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Review
Sensory and feeding enrichment in ruminants and equines

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Contents

1 Executive Summary

In this review we summarise the current literature on sensory abilities, sensory enrichments and feeding enrichment materials/solutions for ruminants and equines. Relevant references from each species are included, and gaps in knowledge are identified when references are lacking. The review is not exhaustive, but represents the more recent, and relevant studies on the topics. The review first outlines the limited information available about the sensory abilities of the species considered with regards to the five senses: hearing, olfaction, touch, vision, and taste. The review then summarises the available literature on sensory enrichment, which like the one on sensory abilities, is very sparse. In general, research has focussed on visual abilities. Although much remains to be studied, there seems to be good potential to use the sensory abilities of the considered species to enrich their environments. The review further outlines current knowledge about various types of feeding enrichments, focusing on diversity and variety of feed, sensory familiarity, feed neophobia, and mode of presentation. There seems to be good potential to enrich the lives of the species considered by acting on feeding methods, strategies and substrates. Lastly, the review highlights key factors to focus on during welfare inspections, as well as gaps in the currently existing knowledge. These points lead to the suggestion of future highly relevant research areas within all topics, which could increase enrichment for all species considered.

2 Foreword

Domestic ruminants and equines are kept in a wide range of environments with varying complexity, from individual housing in barren pens to rearing in large groups in semi-natural environments. The richness of the environment has an impact on animal welfare. EURCAW *Ruminants & Equines* proposed to review the available knowledge on environmental enrichment for the species covered by the Centre. The first review introduces the issue of environmental enrichment in general: What does a enriched environment mean? What are the various types of enrichment and what are the main consequences of a poor vs. enriched environment? Then separate reviews address the various types of enrichment: occupational and physical enrichment; sensory and feeding enrichment; and relational enrichment (including the impact of the presence of conspecifics and that of other species including humans). The goal is to understand the underlying mechanisms and how they impact on the various animal types. Directive 98/58/EC for the protection of farmed animals mentions ethological (behavioural) needs, but not positive emotions or enrichment. Directive 2008/119/EC for the protection of farmed calves further specifies that calves must have visual and tactile contacts and must be kept in group from the age of 8 weeks. Directive 2010/63/EU for the protection of animals used for scientific purposes mentions enrichment, in reference to the expression of behaviour and the reduction of negative emotions (stress). For the purpose of EURCAW *Ruminants & Equines* the reviews on enrichment will therefore mainly address enrichment relevant to behavioural or sensorial needs and will make no distinction between animals used for farming or scientific purposes.

3 Definitions

The present review addresses the enrichments relevant to sensory stimulation and to feeding.

Sensory enrichment can be defined as the modifications of the environment that stimulate one or more of the animal's five senses, which are sight, hearing, smell, touch and taste, in order to improve animal welfare. Sensory enrichment does not refer to only the sensation (detection of sensory information by a sensory receptor), but requires a positive perception of the stimuli involved (organisation, interpretation and conscious experience of them; Rørvang et al., 2020) and/or a cognitive stimulation (Coren, 2003). Consequently, the environmental conditions whose investigation is limited to their ability to improve animal comfort and/or reduce injuries (e.g. flooring substrates: cattle (Tuyttens, 2005); sheep (Færevik et al, 2005)), without addressing their cognitive sensory stimulation for providing positive emotions, are not considered in the review. Besides, as established in the review on the introduction to enrichment in ruminants and equines (Botreau et al., 2023[a]), the environmental conditions that only satisfy basic needs are not considered as enrichments. For example, the provision of light to avoid obscurity, or of "silence" to avoid loud sounds, are not covered by the review. Instead, the stimulations induced by changes in light quality (in time and space) or in music provision, along with the questioning of choices of the individuals, fall within the scope of the review.

The impact of sensory stimulations will depend on the sensory abilities of the different kinds of animals concerned. The first section is thus devoted to review the literature about these abilities. It has to be noted that important discrepancies exist in the knowledge referenced for the different herbivorous species, both with regard to sensory abilities and enrichment studies. Camelids but more importantly buffaloes, bison and deer are very poorly represented in the literature on these topics. All the environments in which animals are housed stimulate the animal's senses as these senses are vital for survival and adaptation. Therefore, all types of enrichment (e.g. physical, occupational, relational, feeding) have multiple dimensions, including a sensory dimension. In order to avoid overlap between reviews, a distinction has been made. As an example, brushes for scratching/grooming can fall within both physical, occupational and sensory enrichment. Brushes and human stroking are considered in the present review as a tactile stimulation dimension. Similarly, the consideration of visual horizons and friendly human voice are included in the present review.

Feeding enrichment can be defined as the modification of the environment related to feed and feeding that stimulates the animal and elicits positive emotions. It involves modifications to the feed (nature, diversity) and the way it is delivered to the animals (accessibility in time and space). In that way, feeding enrichment is not independent from the occupational and physical enrichment. Feeds are characterised by their biochemical composition (contents in nutrients, fibres, etc.) and by their sensory properties (odour, taste, etc.). In this review, we address feeding enrichment sequentially through the lens of nutritional and sensory characteristics. For the sake of clarity, sensory enrichment related to the sense of taste is dealt with the feeding enrichment, as feed is the main source of taste stimulation in the animal's environment.

4 Scientific knowledge on animal needs and abilities

4.1 Sensory abilities

In the sections below we present a brief introduction to the sensory abilities of the species considered. Research on the sensory abilities of domestic ungulates, including the considered species, is sparse. The knowledge presented here is thus by nature incomplete.

4.1.1 Cattle

Sight **-** Cattle have a panoramic view encompassing 320-330°, with limited overlapping sight in front of the head (Entsu et al., 1992; Phillips, 2002). The acuity of vision is 1/22 and hence slightly less than the human acuity that is 1/12 (Entsu et al., 1992). Cattle have both rod and cone receptors, and thus distinguish colours (Gilbert and Arave, 1986; Phillips and Lomas, 2001; Riol et al., 1989), especially those in long wavelengths (yellow, orange, and red) but may have difficulty in distinguishing the shorter wavelengths (blue, grey, and green) (Riol et al., 1989). Cattle are very sensitive to motion and contrasts of light and dark (Grandin, 2000).

Hearing **-** Cattle hear sound frequencies from 23 Hz to 35 kHz (compared to 20 Hz to 20 kHz in humans) with a best frequency set at 8 kHz (Heffner and Heffner 1983; Watts and Stookey 2000 for review). Amplitudes at or above 85 dB seem aversive for cattle (Arnold et al, 2007; Johns et al, 2015).

Smell **-** Cattle possess a great number of functional genes coding for the olfactory receptors: 900-1100, depending on the study, compared to about 800-900 in dogs and less than 400 in humans (Lee et al., 2013; Niimura et al., 2015), which would confer them with good olfactory abilities. Cattle are equipped to detect different types of odours such as fatty, sour, hay-like, sweet, rancid or spicy odours (Lee et al., 2013). Cows are able to distinguish between complex odours (coffee and orange juice) (Rørvang et al., 2017), and to recognise conspecifics or human emotional states using olfactory cues (Destrez et al., 2021)(Baldwin 1977). Using their vomeronasal organ, cattle may be able to detect pheromones indicating the reproductive state or stress state of conspecifics (Terlouw et al., 1998; Boissy et al., 1998).

Taste **-** Cattle perceive the five primary tastes (Phillips, 2002; Waldern and Van Dyk, 1971). Cows have approximately 20,000 taste receptors on their tongue, compared to less than 7000 for humans and 1700 for dogs (Roura et al., 2008). Taste perception, discrimination thresholds and preference change with age (Phillips, 2002).

Touch **-** Cattle perceive tactile stimulations in many situations such as feeding or social interactions (positive such as licking, agonistic, with humans) (Schmied et al., 2008; Laister et al., 2011). Such perception may lead to discrimination or learning, as well as positive/negative appreciation of the stimulations. During human stroking, cattle seem to prefer neck/withers zones than chest as it is the case in intraspecific licking. Cattle are also able to detect low electric currents and are disturbed by these at lower levels than humans (3-mA, 0.7V) (Henke Drenkard et al., 1985).

4.1.2 Sheep and goats

Sight **-** Sheep and goats have a wide field of vision (290° and 320-340°, respectively) and both have good ability to see in low light (Adamczyk et al., 2015). Sheep and goats have a dichromatic vision with a sensitivity to yellow-green (552-555 nm) and blue-purple (444-445 nm) colours (Jacobs et al., 1998; Adamczyk et al., 2015). Sheep can discriminate objects differing in brightness (Bazely and Ensor, 1989).

Hearing **-** Sheep have similar hearing sensitivity to humans but greater sensitivity for ultrasounds (Kendrick 2008) that may make them sensitive to machine sounds. The auditory range of sheep is from 125 Hz to 42 kHz with the best frequency of hearing at 10 kHz (Heffner and Heffner, 1992). The auditory range of goats is from 78 Hz to 37 kHz with best frequency at 2 kHz (Heffner and Heffner, 1992).

Smell **-** Sheep can detect olfactory cues both via the olfactory epithelium and the vomeronasal organ (Adamczyk et al., 2015). The sense of olfaction is particularly important for the establishment of sexual behaviour in female and the ewe-lamb bond at birth (Morgan et al., 1975), and is also involved in the recognition of the flock mates (Fisher & Matthews, 2001).

Taste **-** Sheep have the lingual receptors for the four basic tastes (Bell and Kitchell, 1966), the fifth taste, umami has not yet been investigated. Sheep and goats express preferences or rejection, depending on the taste and its intensity, indicating they perceive them (Ginane et al., 2011 for review). Goats express stronger preferences for sweetness than sheep. Sheep are also quite tolerant to bitterness, at least at low intensities, but less than goats (Goatcher and Church, 1970).

Touch **-** Sheep and goats are sensitive to tactile stimuli. For example, goats detect insects on their muzzle during feeding (Berman et al, 2019). Both goats and sheep are sensitive to intraspecific and human tactile stimulation inducing increased vigour after birth, avoidance/approach or relaxation states (Miranda-de la Lama and Mattiello, 2010; Coulon et al., 2015; Nowak and Boivin, 2015). Social tactile interactions are rare in adult sheep, except body contact during rest, rumination or in stressful situations; they are more frequent in goats, whether positive or negative.

4.1.3 Equines

Sight **-** Horse have a wide field of vision of about 350° (Timney and Macuda, 2001). Horse's eyes have a slow adaptation to changes in luminosity but a good scotopic vision. They are able to discriminate yellow, green, blue, and red boxes from grey (Hall et al., 2006), but have difficulty in discriminating red or blue from grey, with individual variability (Blackmore et al., 2008). Horses have two small blind zones when the neck is horizontal: one just under the nose, the other just behind the tail, but they disappear as soon as the horse moved its head. There are anatomical differences between the donkey, mule, and horse eyes (for details, see Wissdorf et al. (2021) which may affect the way these species perceive and thus react to stimuli in their environment.

Hearing **-** Horses' hearing range is 55Hz to 33.5kHz, with the best sensitivity between 1-16kHz (Heffner and Heffner 1983). They do not have a very precise localisation, from 12° to 22-30° (Heffner &Heffner 1992; Timney and Macuda, 2001) and appear unable to localise pure tones of 2kHz and higher (Timney and Macuda, 2001). Donkeys could be less sensitive than horses to loud sounds (Gonzalez-De Cara et al., 2017).

Smell **-** Horses possess a similar number of olfactory receptor genes as cows (Niimura et al., 2015). Equine nostrils permit stereo-olfaction for localisation of the odour (Stoddart 1980). Lindsay and Burton (1983) documented the existence of the vomeronasal organ in horses. The sense of smell is important in social encounters, and horses show interest in sniffing urine or faeces (Crowell-Davis and Houpt, 1985). Mutual sniffing is commonly observed during greetings (Rubenstein and Hack, 1992; Saslow, 2002) and sexual behaviour (Stahlbaum and Houpt, 1989). Horses can also discriminate between human emotional odours (Sabiniewicz et al., 2020). The olfactory bulb is smaller in donkeys and is rotated more forward than in horses. For detailed anatomical differences of the donkey, mule, and horse see Wissdorf et al (2021).

Taste **-** Generally, horses are able to perceive sweet, bitter, salt and acid in water, and there is large individual variation (Randall et al 1978).

Touch **-** A recent review suggests that equids clearly react to tactile stimulation but not necessarily positively and that the strong variability among studies would require further research (Gueguen et al., 2022). In donkeys, based on the the use of Von Frey filaments, Gonzalez-De Cara et al. (2017) showed that the body areas with the highest sensitivity in donkeys are the withers, back, forelimbs, ribs and stomach (on both sides), while the lowest sensitive areas are the neck, rump, hindlimbs and the front.

For detailed review of all equine sensory abilities see Rørvang et al., 2020.

4.1.4 Camelids

Sight - As camelids have a high placement of their head on a long neck (Faye et al., 2022), and due to the retinal structure of the eye, camelids are considered to have high visual acuity (Harman et al., 2001).

Hearing - Ali et al. (2022) has concluded that camelids have an efficient hearing in desert conditions. Notably, the dimensions of the cochlear parameters of the inner ear mean that camels hear low frequencies even over large distances (Ali et al., 2022).

Smell - The olfactory receptors in camel are unusually located in the rostro-dorsal part of the nasal septum (Abo-Ahmed et al., 2021). Chen et al (2009) found that the rhinencephalon of the Bactrian camel brain was well developed, accordant with a good olfactory sense.

Taste - The attraction of camel for halophytes and aromatic plants neglected by other grazers is well known (Faraz et al., 2022). The histological structures of the papillae on the tongue of camel were similar to those of other domestic mammals, but the well-developed von Ebner's glands suggested their abundant serous secretion reflecting a high gustative ability (Elhassan, 2022).

Touch - The camel skin is thick but highly sensitive. Camel skin is devoid of skin muscle unlike horses and consequently cannot ward off the flies by shaking the skin (Faye et al., 2022). The skin structure of camel is similar to that other ruminants (Jarrar and Faye, 2012) but relatively poor in zinc (Kamili et al., 2020) explaining its sensitivity to skin diseases (Faye et al., 2022).

4.2 Feeding

Most domestic herbivores are generalists and select diverse diets as soon as they have the opportunity to do so (Duncan et al., 2003). They also generally select a diet of better quality than the average value of the available vegetation (Arnold, 1981). The selection of several feed types or plant species occurs in very contrasting situations, both indoors and outdoors, in simple (binary choice) and heterogeneous (dozens of available feed items) feeding environments, with high but also low-quality feed items (cattle: Ginane et al., 2002a; sheep: Agreil and Meuret, 2004; goat: Šarić et al., 2014). This occurs even when one of the feeds is nutritionally balanced or of high quality (cattle: Ginane and Petit, 2005; horse: Goodwin et al., 2002). Consuming a diversified diet may thus appear as a "natural" behaviour for domestic herbivores, which may require, from a positive animal welfare perspective, being provided with such diversity along with the opportunity to express explorative and selective behaviours (Zanon et al., 2022).

The motivation of herbivores for diversified diets is supposed to be due to complementary processes. The "satiety hypothesis" is based on transient aversions for nutrients (Provenza, 1996) and sensory characteristics (Rolls, 1986) along with monotonous feed consumption. The "nutrient balance hypothesis" (Westoby, 1974) is based on the optimisation of diet composition relative to needs, by combining different feeds as a single plant cannot fulfil all of the animal's nutritional requirements (Parsons et al., 1994). The "detoxification limitation hypothesis" (Freeland and Janzen, 1974) is based on the avoidance of the saturation of detoxification pathways relative to each plant's secondary metabolite. The search for optimal ruminal conditions (Cooper et al., 1995), the need for regular sampling of the feeds offered, to update and gain knowledge about them (Westoby, 1974), and the motivation to diversify the sensory properties of the selected diet (Rolls, 1986) are also hypothesised.

This widespread choice for diversity questions the impact of feed monotony on the satisfaction of animal needs and expectations relative to the feeding domain (Beck and Gregorini, 2020; Leiber et al., 2020), both from a nutritional and sensory point of view, while a large part of domestic herbivores are fed with monotonous diets for weeks and months. This is the case for dairy cows or goats on total mixed rations or low diversified fertilized pastures, fattening bulls or lambs as well as horses in riding houses or used for sport or competition that are fed on highly concentrate diets with only limited amounts of straw or hay.

Space and time diversity and variety in feeds on offer may provide animals with the opportunity to compose their diet by mixing feed items, relative to their own nutritional needs and sensory preferences (Villalba et al., 2010; van den Berg et al., 2016). They may also allow taking account of temporal variability in animals' needs and preferences and allow animals to have some control over their environment by having the possibility to make choices (Beck and Gregorini, 2020). Feed diversity *sensu largo* (diversity and variety) thus would provide opportunities for feeding enrichment for an improvement of animal well-being.

Feeds are characterised by sensory properties (detectable before ingestion: texture, odour, taste, etc.) and by biochemical composition (detectable after ingestion: contents in nutrients, fibres, minerals, secondary compounds). Both participate in feeding preferences and are interdependent. Notably, evolutionary processes have shaped feed palatability consistently with their nutrient or toxin contents. This can make the assessment of their respective influence difficult. The literature nevertheless suggests that one can act on both aspects to enrich the feeding environment of the animals, with different potential benefits for them.

5 Minimising welfare problems and supporting best practices

5.1 Sensory enrichment

5.1.1 Visual

5.1.1.1 Light

Offering an animal a choice of, or control over the lighting in its environment potentially increases welfare. Studies on the topic are however sparse. In a study where calves could turn the lights on or off as they wanted, they spent 67% of time with light on (16h/24h) (Baldwin and Start (1981). In dairy cows, enrichment with light, to supplement natural light, showed different effects depending on whether the natural day length was declining or increasing and on the location of the light enrichment (Phillips et al., 1998). Providing supplementary light only in the lying area have adverse effects on cow's production and welfare in decreasing day-length, such effects were not recorded for increasing day-length.

5.1.1.2 Visual horizons

In cattle, providing access to a view of the surroundings does not affect the use of the loafing area, suggesting that their view has little motivational value for cattle (Haskell et al., 2013). In horses, on the contrary, having a view of an inaccessible space increases stereotypic behaviours and decreases the time spent resting compared to having a view of neighbouring horses (Cooper et al., 2000; Lesimple et al., 2020). There is no evidence of the effects of light or visual horizons on other ruminant or equine species.

5.1.2 Auditory

5.1.2.1 Musical enrichment

Music seems positively perceived by cattle. In dairy cows, the exposure to country music stimulates the voluntary approach to being milked (Uetake et al., 1997), the exposure to classical music during milking increases milk let-down speed (Kıyıcı et al., 2013), and milking frequency by an automatic milking system inceases when cows are provided with slow music (Lemcke et al., 2021: 74 pieces of various type (classical, rock, blues, etc.) with a tempo of less than 100 bpm). Playing music in the barn results in less stereotypies, less vocalisations and more locomotive behaviour (Crouch et al., 2019: 4 h per day of classical music, country music, or audiobook). Additionally, when exposed to classical music and audiobooks, cows display more positive social interactions. In sheep and goats, data is sparse and the published studies are quite unconvincing due to weaknesses in methods or in results presentation. In horses, exposure to classical music increases ingestive behaviour, decreases stereotypies as well the time spent vigilant (Huo et al., 2021), and positively affects their emotional state (race horses, Stachurska et al., 2015). Hartman and Greening (2019) showed that classical music exposure at night led to increased ingestion and recumbent resting behaviours. During stressful situations such as transport, classical music can induce a faster post-stress heart rate recovery (Neveux et al. 2016). During farriery, these effects are not observed.

Beyond music, Sueur and Pelé (2019) proposed that animals can be exposed to radio broadcast or television. Radio broadcast is a complex acoustic stimulation mixing human voice and different types of music. In studies on some captive species (including cattle), exposure to radio broadcasts is associated with a decrease in stress indicators or agonistic interactions, or an increase in productivity (Wells, 2009). Sueur and Pelé (2019) stated that animals should be allowed to turn on/off the radio to be stimulated when they wish, however not all animals in a group will have the same motivation.

5.1.2.2 Friendly human voice

In dairy calves, a study showed that positive behaviour from the stockperson, which includes talking calmly to animals (and also gently petting), was associated with animals expressing a higher degree of positive mood (Qualitative Behaviour Assessment, Ellingsen et al., 2014) and lower fear reactions to people (Lensink et al., 2001). In horses, soothing vocal cues do not enhance an animal's ability to perform a novel potentially-frightening task (Heleski et al. 2015). Trösch et al. (2019) found that horse behaviour and heart rate vary depending on the tone: horses react negatively to an angry human voice and positively to a joyful human voice. Results from Lansade et al. (2021) indicate that horses are sensitive to pet-directed speech (the way people spontaneously talk to their pets, similar to baby talk),and that pet-directed speech can thus foster communication between people and horses.

5.1.3 Tactile

5.1.3.1 Opportunities to scratch and human stroking or brushing

In natural conditions, when trees are available, animals use them for scratching different body regions (Kohari et al., 2007). When no trees are available, brushes can be set up in farming systems to satisfy the need of grooming of all species tested, who use them daily. Examples of studies for various species are as follows: cattle: DeVries et al., 2007; Mandel et al., 2013; sheep: Tamioso et al., 2017; goats: Stachowicz et al., 2018; Gomes et al., 2018; horses: Lansade et al., 2022. Brushes are particularly used on body regions hard to reach like the head and the neck (cattle: DeVries et al., 2007; Van Os et al, 2021; horses: Lansade et al., 2022). Cattle prefer automatic rather than stationary brushes (Strappini et al, 2021). The use of brushes have been associated with a decrease in aggressive or stereotypic behaviours (cattle: Ninomiya and Sato, 2009; Meneses et al., 2021), while allogrooming was either increased (horses: Lansade et al., 2022) or decreased (cattle: Meneses et al., 2021) when brushes are present.

If animals are habituated to close human presence, human stroking or brushing is a good way to induce positive emotions as indicated by observed relaxation postures (ears, stretched neck position), reduced heart rate and parasympathetic activation, or oxytocin release (calves: Westerath et al., 2014; dairy cows: Schmied et al., 2008; Proctor and Carder, 2014; sheep: Coulon et al., 2015; Tamioso et al., 2017; horses: Lansade et al., 2018). Dairy heifers can also search for human proximity after just being stroked by humans (Bertenshaw and Rowlinson, 2008) and sheep prefer the human who brushed them relative to a familiar handler who did not (Chaumont et al., 2021). Nevertheless, regarding human brushes or stroking, Westerath et al. (2014) mentioned that some animals could never perceive them as rewarding. The presence of the dam, particularly if untamed, can be also a strong factor that limits the effect of human proximity and stroking in cattle (Boivin et al., 2009), lambs (Boivin et al., 2002) or horses (Henry et al., 2005).

As for all enrichments, brushes should be provided when all minimum standards for animal welfare are met. Indeed, the access to an automated brush does not reduce stress responses in socially isolated dairy cows (Mandel et al., 2019).

5.1.4 Olfactory

5.1.4.1 New odours: for diversity and stimulation

Adding odours to the environment of ruminants and equids can constitute an element of novelty. Studies in cattle olfaction are lacking, and the one study found showed that cattle quickly lost interest in scented enrichment devices (Wilson et al., 2002). Rørvang et al. (2022) showed that all horses approach and sniff odours of non-social origin (here: lavender, orange, cedar wood, peppermint) indicating that horses are motivated to investigate odours.

5.1.4.2 Pheromones for comforting

Results on presumably calming pheromones are conflicting. The actual efficacy of commercially available products must be checked. Falewee et al. (2006) tested a commercially available pheromone (0.1% solution as a spray) in a controlled study on 40 horses and found significantly lower heart rates and less fear-related behaviour in horses treated with the pheromone. Collyer and Wilson (2016) later tested a pheromone gel on horses thought to be experiencing separation anxiety and found no significant effect, except a tendency for the product to dampen extreme anxiety. Berger et al. (2013) tested the pheromone spray during abrupt weaning of foals (n = 14) and found no significant effects of the pheromone treatment on behaviour nor cortisol concentration.

5.1.5 Gustatory

Adding tastes or flavours is considered in the section on « Feeding enrichment ».

5.2 Feeding enrichment

5.2.1 Feeding enrichment - Motivation for feed diversity and variety

5.2.1.1 Stimulation of ingestion

Several studies have observed an improvement of Dry Matter Intake (DMI) when a diversity of feeds is offered to animals. Examples include the studies from Ginane et al. (2002) on cattle, Cortes et al. (2006) and Garrett et al. (2021) on sheep, Šarić et al. (2014) and Murney et al. (2019) on goats, and Goodwin et al. (2002) on horses. They illustrate the increases in intakes as soon as two different types of feed are offered compared to one, a general phenomenon among large domestic herbivores.

The amplitude of the increase is varying, for example, from +10% to 23% in Ginane's study (cattle) to a more than +100% in Šarić's one (goat). This increase is not systematic, since in some studies such increase is not reported (sheep: Catanese et al., 2013; Villalba et al., 2012). The probability for an increase in intake is greater when the feed offered alone is of low quality compared to the additional feeds (sheep: Meier et al., 2014), when the magnitude of differences between feeds is high (as shown in pigs, Middelkoop et al., 2018), and when the number of feed alternatives is high (goat: Šarić et al., 2014). The facility for the animal to sort (even a little) the preferred elements from the monotonous diet (e.g., low facility in a total mixed ration), and the accessibility of the alternatives, also affects the increase in total DMI as these elements affect the rate at which feeds can be consumed.

5.2.1.2 Search for diversity and variety

As mentioned previously, the choice for diversity is widespread in domestic herbivores. Some situations allow highlighting more particularly the animal's motivation for diversity. For example, when one of the feeds is nutritionally balanced or of high quality, one can assume the animal to select only this feed as it provides the best balance of benefits over costs. However, it is not unusual to observe a non-negligible intake of and feeding time on alternatives including when their quality is far lower (cattle: Ginane et al., 2002), when they are the least preferred feeds (horse: Goodwin et al., 2002), or when there is a cost for obtaining the lower value alternatives (cattle: Ginane and Petit, 2005;Meagher et al., 2017). Horses have also been shown to prefer spending time in a stall that provides multiple forages rather than only one (horse: Goodwin et al., 2007).

These responses are often observed in the short-term (up to few days). On a longer term, some studies have shown a progressive extinction of partial preferences (sheep: Favreau et al., 2011), suggesting that a long-lasting diversified diet can become monotonous. This underlines the potential beneficial effects of feed variety, *i.e.* "the temporal allocation of different feeds" (Garrett et al., 2022) beyond feed diversity. The motivation for feed variety is mostly expressed by a temporary increase in preference for the feed not recently consumed, including when it is of low quality (cattle: Ginane et al., 2002; sheep: Favreau et al., 2010).

5.2.2 Feeding enrichment – Benefits of feed diversity and variety

5.2.2.1 Lower stress levels and improved welfare

Feed diversity is associated in some studies with lower stress levels, expressed either as lower levels of cortisol or lower lymphocyte numbers (sheep: Catanese et al., 2013), or as lower occurrence of stereotypical (sheep: Garrett et al., 2021) or agonistic behaviours (horse: Jørgensen et al., 2011). The effects of feed diversity on cortisol levels vary between studies, some studies showing low (sheep: Villalba et al., 2012) or no effect (cattle: Lagrange et al., 2021).

One hypothesis is that food diversity can increase the time spent foraging (Dumbell and Tackley, 2007; Garrett et al., 2022). This is notably the case when animals are provided with fibrous feeds with a low intake rate such as straw (horses: Lundqvist and Elisabeth Müller, 2022), when they have to seek a patch of herbage at pasture or when they have to sort the preferred feed items within mixtures (cattle: DeVries et al., 2008; sheep: Cortes et al., 2006). So, beyond the nutritional enrichment, the increases in feeding times may make feed diversity an occupational enrichment as well (see Botreau et al. (2023)[b] for the EURCAW *Ruminants & Equines*' review on physical and occupational enrichment).

5.2.2.2 Improvement of performances

Beyond changes in ingestion, some studies have shown an improvement of performance due to feed diversity or variety, such as increases in milk production (goat: Murney et al., 2019) or in daily weight gain (cattle: Lagrange et al., 2021; lamb: Garrett et al., 2021) when offered the choice of several feeds.

5.2.2.3 Benefits for animal health

Feed diversity is beneficial for animal health as it can allow animals to select a feed item that may rectify some disorders. For example, lambs subjected to gastrointestinal parasitic load increase their preference for a feed rich in a secondary metabolite (condensed tannin) (sheep: Juhnke et al., 2012). In another context, dairy cows under subacute ruminal acidosis challenge can increase their selection of longer feed particles supposed to stimulate salivation, where saliva has a buffer effect on pH due to its content of bicarbonates (Keunen et al., 2002; DeVries et al., 2008; Kmicikewycz and Heinrichs, 2015).

5.2.2.4 Improved adaptability to new feeding contexts

Feed diversity can improve the acceptability of novel feeds later in life (sheep: Catanese et al., 2012), which can facilitate feed transitions and lower stress at these new encounters.

5.2.3 Feeding enrichment – Method and pattern of feed delivery

5.2.3.1 Pattern of feed delivery over time

In dairy cows, increasing the number of daily feed deliveries (x1, x2 or x4) increases feeding time and leads to a more even feeding activity over the day, which may limit pH diurnal fluctuations (DeVries et al., 2005). This also allows for a more equal access to fresh feed for all cows and, whilst it does not decrease the occurrence of aggressive interactions, it seems to reduce displacement of the subordinate cows by more dominant ones. This may reduce the variation in consumed diet quality between cows, as their sorting behaviour leads to a decrease in the ration value over the day (DeVries et al., 2005). In sheep, adding a feed delivery improves total intake by simulating feeding activity and over-riding satiety (Baumont et al., 1990a). For horses that are out in a paddock during the day and indoors at night, feeding them both day and night, compared to only at night modifies their time budget by increasing foraging and affiliative interactions while decreasing locomotion, standing alert and agonistic behaviours (Benhajali et al., 2009). Mares fed with "continuous" access to hay present fewer oestrus abnormalities and an increased conception rate compared to mares with access only at night (Benhajali et al., 2013).

Concerning the predictability of feed delivery, one study in milk-fed calves shows that animals accustomed to irregular or regular feed delivery do not differ in behaviours, indicating that predictability may not be so important to them. However, occasional deviations in a predictable scheme induces frustration behaviour (Johannesson and Ladewig, 2000). In horses, a delayed feeding time induces a greater expression of frustration as well (Zupan et al., 2020).

5.2.3.2 Way of feed delivery

In dairy cows, increasing feeding space, but above all, adding feed stalls leads to increased feeding time and lower displacements of subordinate cows, thereby improving their access to the feed and lowering social competition (DeVries and Von Keyserlingk, 2006). In fattening steers, the addition of a drum can for hay delivery inside the pen in addition to a conventional trough, increases the frequencies of active behaviours including feeding time once the steers had habituated to the drum can (Ishiwata et al., 2006). More steers also fed at the drum can than at the trough, the authors suggested that the drum may better facilitate the expression of foraging behaviour. In goats, when animals have the choice between feeders positioned at three different heights, from the ground level to an elevated level (upward angulation of head and neck mimicking the browsing posture), they consume more feed and at a higher rate from the elevated feeder (Neave et al., 2018). A greater level of competition between goats is also observed, as shown by a higher frequency of displacements at the elevated feeder. This indicates a higher motivation of goats for the elevated feeder that promotes their natural browsing posture. Elevated troughs should be in sufficient number to avoid competition. In horses, offering hay in a hay-bag, hay-net or other types of slow-feeders increases the time spent eating compared to offering hay without such devices (Rochais et al., 2018; Correa et al., 2020). The slow-feeders can decrease the occurrence of abnormal behaviours and increase positive behaviour toward humans. However, hay-bags can also increase the expression of frustration behaviours (Rochais et al., 2018).

5.2.3.3 Feed processing

In dairy calves, the provision of wheat straw as a supplement of the starter diet, decreases non-nutritional behaviours and increases solid feed intake, but the particle size of wheat straw has no effect on feeding behaviour nor on other activities (Bagheri et al., 2021). This may be due to the small difference in particles sizes (1, 4 or 7 mm-long). When differences are greater (3-4 cm vs. 2 mm) for grass hay, calves express lower non-oral behaviours, greater intake and diet digestibility with the coarsely-chopped than with the finely-chopped hay (Montoro et al., 2013). In sheep, providing hay in rolls (i.e. round bales) induced a lower frequency of the abnormal wool-biting behaviour post-feeding, compared to animals offered hay as bales (Huang and Takeda, 2017). The rolled hay is supposed to allow sheep expressing normal foraging movements, thus preventing the frustration due to the lack of oral stimulation with baled hay (Huang and Takeda, 2018). Similarly, in fattening lambs, when animals are provided with long straw, they spend more time foraging and playing and express less stereotypies than when they receive chopped straw (Aguayo-Ulloa et al., 2019). When lambs can choose between the two, they clearly prefer long straw.

5.2.4 Sensory enrichment from feeds

Within the feeding activity, the sensory stimulation coming from feed is important although it is difficult to dissociate from the nutritional value of the feed. They bear diverse roles such as a way to discriminate between feeds, a means of pleasure or a cue to the feed value (Favreau-Peigné et al., 2013). In this section, we will focus on the hedonic value of feed sensory characteristics, i.e., on their palatability, as a potential enrichment for the animals in the pleasure they can provide them with during their feeding activity. Complementary to elements presented in the section on the nutritional enrichment, the feed sensory characteristics will be considered for their own value, independently from the feed nutritional value, as much as possible.

In humans, the hedonic value of feed sensory properties can override the satiety signals, decreasing their ability to stop feeding (Yeomans et al., 2004). In herbivores, some feeds are more palatable than others (e.g., grain or fresh sward) sometimes leading to excessive intake (Baumont et al., 1990b). In studies where the post-ingestive consequences of the feeds or flavours are controlled, animals often express clear preferences for some feeds, flavours or tastes (sheep: Favreau et al., 2010a, c, b; horses: Goodwin et al., 2005), with different degrees of variability between individuals. This indicates that large herbivores are sensitive to the sensory properties of feeds.

5.2.4.1 Diversity and variety in feed sensory properties

The sensory-satiety hypothesis states that the hedonic response to the sensory characteristics of a given feed changes and decreases as the feed is consumed (Rolls, 1986), motivating the animal to search for alternative feeds or flavours (Provenza, 1996). This theory has been applied to large domestic herbivores and suggests that these animals are sensitive to diet monotony and that diverse oro-sensorial stimuli affect the motivation to eat and so may constitute a feeding enrichment. The studies that investigated the effects of diversity or variety in feed sensory characteristics, independently from the nutritional ones are few in number.

In sheep, the access to a given ration flavoured with different basic tastes or flavours can slightly increase total intake (Villalba et al., 2011, +4 to +8%), although this depends on the study and the type of ration (Distel et al., 2007; Villalba et al., 2015). In the study by Villalba et al. (2011), this tended to be accompanied by an increase in lambs' growth (+26%). Feed sensory properties can greatly influence short term choices with a clear preference for the forage that was not previously consumed, independently from the associated post-ingestive consequences (sheep: Favreau et al., 2010c).

5.2.4.2 Sensory familiarity to decrease neophobia

Feed neophobia can be a problem when animals are confronted with drastic changes in diet during their productive life (Costa, 2015). Neophobia occurs as a protective mechanism towards potentially negative consequences of eating an unknown feed. It is all the more important if the exposure to a new feed occurs in an unfamiliar environment (Burritt and Provenza, 1997). Flavour learning, notably the one that occurs in young age (pre- and postnatal) can help animals to cope with stressful events such as weaning when they are re-exposed to the known flavours during those events (e.g., in pigs: Oostindjer et al., 2011). In <u>sheep</u>, the use of a familiar flavour of a new feed can increase its acceptance by animals as seen by an increased intake and intake rate (Launchbaugh et al., 1997) including from the first day of exposure (Tien et al., 1999). In <u>goats</u>, the intake of the fragrant plant *Chromonaela odorata* during gestation, induces a greater acceptance of the plant in their kids after weaning (Hai et al., 2012), suggesting the development of a sensory familiarity that decreases neophobia.

5.2.4.3 Mode of presentation

In <u>horses</u>, wetting or wetting and sweetening the feed (oat) increases the willingness to eat, indicated by a lowered smelling time before feeding, a longer feeding time, lower breaks in feeding activity, and lower amounts of leftovers (Stachurska et al. 2022).

Table 1: Summary of sensory and feeding enrichments found in the scientific literature and their relevance for ruminants and equines. ✓ = tested and relevant, -- = tested and controversial effects, ✗= tested and not relevant, ? = not tested but probably relevant (expertise), ▒ = not tested and uncertain

	Enrichment	Roles/needs covered	Comment	Cattle	Buffaloes	Bisons	Goats	Sheep	Horses	Donkeys	Camelids	Deer
Sensory enrichment	Light	Supplementary indoor light		--								
	Visual horizons	Decrease boredom	Lead to frustration if inaccessible	--					✗			
	Music	Decrease stress		✓	?	?	?	?	✓	?		
	Friendly human voice	Decrease stress		✓	?	?	?	?	?	?	?	?
	Supports to scratch, human stroking/brushing	Grooming, positive emotions	Human stroking: depends on human proximity, prior experience and forced or not	✓	?	?	✓	✓	✓	?	?	?
	Odours and pheromones	Decrease boredom and anxiety	Very sparse studies	--					--	?	?	?
Feeding enrichment	Feed diversity and variety	Stimulate ingestion, pleasure	Choice between feed is better	✓	?	?	✓	✓	✓	?	?	?
	Increased feed delivery frequency	Stimulate feeding, decrease competition	Warning if deviates from a predictable scheme	✓	?	?	?	✓	✓	?	?	?
	More space at trough	Increase feeding, decrease competition		✓	?	?	?	?	?	?	?	?
	Slow-feeder	Increase foraging activity and time	Can lead to frustration if too much slowing effect				?	?	✓	?	?	
	Elevated feeder	Browsing behaviour	For browsing species				✓					?
	Longer straw/hay particle length	Increase foraging activity and time	Tested on young animals	✓				✓				
	Wet feed	Increase foraging							✓			
	Sensory familiarity on new feed	Decrease neophobia		?			✓	✓	?			

6 Key factors to focus on during welfare inspections

Factors to focus on during inspection of sensorial and feeding enrichment are listed below.

6.1 Factors related to sensory enrichment

- Light and visual horizons: providing the animals with a choice or a sense of control over the light in their environment might improve their welfare
- Music and friendly human voice: Music and friendly human voice can lower stress, provide positive affective states, and be perceived as positive social interactions
- Scratching and stroking: an opportunity to scratch against a physical device or being stroked by a human can induce behaviour indicative of positive affective states
- New odours: exposure to a more complex olfactory environment with non-aversive odours can add diversity and olfactory stimulation
- Pheromones: should be used with caution because potential positive effects have not been demonstrated in the considered species

6.2 Factors related to feeding enrichment

- Strategy for feed delivery: attention required regarding the predictability of feed delivery for the animals. Be aware that occasional deviations can have a negative impact
- Strategy for feed delivery: favouring a greater number of feed distributions
- Presence of solutions for increasing feeding duration: long-fibre feeds, hay nets or slow-feeders, considering that they are available for all individuals
- Places at trough: at least one per animal, more is better
- For goats: height of trough or feeder. Elevated position to be favoured, but considering a good availability for all goats and all feeds (otherwise risks of aggressive social competition).

7 Gaps in knowledge and further studies needed

As clearly illustrated in *Table 1*, much scientific knowledge is still lacking concerning sensory and feeding enrichment for ruminants and equines.

7.1 Gaps related to sensory enrichment

- “Music” enrichment: ruminant and equine species have hearing abilities close to those of humans. The studies cited in this review that investigated music as an enrichment showed globally positive effects, in horses and cattle. This encourages further investigations on the potential of music, notably in other species, and for a variety of acoustic stimuli, so as to identify those characteristics of “music” that make such sounds enriching or not: frequency, amplitude, type, volume, duration of play, time of play; and to understand the underlying mechanisms: masking-effect of the ambient noise or specific positive effects (Wells, 2009).
- Enrichment from brushes: the literature shows that both ruminants and equines appreciate brushes, but some preferences are referenced between static, automatic or human-mediated ones. It would be useful to understand the relative influences of the tactile vs. occupational

vs. social (or relational) incentives in making brushes an enrichment and in motivating the animals to use them. It could also be useful to know the number of brushes to have for a given herd size. This could help choosing the type of brush depending on the objectives.

- Olfactory enrichment: although herbivorous species are considered to have good olfactory abilities, there is a lack of knowledge on how these abilities may be used to enrich their environment. The hypothesis of a comforting effect of familiar (or conditioned) odours previously associated with positive experience or environment, or of appeasing/stimulating effects of pheromones or essential oils, deserve to be tested, even if the manipulation of odours may not be easy on farm. As for the auditory enrichment, the area of research is vast and many factors could be tested such as the type of smell, intensity and dose effect, duration and area of exposition, animal's stage of life, species, experience, etc., with the need to identify priorities.
- For auditory enrichment, and a lesser extent olfactory and visual, the enrichment applies to all animals within a given area (wide reach). Particularly for these kinds of enrichment, attention will need to be paid on the individual variability relative to the effects of enrichment and to animal preferences. Solutions for allowing animals to escape stimuli will also have to be considered.
- For tactile enrichment,considering aspects such as flooring types/designs could add more to the welfare of the ruminants and equines than lying or walking comfort. Offering animals a choice between flooring types should be tested to check if the choice *per se* increases welfare.

7.2 Gaps related to feeding enrichment

- Sensory enrichment from feeds: very few studies investigated the hedonic aspect of offering a diversity or variety of feeds while controlling for the effects of the nutritional properties. Effects on positive emotions and affective states as well as on feeding motivation, and consequences on animal health and performance, at different time scales and considering individual variability, deserve to be tested.
- Feed diversity vs. variety: there is no study that compares these two modes of offering feeding enrichment for ruminants and equines. As they may fulfil different expectations in animals and imply different constraints for the farmer, their effects on animals (motivation, anticipation, impact on stereotypical behaviour, performance) should be compared. Effects should be investigated over different time periods.
- Feed diversity for allowing each individual to select its own appropriate diet: this is considered an important benefit of feed diversity in recent reviews but has not been comprehensively tested (excepted relative to toxic feeds or to nutritive ones in nutrient-deficient animals). Knowing whether and when animals are able or not to self-regulate (nutrient balance, self-medication), including when highly palatable feeds are provided, should be investigated.
- Feed diversity for facilitating feeding transitions: periods of changes in diet composition may be challenging for the ruminants and equines, particularly when they are not familiar with the new feeds, due to a neophobic process. Consequences can be important in terms of intake level, welfare and performance. The potential of feed diversity (habituation to diverse feeds, notably in young age) to lower neophobia and facilitate feeding transitions, deserves to be investigated.

8 Conclusions

The review highlights a need for more information about the sensory abilities of ruminants and equines, in order to promote research on sensory enrichment, which is hugely underrepresented in the research field on enrichment. Generally, the available research focusses on visual abilities of the animals, and on topics directly linked to increasing production output. Although a large amount of research remains to be done, there seems to be good potential to use the sensory abilities of the considered species to enrich their environments. Olfactory enrichment by use of novel or calming odours, auditory enrichment in the form of music, tactile enrichment in the form of brushes are areas with good potential. In relation to feeding enrichment, knowledge is also sparse, although there seems to be potential to increase the use of feed for enriching the environment. Areas of potential impact could be by increasing diversity and variety of feed, using this to avoid/circumvent feed neophobia and adapting the mode of feed presentation. Collectively, this review highlights two under represented areas of enrichment; sensory and feeding enrichment, which warrant further research. More knowledge could constitute a vast potential to increase enrichment materials, strategies and procedures for all species considered.

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About EURCAW *Ruminants & Equines*

EURCAW *Ruminants & Equines* is the third European Union Reference Centre for Animal Welfare. It focuses on ruminant and equine welfare and legislation, and covers the entire life cycle from birth to the end of life. EURCAW *Ruminants & Equines*' main objective is a harmonised compliance with EU legislation regarding welfare in EU Member States. This includes:

- Directive 98/58/EC concerning the protection of animals kept on farms;
- Regulations 1/2005/EC and 1099/2009/EC concerning their protection during transport and slaughter;
- Directive 2010/63/EU concerning the protection of animals used for scientific purposes;
- Directive 2008/119/EC laying down minimum standards for the protection of calves.

EURCAW *Ruminants & Equines* supports:

- Inspectors of Competent Authorities (CAs);
- Ruminant and equine welfare policy workers;
- Bodies supporting CAs with scientific expertise, training, and communication.

Website and contact

EURCAW *Ruminants & Equines*' website offers relevant and actual information to support enforcement of ruminant and equine welfare legislation.

We offer a 'Questions to EURCAW' service for official inspectors, policy workers, and other personnel providing advice or support for official controls of ruminant and equine welfare in the EU. For more information go to https://www.eurcaw-ruminants-equines.eu/questions-to-eurcaw/.

Activities of EURCAW *Ruminants & Equines*

- Coordinated Assistance
  Providing support, networking and Questions to EURCAW;
- Welfare indicators, Assessment & Best Practice
  Identifying animal welfare indicators, including animal based, management based and resource based indicators, that can be used to verify compliance with the EU legislation;
- Scientific and technical studies
  Preparing Scientific Reviews of knowledge on welfare topics and identify research needs;
- Training
  Developing training materials and training standards for official inspectors;
- Communication and Dissemination
  Increasing awareness of our outputs via the website, twitter, and newsletter;

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