

POSITION PAPER

The relevance of feed diversity and choice in nutrition of ruminant livestock

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In this position paper, we argue that the realisation of forage diversity and feed choice for ruminant livestock should be considered as an essential aspect of animal welfare because selection from an array of different plants is an important experience for such animals. We provide examples that diet balancing with regard to nutrients and plant secondary metabolites is particularly for ruminants so much essential that this ability must be a deeply rooted cognitive and behavioural predisposition. In this context, we assume feed choice to be a behavioural need of ruminants. Therefore, we argue in favour of nutritional concepts, which account for botanical and biochemical diversity and are based on behavioural research approaches. We provide a brief outlook of potential research topics, which we consider important if the societal target of animal welfare is to be reached in European ruminant production systems.

1 Feeding as part of animal welfare

Animal welfare cannot be defined only by the absence of distress like fear, pain, hunger, and disease; it also must include the presence of certain stimuli, including eustress (Villalba and Manteca, 2019), and the opportunity to express key species-specific behaviour (Fraser et al., 2013). The latter is realised in many livestock systems to a very limited degree or not at all. Degrees of freedom in social and reproductive behaviour are extremely low, as is the range of movement

and the opportunity to explore the environment compared to situations in wildlife for the same species. A further aspect of behaviour, which appears to be underestimated in its meaning to animals in agriculture, is feed selection, including the experience of taste, smell, exploration, and choice. Using ruminants as an example, the presented position paper argues that feed choice could be a fundamental physiological and behavioural need of herbivores. Therefore, neglecting it in contemporary feeding schemes would imply a serious violation of welfare.

2 Biological background

In their natural feeding behaviour, animals do not primarily optimise the ratio of spent over gained energy. They often rather prefer to explore and to search for less easily accessible feed (Inglis et al., 1997), select not only nutrients but also bioactive plant compounds (Villalba et al., 2010), and thereby maintain diurnal rhythms (Rutter, 2010) and balance metabolic processes (Villalba et al., 2010). There appear to be several evolutionary reasons for the development of such behaviour. For herbivores, the balancing of their diets by combining feed plants with different nutrient profiles is essential for digestive efficiency and metabolic health. Since these nutrient profiles change with phenological stage, the animals have to be able to adapt their behaviour continuously (Westoby, 1978). However, the challenge is not only

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to balance nutrients like proteins and carbohydrates. Herbivores also have to avoid or select potential toxins in certain situations, e.g. when they are needed in low dosages in order to control diseases or metabolic processes (Villalba et al., 2010; Poli et al., 2018). For ruminant livestock, this has also a veterinary aspect (Walkenhorst et al., 2020).

Diet balancing (Westoby, 1978) and targeted selection for or against specific secondary plant metabolites have a further dimension in ruminants: control of the foregut fermentation process. The rumen microbiome is sensible to diet characteristics regarding degradability of carbohydrates as well as energy to protein balances (Snelling et al., 2019), but also concerning bioactive compounds such as saponins (Goel et al., 2008) and polyphenols (Vasta et al., 2019). Balance of nutrients (including their ruminal degradability) is important in order to avoid inefficient utilisation of protein or energy but also to prevent collapse of the rumen, for instance, by rumen acidosis or bloat. However, there are also other differentiated balances, which the ruminant has to maintain in the foregut, for instance in order to protect essential plant metabolites from ruminal degradation. One illustrious example is linolenic acid, which is the only relevant source of omega-3 fatty acid configuration for herbivores. More than 95 % of ingested linolenic acid, which is essential for many functions in the mammal organism (Sinclair et al., 2002), may be lost by derivatisation in the rumen (Chilliard et al., 2007). Given this example, it is our hypothesis that a foregut-fermenting species must by all means ensure that the microbiome in their stomach is balanced so that not too much of essential plant nutrients are degraded or modified and lost. One effective instrument for the animal to control the rumen microflora are bioactive secondary plant compounds (e.g. essential oils, phenols, alkaloids) with antimicrobial properties (Vasta et al., 2019). Experimental evidence shows that dietary secondary plant compounds can protect linolenic acid in the rumen (Vasta et al., 2019), which results in increased linolenic acid concentrations in milk (Kälber et al., 2011), muscle and adipose tissue (Willems et al., 2014). The case of linolenic acid is an example that shows the importance of rumen control by finely dosed ingestion of secondary plant metabolites. We hypothesize that this requires a highly differentiated feed selection ability of the ruminant. The concept of nutrient balancing (Westoby, 1978) must therefore take into account these substances, also considering the trade-off with fermentation efficiency in the rumen, which makes the task for the (wild) ruminant even more challenging.

3 Does feed choice have an emotional implication?

Nutrients, as well as secondary plant metabolites, possess odour and taste properties, such as sweet, bitter, astringent, or sharp but also specifically aromatic (Wichtl, 2009). A neuronal relation between metabolic needs for (or excess of) certain substances and the odour and taste experience is therefore strongly developed in ruminants (Ginane et al., 2011). A sensory feedback, based on genetic determination (Clausen et al., 2010), epigenetic effects (Wiedmeier et al., 2012), and

individual experience (Villalba and Manteca, 2019) influences dosed selection or refusal of nutrients and bioactive plant compounds ingested from the natural forage environment in which ruminants have evolved. We should consider that the ability to translate metabolic needs into flavour-guided differentiation of herbal biomass must be deeply rooted in the ruminants' behaviour because it is a precondition of their survival and evolution. This ability is expressed in various examples of self-medication in ruminants (Villalba et al., 2010; Poli et al., 2018). A further aspect of selective eating behaviour is diurnal alteration in preferences as described by Rutter (2010), who found that ruminants decrease their preference for protein-rich forage during the course of the day. Another study demonstrated high sensibility of the diurnal eating and rumination rhythm of dairy cows to even small changes in monotonous mixed rations (Leiber et al., 2015). It seems likely that ruminants are able and show a behavioural need to influence their "gut feeling" in accordance with their sensory feedback by actively choosing not only the composition but also time, duration, and amount of intake.

Diet selection by ruminants has thus at least three inter-related levels of implication: (i) the physiological need for selection, (ii) the translational processes, which connect physiological needs with sensorial experience and action, and (iii) the emotional importance for the animal to display a differentiated explorative behaviour in challenging environments (reviewed by Villalba and Manteca, 2019). We consider the emotional level of behavioural experience to be possibly so much important that the deprivation from feed selection may have a highly negative impact, even if all nutrients and phytochemicals are provided in a perfect diet. If animal nutrition does only account for the molecular composition of diets in order to elevate nutrient efficiency to the max, we must assume that the better the nutritionists work, the worse it will be for the animal as a being which needs to have varying sensorial experience. Scientists, which have worked on selection behaviour of ruminants, have clearly stated the possibility of frustration and poor welfare if feed choice is not possible (Rutter, 2010; Villalba et al., 2010). This implies that the standardisation of feed rations for ruminants, commonly used in most European dairy production systems, including organic, impairs welfare and neglects the principle of enabling species-specific behaviour in livestock husbandry in a rather severe way.

4 A paradigm-shift for ruminant nutrition concepts

"Even after thousands of years of domestication, livestock appear to retain at least some of the survival traits that evolved in their ancestors. Rather than ignore these evolutionary traits, we should endeavour to consider them when designing livestock management systems" (Rutter, 2010).

In the light of the above-mentioned considerations, a paradigm shift in agricultural ruminant nutrition is needed with the primary intention to include the animals' feeding behaviour as an integrative aspect into the concepts for livestock nutrition. The discussion on whether it must become

compulsory to diversify and enrich the diets of ruminants and give them opportunities for choice is of particular importance in organic agriculture striving for high animal welfare. How this can be realised largely depends on factors such as farmland resources, animal productivity levels, and trade-off considerations with sustainability issues.

From a researcher's point of view, we need a new feeding recommendation system, which regards the feeding behaviour of animals as a welfare issue. Also, feeding behaviour should be systematically used as an evaluation tool for metabolic needs of the animals, in particular in terms of phytochemicals. This requires a large range of new research, including systematic evaluation of behavioural and metabolic responses of animals to forage plants rich in secondary metabolites and offered separately or integrated into new sward mixtures. Basic research is needed in order to reach a new understanding of ruminant requirements in a dynamic interaction between animal phenotypes and botanical environments (which include barn feeding), respecting temporal patterns of intake and feed choice.

In applied research, practical solutions for the realisation of feed diversity need to be developed and introduced into teaching materials and production standards. Access to pasture swards with high botanical diversity is surely the most direct way to achieve such goals. However, also for winter feeding and for permanent indoor systems, it would be necessary to develop options of forage diversification (more plant species, introduction of browse, sequential offers of different feed qualities, offers on choice). In concentrated feeds, phenol-rich components like buckwheat, spices, or specific oilseeds, but also all kinds of by-products, could be considered. The main target of developments for the practice should be to enable animals to choose their feed or at least to offer feed in sequential variation. On the forage production level, we also need to develop practical solutions for achieving higher diversity (botanical, phenological, biochemical) because the existing knowledge is not yet broadly applicable to agricultural systems.

Depending on different production systems (low-input, high-input, organic, etc.) different approaches are needed to realise feed diversity. If we consider the aforementioned importance of feed diversity for animal welfare, we must also reassess production systems where high milk yields are achieved only on the basis of highly designed diets, which apparently do not provide deliberate feed choices or at least varying feed offers. The question of where diversity and choice can be integrated into diets of high-yielding cows should be an open topic of research. Nonetheless, what we demand is to shift the idea of a perfect diet away from an engineer's work targeted at maximal performance of the ruminal fermentation chamber towards a cooperation project between the researcher, the farmer and the cow with the aim of an optimal balance of the processes in the foregut (Leiber, 2014). Clearly, our approach is much more directed to natural low-input rather than high-input diets. Since the continuation of arable crop inputs into dairy and beef production is challenged for reasons of sustainability (Schader et al., 2015), our suggestion includes a general critique towards

high-performance strategies with cattle. Returning to more natural feeding systems would consequently also include changes in breeding goals towards genotypes better adapted to regionally available resources (Bieber et al., 2019).

5 Conclusion

There is evidence that feed selection behaviour has such high importance for the cognitive well-being of ruminants that access to feed diversity should be a compulsory criterion of welfare. Under this paradigm, always feeding total mixed rations would be no longer acceptable, and new feeding concepts that take into account diversity of feeds are required. It appears that a more natural feeding concept for ruminants can result in several positive effects. Besides the animal welfare and health aspect of more diverse feed and natural feeding, the suggested approach could also result in higher biodiversity of pastures and feed crops, as a positive side-effect. Last but not least, product quality also increases when ruminants receive diverse types of forage with high proportions of herbs. We must therefore pay more attention to these aspects, in practice, in research, and in standards, in particular in the context of organic agriculture.

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