Feed Preference and Feed Intake: Is there a Real-World Link that NASEM Predictive Models Overlook?

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Take Home Messages

- Current and historical equations to predict dry matter intake (DMI) have focused on the physiological aspects that influence feed intake.
- Surprisingly there may already be aspects of the current DMI models that consider feed palatability characteristics including forage fragility and the filling effect of feeds.
- There are large opportunities to explore feed palatability, its subsequent positive or negative influence on animal feed preference and DMI, and potential integration into predictive equations for intake.

Introduction

During the height of the civil war in 1863 the National Academy of Sciences was established to bring scientific experts together and develop scientific and technical recommendations. After some time, in 1906 chemists and applied nutritionists were locked in a debate of animal feed preference. More specifically, one nutritionist declared that "… the cow knows better than the chemist what she likes to eat, and it is little use to offer her foods she does not relish" (Jordan, 1906), whereas chemists commonly believed that animals lack the cognitive precision needed to select their feed. Research activity in feed preference carried on, but with less emphasis. This may be in part because of the efforts demanded for World War II. This was when the National Academy of Sciences formed committees to undertake and assess research that would be used to develop feeding standards for livestock. These feeding standards were commonly referred to as NRC, and later NASEM, for the National Academy of Science Engineering and Medicine, feeding recommendations. This new focus may have contributed to a shift of attention away from studying feed preference and additional efforts placed into controlled feeding experiments aiming to understand chemical characteristics of feed, digestibility and whole-animal physiological mechanisms that controlled dry matter intake (DMI). We speculate that individual feed preference is an important component of the overall variance observed in feed intake (Carroll et al., 2022). Feed preference is at least in part influenced by the 'palatability factors' including aroma, taste, and physical structure. Feed preference can be defined as the action of choosing and it is influenced by these factors. Preference can be measured in a variety of ways such as 'cafeteria' type experiments where animals can select from a variety of feeds to make a 'diet'. However, in dairy cattle two to four ingredients of interest are generally placed in front of the animal for a fixed period of time. In response, the animal will consume the most 'preferred' feed, and subsequently return to its ration. The objective of this presentation is to highlight NASEM predictions for DMI and to discuss how the concepts of palatability and preference may also affect feed intake.

Dry Matter Intake

How does the NASEM predict DMI? The control of DMI within lactating dairy cattle is complex and influenced by both physiological signals and the diet itself, which when combined, affects feeding behaviour and in turn, DMI. In the most recent NASEM publication, DMI is estimated for lactating dairy cows using two different equations:

Eq. 2-1; Page 12:

$$DMI\ (kg/d) = [(3.7 + Parity \times 5.7) + 0.305 \times MilkE\ (Mcal/d) + 0.022 \times BW\ (kg) + (-0.689 + Parity \times -1.87) \times BCS] \times [1 - (0.212 + Parity \times 0.136) \times e^{(-0.053 \times DIM)}]$$

Eq. 2-2; Page 13:

$$DMI\ (kg/d) = 12.0 - 0.107 \times FNDF + 8.17 \times ADF/NDF + 0.0253 \times FNDFD - 0.328 \times (ADF/NDF - 0.602) \times (FNDFD - 48.3) + 0.225 \times MY + 0.00390 \times (FNDFD - 48.3) \times (MY - 33.1))$$

The first equation included animal-based factors that affect DMI such as parity, milk energy (MilkE) output, body weight (BW), body condition score, and days in milk (DIM). This equation was similar to that of NRC (2001) that used animal factors to predict DMI. The second equation was new to NASEM (2021) and included dietary factors such as forage neutral detergent fibre (NDF) digestibility (FNDFD), the ratio of acid detergent fibre (ADF) to NDF, and milk yield (MY). These factors were used to represent the filling effect of feed that is thought to limit DMI through distention. While this may be true in animals greater than 60 DIM (Allen et al., 2019), for animals less than 60 DIM, DMI may be more controlled through chemostatic regulation and thus the first equation may be more applicable.

▪ Cattle Chemical Senses

Taste: Taste is thought to be the most important sense to affect feed preference (Houpt, 2004). In animals, taste receptor cells are located in taste buds and cattle possess 2-3 times as many taste buds as humans. These taste buds are distributed evenly across both halves of the tongue but are in greater quantity on the first two-thirds and especially dense on the tip (Ginane et al., 2011). Like humans, cattle have the ability to taste five distinct flavours: sweetness, saltiness, bitterness, sourness, and umami also known as savouriness (Myers and Coulter, 2004). The mechanisms for taste receptors are not fully understood; however, there are two families of taste receptors including those that can sense sweet/umami, and those that can sense bitterness. Interestingly, salty and sour are not mediated by receptors but by changes in the ion channels.

Smell: Current research regarding the sense of smell in cattle has predominantly been related to pheromones and the vomeronasal organ. Scents pertaining to feed are processed through odorant receptors within the nasal cavity. Interestingly, normal respiration allows for scent to be processed, but a ‘sniffing’ action causes the air to more forcefully contact the scent receptors. Unlike taste receptors, odorant receptors are highly variable across species and have been hypothesized to be selective. More specifically, these odorant receptors differ between species in a similar manner to how different species process visual colours (Myers and Coulter, 2004). Thus, it is difficult to extrapolate human experiences of scent to that of cattle. Due to the close nature of an interplay between smell and taste, food consumption can also be mediated by smell. For example, cattle will avoid consuming forage when feces are placed under, but are not touching, the feed source for a period of up to 35 days (Dohi et al., 1991). However, smell is generally a secondary aspect of preference relative to taste.

▪ Preference and Palatability

What is feed preference and palatability and the associated role on feed intake Feed preference, in its simplest form, is a choice of one feed item over another. Given that animals have their own volition, it stands to reason that the display preference differs across animals (Galef, 1991). Livestock possess what is described as ‘first order preference’, while humans possess both ‘first and second order preference.’ This means that if an animal desires something it will be followed up by a single action whereas humans may desire something but take no action into obtaining it (Jeffrey, 1974). Palatability is defined as feed characteristics or conditions that stimulate a selective response by the animal (Baumont, 1996). Therefore, preference is the action, but palatability is the characteristic(s) that drives that action. One such physiological aspect that influences preference outside of taste includes the cow’s organ of prehension, the tongue. The cow’s tongue moves across a horizontal plane in order to ‘scoop’ feed into the mouth (Hudson and Frank, 1987). Thus, feeds that make this action easier may be more preferred.

▪ Preference and DMI

How do DMI and preference overlap? It has been generally believed that a cow's behaviour could direct her to eat to meet her nutritional requirements. Alternatively, it was also argued that animals were non-discerning and would eat to illness, and thus nutritionists needed to formulate diets to meet their nutritional requirements (Jordan, 1906). An example of eating to illness is a cow accessing grain stores, engorging in carbohydrates (starch), and subsequently developing rumen acidosis (Radostits et al., 2007). Aspects of current DMI equations overlap these concepts. One interesting facet of the NASEM 'feed factor' DMI equation (Eq. 2-2 above) is that it accounts for elements related to diet palatability factors that could be linked to animal preference. This facet is the ADF/NDF ratio, which can be influenced by forage type. This ratio is believed to be related to forage fragility and leaf to stem ratio of the forage. Animals generally prefer leaves over stems (Hodgson et al., 2015). In animals on pasture this choice may also reflect the relative ease of grazing because of lower shear strength. Another concept to consider is the filling effect of these feeds; the NASEM equation 2-2 was designed to at least in part represent this concept. Sheep have been observed to avoid alfalfa hay and prefer feeds like beet pulp and wheat bran after their rumens were filled with balloons occupying 1.8 to 4.5 L (Villalba et al., 2009). Thus, ruminal distention may influence an animal's preference for feeds with different filling natures.

▪ Preference Factors Not Represented in Equations to Predict DMI

Physical Characteristic of Feeds: Forages Sorting

There are opportunities to use laboratory assays to identify and detect some factors that affect preference of feeds. One of the most simple and well recognized signs of dairy animals showing preference is sorting. Animals will generally sort against longer particle size feeds in favour of those with finer particle size (Onetti et al., 2004), but this is not universal and depends on the nature of the long particle. Animals also generally prefer pellets to meals, partly because of the ability of the tongue to sweep and scoop pellets more easily than meals (Krogstad et al., 2021). This aspect of particle size and feed consumption may have application to AMS systems and the use of pellets. Another management strategy to reduce sorting is through the addition of water (Leonardi et al., 2005). A general recommendation for TMR DM content is from 50–60%; however, guidelines for DM content are not well defined and are likely greatly influenced by the forage type included in a TMR. Decreasing DM content of a dry forage diet from 81% to 64% decreased TMR sorting, but decreasing DM from 58% with no dry forage to below 48% can have an opposing effect and increase sorting activity (Miller-Cushon and DeVries, 2009).

Preservation Methods

Along with particle size, organic acids in silage and inherent plant secondary metabolites can decrease palatability by eliciting a sense of sourness and/or astringency resulting in a mix of both bitter and sour tastes. Organic acids are naturally produced through the ensiling of forages. Previous research with goats has shown that DMI can be reduced with even subtle increases in end products of aerobic grass silage fermentation. These end products include ammonia nitrogen and butyric acid (Gerlach et al., 2014). Feed intake in dairy cattle may also be reduced when silages are exposed to air for a period of time and this is caused by unpalatable end products of aerobic fermentation including silage decomposition spurred by moulds and yeasts. Additionally, a poor fermentation with slow lactic acid build up may influence the amount of butyric acid produced by forages and may reduce DMI (Broderick et al., 2002). It is likely that the pungent aroma of butyric acid plays an important role in feed intake. Although butyric acid is also produced in the rumen it is not known if cows can distinguish between the compound originating from the feed versus that from her digesta. Nonetheless, silage practices that affect fermentation and storage such as face management, compaction, and feeding rate may affect the palatability of silages. Fortunately, many of these factors can be tested analytically or even evaluated through human sight, touch, and smell for quick results. However, caution should be exercised in using human senses to 'test' feeds that may contain harmful organisms and mycotoxins.

Secondary Metabolites

Unpalatable flavours can also be inherent to the plant in either grazing or stored forage systems. Plants produce tannins, saponin, and other compounds to naturally protect themselves from predation and pathogens. Tannins are predominantly found in big trefoil, birds foot trefoil, red clover, and perennial ryegrass, with small quantities in alfalfa (Radostits et al., 2007). They may negatively influence feed preference through characteristics of sourness and bitterness (Shewangzaw, 2016) because relative to sheep and goats, cattle possess lower concentrations of the enzymes that bind tannins prior to the cows tasting them. When tea saponin is mixed into a TMR, cows may refuse to eat; this likely is a function of the bitterness but this may be overcome by pelleting the ingredient (Guyader et al., 2017). Unfortunately, analysis of secondary metabolites is time consuming so targeted analysis should occur when plants of high tannin or saponin concentration are used within the ration.

Sugars, Maillard Products

Cattle possess the ability to sense sweetness, and molasses has long been used to enhance preference. Not only is molasses sweet but it acts as a binder to improve feed palatability. Although not a novel concept, the property of "sweetness" has yet to be integrated into DMI equations. One means of conserving sugar content of forage would be cutting in the afternoon when grass sugar levels are high (Kagan et al., 2011). Sugars may also play a unique role in palatability by interacting and bringing forth a 'roasted and caramelized' flavour (Wong et al., 2008). Sugars form complexes with proteins during the heating process resulting in Maillard products. This heating can occur naturally, for example, when alfalfa is baled wet or when byproducts such as distillers grains are dried. For humans, Maillard products are associated with a caramelized taste one gets when consuming foods such sautéed onions or event toasted bread. Previous research has shown that cattle will consume more corn gluten pellets relative to those containing increased sugar content through the addition of molasses indicating that Maillard products taste may be more palatable relative to sugar's sweetness (Carroll et al., 2023). Although Maillard products may be preferred over sugars, sugars may be more easily implementable in future intake equations.

Feed Flavouring

Along with the inherent chemical characteristics of feeds, there are opportunities to influence animal preference for feeds with flavouring agents. These flavouring agents can be used both to mask unpleasant flavours and impart more desirable flavours. For example, molasses has been a long-standing ingredient added to improve palatability. However, there are opportunities to use other ingredients as well. By leveraging on umami and salt taste receptors, sheep have been observed to eat more pelleted straw relative to pelleted alfalfa when it was sprayed with monosodium glutamate (MSG) and salt (Grovum, 1984). Interestingly both of these are flavouring agents that make food more palatable to humans as well. Spices including fenugreek (Migliorati et al., 2005), oregano, and vanilla improve feed preference (Harper et al., 2016; Carroll et al., 2023). Interestingly, oregano not only seems palatable to cows, but may also mask unpleasant flavours such as bitterness in feeds such as hydrolyzed feather meal. Ultimately there are many flavouring agents available that can impart palatable characteristics in feeds, and opportunities exist to use flavouring agents to mask potentially off-putting flavours that may negatively affect animal intake.

Applications and Conclusions

Historically the field of ruminant nutrition has placed emphasis on animal factors in understanding and predicting feed intake. Clearly some feed intake equations already contain aspects related to palatability. Future thought should be given to integrating feed palatability characteristics with equations to predict feed intake. Routine measures such as particle size and sugar content could be implemented in the future equations with greater ease, whereas more time-consuming and costly measures of determining organic acids produced during and after fermentation, secondary metabolites, and Maillard products could be explored to better understand factors that affect feed intake.

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