4977.

Guo F, Si R, He J, Liyun Y, Le H, Liang M, Li Y, Ji R. 2019. Comprehensive transcriptome analysis of adipose tissue in the Bactrian camel reveals fore hump has more specific physiological functions in immune and endocrine systems. Livestock Science **228**:195-200.

Guo F, Si R, Li Q, Hai L, Yi L, He J, Ming L, Ji R. 2021. Reversible insulin resistance helps Bactrian camels survive fasting. Scientific Reports (e18815) DOI: 10.1038/s41598-021-98234-y.

Hasi S, Yao J, Yu S, Tian Y. 2018. Diversity and distribution of CYP gene family in Bactrian camel. Functional & Integrative Genomics **18**:23-29.

He J, Yi L, Hai L, Ming L, Gao W, Ji R. 2018. Characterizing the bacterial microbiota in different gastrointestinal tract segments of the Bactrian camel. Scientific Reports (e654) DOI: 10.1038/s41598-017-18298-7.

Hirata M, Higashiyama M, Hasegawa N. 2011. Diurnal pattern of excretion in grazing cattle. Livestock Science **142**:23-32.

Hare J. 2008. Camelus ferus. The IUCN Red List of Threatened Species 2008 (eT63543A12689285) DOI: 10.2305/IUCN.UK.2008.RLTS.T63543A12689285.en.

Holcomb KE, Stull CL. 2016. Effect of time and weather on preference, frequency, and duration of shade use by horses. Journal of Animal Science **94**:1653-1661.

Hulbert, I. A., Wyllie, J. T., Waterhouse, A., French, J., & McNulty, D. 1998. A note on the circadian rhythm and feeding behaviour of sheep fitted with a lightweight GPS collar. Applied Animal Behaviour Science **60**:359-364.

Iqbal A, Khan BB. 2001. Feeding behaviour of camel—Review. Pakistan Journal of Agricultural Sciences **38**:58-63

Jalali AR, Nørgaard P, Weisbjerg MR, Nielsen MO. 2012. Effect of forage quality on intake, chewing activity, faecal particle size distribution, and digestibility of neutral detergent fibre in sheep, goats, and llamas. Small Ruminant Research **103**:143-151.

Jemmett AM, Groombridge JJ, Hare J, Yadamsuren A, Burger P, Ewan JG. 2022. What's in a name? Common name misuse potentially confounds the conservation of the wild camel *Camelus ferus*. Oryx DOI: 10.1017/S0030605322000114.

Ji R, Cui P, Ding F, Geng J, Gao H, Zhang H, Yu J, Hu S, Meng H. 2009. Monophyletic origin of domestic bactrian camel (*Camelus bactrianus*) and its evolutionary relationship with the extant wild camel (*Camelus bactrianus ferus*). Animal Genetics **40**:377–382.

Kadim IT, Mahgoub O, Mbaga M. 2014. Potential of camel meat as a non-traditional high quality source of protein for human consumption. Animal Frontiers **4**:13-17.

Kadim IT, Mahgoub O, Purchas RW. 2008. A review of the growth, and of the carcass and meat quality characteristics of the one-humped camel (Camelus *dromedarius*). Meat Science **73**:619–625.

Kaske M, Osman T, Lechner-Doll M, Larsson M, Engelhardt W. 1989. Circadian changes of forestomach motility and of rumination in camels. Asian-Australasian Journal of Animal Sciences **2**:301-302.

Kaskous S. 2016. Importance of camel milk for human health. Emirates Journal of Food and Agriculture **28**:158-163.

Kassilly FN. 2002. Forage quality and camel feeding patterns in Central Baringo Kenya. Livestock Production Science **78**:175–182.

Khademi TG. 2017. A review of genetic and biological status of Iranian two-humped camels (Camelus bactrianus), a valuable endangered species. Journal of Entomology and Zoology Studies **5**:906-909.

Khan B, Leteef M, Bilal MQ, Iqbal A, Hassan R. 1998. A study on some of the activity patterns of Camelus dromedarius maintained in Thal area of the Punjab Pakistan. Pakistan Journal of Agricultural Sciences **33**:67-72.

Khan BB, Iqbal A, Riaz M. 2003. Production and Management of Camels. University of Agriculture, Faisalabad, Department of Livestock Management.

Khaskheli AA, Khaskheli MI, Khaskheli AJ, Khaskheli AA. 2020. Assessment of the food base and eating behaviour of camels in different regions of the world. Journal of Veterinary Sciences & Animal Husbandry **8**:103.

König HE, Skewes O, Helmreich M, Böck P. 2014. Macroscopic and histological investigation of guanaco footpads (*Lama guanicoe*, Müller 1776). Journal of morphology **276**:331-341.

Konuspayeva G, Faye B, Loiseau, G. 2009. The composition of camel milk: a meta-analysis of the literature data. Journal of food composition and analysis **22**:95-101.

Lainez MM, Hsia LC. 2004. Effects of season, housing and physiological stage on drinking and other related behavior of dairy cows (*Bos taurus*). Asian-australasian Journal of Animal Sciences **17**:1417-1429.

Lee SM, Kwon JC, Kim EJ. 2012. Effect of Stocking Density on Eating Behavior of Finishing Hanwoo Steers (*Bos taurus coreanae*). Journal of the Korean Society of Grassland and Forage Science **32**:397-404.

Li H, Cui I, Wang Y, Qiu H, Afedo SY, Huang Y, Bai X. 2020. Distribution and microstructure of intrarenal arteries in Bactrian camels (*Camelus bactrianus*). Histology and Histopathology **35**:279-287.

Li Z. 2013. Sex-Age Related Rumination Behavior of Père David's Deer under Constraints of Feeding Habitat and Rainfall. Plos ONE (e66261) DOI: 10.1371/journal.pone.0066261.

Lindgren E. 2009. Validation of rumination measurement equipment and the role of rumination in dairy cow time budgets [MSc. Thesis]. Swedish University of Agricultural Sciences, Uppsala.

MacKay E, VanHoy G, Lakritz J. 2022. Old World Camelids. Pages 624-643 in Niehaus AJ, editor. Medicine and Surgery of Camelids, 4th Edition. Wiley-Blackwell, Oxford.

MACR. 2006. Vyhláška č. 346 ze dne 22. června 2006 o stanovení bližších podmínek chovu a drezúry zvířat. Pages 4411-4421 in Sbírka zákonů České republiky, 2006, částka 107. The Czech Republic.

MACR. 2021. Vyhláška č. 451 ze dne 29. listopadu 2021 o ochraně druhů zvířat vyžadujících zvláštní péči. Pages 6162- 6191 in Sbírka zákonů České republiky, 2021, částka 203. The Czech Republic.

Martini P, Schmid P, Costeur L. 2018. Comparative morphometry of Bactrian camel and Dromedary. Journal of Mammalian Evolution **25**:407-425.

Mason GJ. 1991. Stereotypy: a critical review. Animal Behaviour **41**:1015-1038.

McLean K, Niehaus AJ. 2022. General Biology and Evolution. ages 1-18 in Niehaus AJ, editor. Medicine and Surgery of Camelids, 4th Edition. Wiley-Blackwell, Oxford.

Mengli Z, Willms WD, Guodong H, Ye J. 2006. Bactrian camel foraging behaviour in a *Haloxylon ammodendron* (C.A. Mey) desert of Inner Mongolia. Applied Animal Behaviour Science **99**:330-343.

Ming L, Siren D, Hasi S, Jambl T, Ji R. 2022. Review of genetic diversity in Bactrian camel (*Camelus bactrianus*). Animal Frontiers **12**:20-29.

Ming L, Yi L, Sa R, Wang ZX, Wang Z, Ji R. 2016. Genetic diversity and phylogeographic structure of Bactrian camels shown by mitochondrial sequence variations. Animal Genetics **48**:217-220.

Mohandesan E, Fitak RR, Corander J, Yadamsuren A, Chuluunbat B, Abdelhadi O, Raziq A, Nagy P, Stalder G, Walzer C. 2017. Mitogenome sequencing in the genus Camelus reveals evidence for purifying selection and long-term divergence between wild and domestic bactrian camels. Scientific Reports (e9970) DOI: 10.1038/s41598-017-08995-8.

Nath K, Ranjan R, Narnaware SD, Sawal RK, Patil NV. 2016. A comparative study on sexual and maternal behaviour of bactrian and dromedary camel. Indian Journal of Animal Reproduction **37**:9-13.

Nelson KS, Bwala DA, Nuhu EJ. 2015. The Dromedary Camel; A Review on the Aspects of History, Physical Description, Adaptations, Behavior/Lifecycle, Diet, Reproduction, Uses, Genetics and Diseases. Nigerian Veterinary Journal **36**:1299-1317.

Norton P L, Gold JR, Russell KE, Schulz KL, Porter BF. 2014. Camelid heat stress: 15 cases (2003–2011). The Canadian Veterinary Journal **55**:992.

O'Connor D, Butt B, Foufopoulos J. 2015. Foraging ecologies of giraffe (*Giraffa camelopardalis reticulata*) and camels (*Camelus dromedarius*) in northern Kenya: Effects of habitat structure and possibilities for competition?. African Journal of Ecology (e12204) DOI: 10.1111/aje.12204.

Orban DA, Siegford JM, Snider RJ. 2016. Effects of guest feeding programs on captive giraffe behavior. Zoobiology **35**:157-166.

Oselu S, Ebere R, Arimi JM. 2022. Camels, Camel Milk, and Camel Milk Product Situation in Kenya in Relation to the World. International Journal of Food Science (e1237423) DOI :10.1155/2022/1237423.

Owens FN, Secrist DS, Hill WJ, Gill DR. 1998. Acidosis in Cattle: A Review. Journal of Animal Science **76**:275-286.

Padalino B, Aubé L, Fatnassi M, Monaco D, Khorchani T, Hammadi M, Lacalandra GM. 2014. Could dromedary camels develop stereotypy? The first description of stereotypical behaviour in housed male dromedary camels and how it is affected by different management systems. PLoS One (e89093) DOI: 10.1371/journal.pone.0089093.

Padalino B, Menchetti L. 2020. The First Protocol for Assessing Welfare of Camels. Frontiers in Veterinary Science (e 631876) DOI: 10.3389/fvets.2020.631876.

Padalino B, Rateb SA, Ibrahim NB, Monaco D, Lacalandra GM, El-Bahrawy KA. 2016. Behavioral indicators to detect ovarian phase in the dromedary she-camel. Theriogenology **85**:1644-1651.

Park YW, Haenlein GFW. 2006. Handbook of Milk of Non-Bovine Mammals (1st ed.). Blackwell Publishing, Carlton.

Perez W, König HE, Jerbi H, Clauss M. 2016. Macroanatomical aspects of the gastrointestinal tract of the alpaca (*Vicugna pacos* Linnaeus, 1758) and dromedary (*Camelus dromedarius* Linnaeus, 1758). Vertebrate Zoology **66**:419-425.

Pešková I. 2021. Etologie a potravní chování velbloudovitých [BSc. Thesis]. Czech University of LifeSciences Prague, Prague.

Qureshi AS, Rehan S, Usman M, Hayat K, Umar Z, Sarfraz A. 2019. Quantitative Evaluation of Age-Related Anatomical Characteristics of Selected Digestive Organs of Dromedary Camel. Pakistan Veterinary Journal **40**:175-180.

Ratnakaran AP, Sejian V, Jose VS, Vaswani S, Bagath M, Krishnan G, Beena V, Devi PI, Varma G, Bhatta R. 2016. Behavioral Responses to Livestock Adaptation to Heat Stress Challenges. Asian Journal of Animal Science **11**:1-13.

Reith S, Brandt H, Hoy S. 2014. Simultaneous analysis of activity and rumination time, based on collar- mounted sensor technology, of dairy cows over the peri-estrus period. Livestock Science **170**:219–227.

Reynolds MA, Borchers MR, Davidson JA, Bradley CM, Bewley JM. 2019. Technical note: An evaluation of technology-recorded rumination and feeding behaviors in dairy heifers. Journal of Dairy Science **102**:6555-6558.

Ridge EE, Foster MJ, Daigle CL. 2020. Effect of diet on non-nutritive oral behavior performance in cattle: A systematic review. Livestock Science (e104063) DOI: 10.1016/j.livsci.2020.104063.

Roberts K, Hemmings AJ, McBride SD, Parker MO. 2017. Causal factors of oral versus locomotor stereotypy in the horse. Journal of Veterinary Behaviour **20**:37-43.

Rose P, Roffe S, Jermy M. 2007. Enrichment methods used for bactrian camel (*Camelus bactrianus*) and tufted deer (*Elaphodus cephalophus michianus*) at the East Midland Zoological Society: Twycross Zoo. Ratel **34**:7-11.

Sahoo A. 2020. Camel: A Fast Declining Animal Species but Can Strive with its Unique Climate Resilience and 'Desert to Medicine' Application. EC Veterinary Science **5**:43-57.

Sazmand A, Joachim A, Otranto D. 2019. Zoonotic parasites of dromedary camels: so important, so ignored. Parasites & Vectors (e610) DOI: 10.1186/s13071-019-3863-3.

Scherer CS. 2013. The Camelidae (Mammalia, Artiodactyla) from the Quaternary of South America: Cladistic and Biogeographic Hypotheses. Journal of Mammalian Evolution **20**:45-56.

Schirmann K, Chapinal N, Weary DM, Heuwieser W, von Keyserlingk MAG. Short-term effects of regrouping on behavior of prepartum dairy cows. Journal of Dairy Science **94**:2312-2319.

Semprebon GM, Rivals F. 2010. Trends in the paleodietary habits of fossil camels from the Tertiary and Quaternary of North America. Palaeogeography, Palaeoclimatology, Palaeoecology **295**:131-145.

Si R, Na Q, Wu D, Wu X, Ming L, Ji R. 2022. Effects of Age and Muscle Type on the Chemical Composition and Quality Characteristics of Bactrian Camel (*Camelus bactrianus*) Meat. Foods (e1021) DOI: 10.3390/foods11071021.

Silva ICS, Cutrim JAA, Da Silva EM, Pereira AL, Mesquita SAA, Gomes RS. 2019. Feeding behavior of goats, castrated and uncastrated, supplemented with Vitamin E. Comunicata Scientiae **10**:262-271.

Slepica M. 2018. Faktory ovlivňující přežvykování žiraf (*Giraffa camelopardalis*) [BSc. Thesis]. Czech University of LifeSciences Prague, Prague.

Soriani N, Panella G, Calamari L. 2013. Rumination time during the summer season and its relationships with metabolic conditions and milk production. Journal of Dairy Science **96**:5082-5094.

Stolzl AM, Lambertz C, Gauly M. 2015. Grazing behaviour and dry matter intake of llamas (Lama glama) and German blackhead mutton sheep (Ovis orientalis forma aries) under Central European conditions. Berliner und Münchener tierärztliche Wochenschrift **128**:409–415.

Tabbaa D. 2012. The Economic Significance and Traditional Management of Dromedaries in Syria. Pages 163-168 in in Knoll EM, Burger PA, editors. Camels in Asia and North-Africa-Interdisciplinary Perspectives on their Past and Present Significance. Austrian Academy of Sciences Press, Wien.

Tandoh G, Gwaza DS. 2017. Sex Dimorphism in the One Hump-Camel (*Camelus dromedarius*) from Selected Populations in Nigeria. Journal of Applied Life Sciences International **15**:1-10.

The Bactrian Camels Genome Sequencing and Analysis Consortium. 2012. Genome sequences of wild and domestic bactrian camels. Nature Communications (e1202) DOI: 10.1038/ncomms2192.

Tibary A, El Allali K. 2020. Dromedary camel: A model of heat resistant livestock animal. Theriogenology **154**:203-211.

Turnbull KL, Smith RP, St-Pierre R, Wright ADG. 2012. Molecular diversity of methanogens in fecal samples from Bactrian camels (*Camelus bactrianus*) at two zoos. Research in Veterinary Science **93**:246-249.

Vater AL, Zandt E, Maierl J. 2021. The topographic and systematic anatomy of the alpaca stomach. The Anatomical Record **304**:1999-2013.

Vaughan A, de Passillé AM, Stookey J, Rushen J. 2014. Urination and defecation by group-housed dairy calves. Journal of Dairy Science **97**:4405-4411.

Villettaz Robichaud M, de Passillé AM, Pellerin D, Rushen J. 2011. When and where do dairy cows defecate and urinate?. Journal of Dairy Science **94**:4889-4896.

Wanet s.r.o. 2022. Počasí z meteostanice Bohumín. Wanet s.r.o., Valašské Meziříčí. Available from www.meteo-pocasi.cz (accessed August 2022).

Wanet s.r.o. 2022. Počasí z meteostanice Olomouc Droždín. Wanet s.r.o., Valašské Meziříčí. Available from www.meteo-pocasi.cz (accessed July 2022).

Wanet s.r.o. 2022. Počasí z meteostanice Praha – Libeň. Wanet s.r.o., Valašské Meziříčí. Available from www.meteo-pocasi.cz (accessed September 2022).

Wanet s.r.o. 2022. Počasí z meteostanice Tábor. Wanet s.r.o., Valašské Meziříčí. Available from www.meteo-pocasi.cz (accessed June 2022).

Wang JL, Lao G, Wang GX, Li HY, Xie ZM. 2000. Anatomical subdivisions of the stomach of the Bactrian camel (*Camelus bactrianus*). Journal of Morphology **245**:87-176.

Wang S, Diao QY, Hu FM, Bi YL, Piao MY, Jiang LS, Sun F, Li H, Tu Y. 2022. Development of ruminating behavior in Holstein calves between birth and 30 days of age. Journal of Dairy Science **105**:572-584.

Welch JG, Hooper AP. 1988. Ingestion of feed and water. Pages 108-116 in Church DC, editor. The ruminant animal: digestive physiology and nutrition. Prentice Hall, Englewood Cliffs, USA.

Wheeler JC. 2012. South American camelids - past, present and future. Journal of Camelid Science **5**:1-24.

Yam BZ, Khomeiri M. 2015. Introduction to Camel Origin, History, Raising, Characteristics, And Wool, Hair and Skin, A Review. International Journal of Agriculture and Environmental Research **1**:01-19.

Yang J, Wang D, Liu X, Xu Q. 2019. China's highways threaten wild camels. Science (e1242) DOI: 10.1126/science.aay1264.

Zappaterra M, Menchetti L, Nanni Costa L, Padalino B. 2021. Do Camels (*Camelus dromedarius*) Need Shaded Areas? A Case Study of the Camel Market in Doha. Animals (Basel) (e480) DOI:10.3390/ani11020480.

Zehner N, Niederhauser J, Nydegger F, Grothmann A, Keller M, Hoch M, Haeussermann A, Schick M. 2012. Validation of a new health monitoring system (rumiwatch) for combined automatic measurement of rumination, feed intake, water intake and locomotion in dairy cows. Pages C-0438 in Proc. Information Technology, Automation and Precision Farming. International Conference of Agricultural Engineering-CIGR-AgEng 2012: Agriculture and Engineering for a Healthier Life, Valencia, Spain, 8–12 July 2012, CIGR-EurAgEng, Cranfield, UK.

Zhang H, Yao J, Zhao D, Liu H, Li J, Guo M. 2005. Changes in chemical composition of Alxa Bactrian camel milk during lactation. Journal of Dairy Science **88**:3402-3410.

Zhang Y, Zhong Y, Hong Y, Xue Y, Li D, Zhou C, Liu S. 2019. RAD-Seq data advance captive-based conservation of wild bactrian camels (*Camelus ferus*). Conservation Genetics **20**:817-824.

Zhao D, Bai Y, Niu Y. 2015. Composition and characteristics of Chinese Bactrian camel milk. Small Ruminant Research **127**:58-67.

Zwick RK, Guerrero-Juarez CF, Horsley V, Plikus MV. 2018. Anatomical, Physiological, and Functional Diversity of Adipose Tissue. Cell Metabolism **27**:68-83.

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Appendices

List of the Appendices:

Appendix 1: Daily metabolizable energy requirements for maintenance (MEm) of the Arabian camel (*Camelus dromedarius*) in megajoules per day. Estimates include an additional 10% for minimal activity (Al-Jassim 2019).

Body weight (kg)	MEm (MJ per day)
300	24.9
350	27.9
400	30.9
450	33.7
500	36.5
550	39.2
600	41.9

Appendix 2: Metabolizable energy requirements for growing and mature camels (Al-Jassim 2019).

Body weight (kg):	100	150	200	250	300	350	400	450	500	550	600
MEm required (MJ/d):	10.9	14.8	18.4	21.7	24.9	27.9	30.9	33.7	36.5	39.2	41.9
Daily gain, kg											
0.10	14.9	18.8	22.4	25.7	28.9	31.9	34.9	37.7	40.5	43.2	45.9
0.20	18.9	22.8	26.4	29.7	32.9	35.9	38.9	41.7	44.5	47.2	49.9
0.30	22.9	26.8	30.4	33.7	36.9	39.9	42.9	45.7	48.5	51.2	53.9
0.40	26.9	30.8	34.4	37.7	40.9	43.9	46.9	49.7	52.5	55.2	57.9
0.50	—	—	38.4	41,7	44.9	47.9	50.9	53.7	56.5	59.2	61.9
0.60	—	—	—	—	48.9	51.9	54.9	57.7	60.5	63.2	65.9
0.70	—	—	—	—	—	55.9	58.9	61.7	64.5	67.2	69.9
0.80	—	—	—	—	—	59.9	62.9	65.7	68.5	71.2	73.9
0.90	—	—	—	—	—	—	66.9	69.7	72.5	75.2	77.9
1.00	—	—	—	—	—	—	70.9	73.7	76.5	79.2	81.9

Appendix 3: Digestible crude protein (DCP) and total crude protein (TCP) maintenance requirements for camels (g/day) (Al-Jassim 2019).

Body weight (kg)	DCP (g/day)	TCP (g/day) *
100	72.7	120.3
150	98.7	163.3
200	122.4	202.5
250	144.7	239.4
300	165.8	274.4
350	186.1	307.9
400	205.6	340.2
450	224.7	371.8
500	243.1	402.2
550	261.3	432.3
600	278.8	461.2

*Total crude protein estimates were calculated using a total tract apparent digestibility coefficient value of 63.46% (Farid, 1995) and with added 5% as a safety margin.

Appendix 4: List of observed animals (Pešková 2023).

Institution	Name	Sex	Birth	Body condition	Note
Camel Farm Záhostice	Šajtan	male	2005	normal	castrated
	Khán	male	2008	normal	castrated
	Eda	male	May 2013	normal	
	Sába	female	spring 2011	leaner	lactating
	Gejša	female	March 2012	normal	lactating
	Gobi	female	autumn 2014	normal	lactating
	Amra	female	spring 2015	normal	
	Lenka	female	spring 2022	normal	Sába X Eda
	Farrid	male	spring 2022	normal	Gejša X Eda
Prague Zoo	Ibrahim	male	16/04/2016	normal	
	Sofia	female	24/04/2010	fatter	
	Sara	female	04/04/2017	fatter	
	Fidorka	female	15/04/2019	leaner	lactating
	Morgana	female	25/06/2013	normal	
	Margotka	female	16/06/2021	normal	Sofia X Ibrahim
	Hynek	male	01/05/2022	normal	Fidorka X Ibrahim
Olomouc Zoo	Eliška	female	1995	very lean	arthrosis
	Tereza	female	2011	normal	
	Masafi	female	2019	leaner	
	Lorenzo	male	2017	normal	
Ostrava Zoo	Spiša	female	05/02/2004	normal	
	Polly	female	10/03/2007	normal	
	Youri	male	03/04/2011	normal	
	Sněženka	female	08/03/2013	normal	lactating
	Flo	female	25/02/2014	leaner	
	Gioja	female	05/05/2013	normal	
	Katniss	female	12/04/2014	normal	lactating
	Muf	male	04/03/2021	leaner	Flo X Youri
	Hubert	male	06/03/2022	normal	Katniss X Youri
	Sarah	female	05/04/2022	normal	Sněženka X Youri

Note: "X" in the column Note indicates that the animal is an offspring of these animals.