Fibre, an untapped energy source – the role of the rumen engine

Current context of high price of feed raw materials is driving us to reconsider the importance of farm-grown fibrous material in the ration of ruminant. Indeed, fibre is an essential component of plants which is resistant to degradation by the digestive enzymes of most monogastric animals.

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Ruminants, on the other hand, have the unique ability to release the energy from part of the fibre structure thanks to the fermentative activity of the rumen. Ruminant digestive system has the ability to degrade and ferment fibre through microbial activity. The fibre components, and the subsequent production of volatile fatty acids (VFAs), provide the majority of the energy for the ruminant. Hence, the producer's goal should be to maximise fibre digestibility to extract more energy from the cell wall components of the plant.

Better understanding of how fibre is degraded in the rumen helps identify the levers that can help reach this goal and make sure fibre is no longer an untapped energy source.

From fibre to energy to milk

Fibre is slowly degraded in the rumen due to its physical structure and the lignin cross-linking that holds the fibre intact. Fibre degradation in the rumen is influenced by (Fig. 1):

- The anatomy of the fibre (pectin, hemicellulose and cellulose concentration), which is related to species.
- Lignin content and structure (maturity, species, stressors, etc.).
- Particle size.
- Passage rate (highly influenced by particle size, uNDF, DMI) and its impact on rumen dynamics.
- Cud-chewing and ruminal contractions.

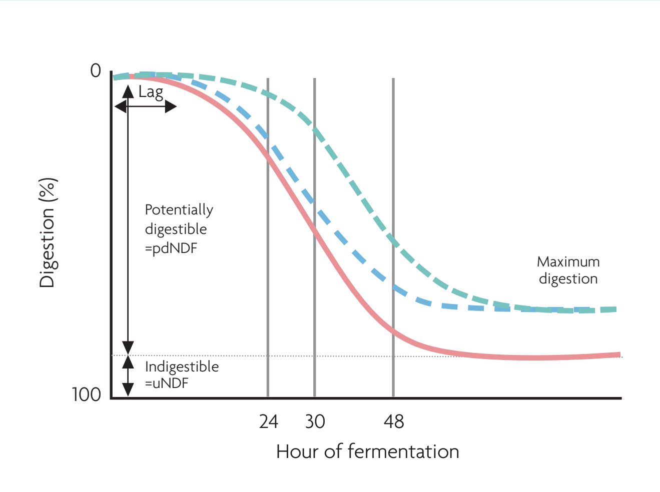

Fig. 1. Fibre digestibility depending on rumen conditions and fibre type (MB Hall, 2014).

- Rumen microbial population (microbiome) influenced by several factors (diet, environment).

The ruminant reduces the particle size of the forage through the eating process via initial mastication (chewing). These particles are swallowed and float to the top of the rumen mass.

The particles are then regurgitated and rechewed (cud-chewing) to increase moisture content and surface area of the material as well as to abrade the fibrous portion.

After initial mechanical abrasion of fibre through mastication, the feed is then exposed to the diverse population of micro-organisms in the rumen.

The first step in fibre degradation is the colonisation in the rumen of the particle of fibre by fungi and bacteria. Fibrolytic microbiota are very sensitive to oxygen. Strict anaerobic conditions (measured though redox potential) are necessary to ensure the maximum colonisation.

Many species of bacteria can produce fibre-degrading enzymes and are broadly categorised as fibrolytic bacteria. Furthermore, other micro-organisms can similarly degrade fibre including protozoa and fungi. Fibre degradation in the rumen is leading to production of VFAs that represents up to 70% of the energy required for milk production. Thus, the efficacy of fibre degradation in the rumen is an important driver of milk production yield.

Oba and Allen have determined that, for every 1% increase in NDF digestibility, milk production increases by 0.24kg/d, and Fat Corrected Milk (FCM) increases by 0.25kg/d.

> +1% NDF digestibility.
> ↓
> +0.25kg per day fat corrected milk.

Factors affecting fibre digestibility

There are several factors that can alter the population of the rumen micro-organisms (rumen microbiome), including the influence of diet.

Ruminal pH and SARA:

Since fibrolytic bacteria need a pH above 6.2, decreases in pH can inhibit their growth and performance. If rumen pH falls below 6.0, fibre digestion in the rumen begins to decline. When ruminal pH falls below 5.8 to 5.9, the rumen is mildly acidic, and fibre digestion in the rumen is disrupted.

Any diet that can alter the pH can negatively impact fibrolytic species and result in reduced fibre degradation (Fig. 2).

This decreased pH can further lead to subacute rumen acidosis (SARA).

SARA can be influenced by a number of factors such as forage particle size, feeding behaviour, starch content of the diet and grain level of the diet.

Impact of particle size:

The particle size of the ingested forage can play a role in fibre digestibility.

Longer particles may increase a lag to digestion due to a lag in hydration and a reduction in bacterial attachment.

Feeding behaviour:

Dairy cattle have the capacity to consume human inedible feed, including the digestion of cellulose, with forages as the main source thanks to grazing and foraging.

The grazing/foraging behaviour would be spread out over a long period of time with frequent small meals.

Considering the modern dairy cow now has access to a total mixed ration (TMR), they typically consume their daily DMI in three to five hours per day, spread between 6 to 10 meals with the largest meal occurring after the delivery of fresh feed.

Rumen pH generally declines after each meal as rumen available carbohydrates are fermented and VFAs are produced.

When VFA production exceeds the ability of the rumen environment to neutralise or absorb the acids, SARA occurs.

The size of the meal and the amount of rapidly fermentable carbohydrates can have an impact on the decline in rumen pH. Having smaller and more frequent meals reduces variability in rumen fermentation patterns as well as the rate of pH decline and the amplitude of the rumen pH.

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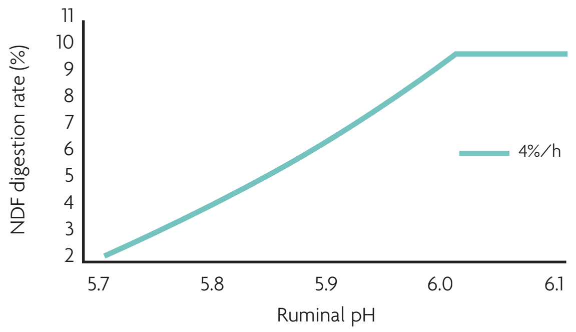

Fig. 2. Impact of the rumen pH on the NDF digestion rate of a raw material (Fox et al., 2003).

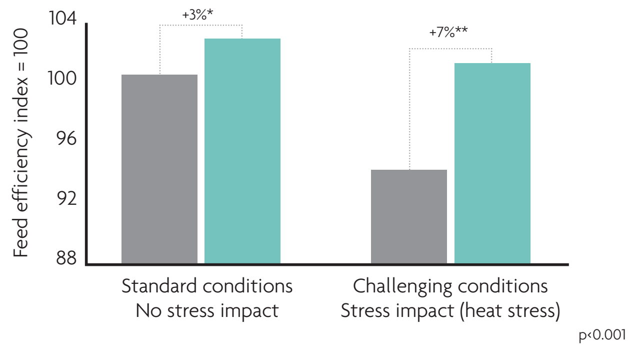

Fig. 3. S. cerevisiae CNCM I-1077 (Levucell SC) effects of dairy cow feed efficiency (average of several trials). Levucell SC improves feed efficiency (+3%*) with a higher effect (+7%) in challenging conditions.**

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In consideration of these factors, it is safe to conclude that changes in feeding behaviour as a result from TMR feedings can increase the risk of SARA.

Changing feeding behaviour can reduce the risk of cows experiencing SARA.

Rumen modifiers:

Rumen specific live yeast Saccharomyces cerevisiae CNCM I-1077 (LEVUCELL SC) used as a feed additive, has the ability to enhance fibre degradation through its rumen modifier effects, translated into higher feed efficiency in dairy cows.

The effects and modes of action of this live yeast on rumen microbiota have been extensively studied. The main effects attributable to this strain include:

1. Stabilisation of ruminal pH.
2. Increase in fibre degradation and the subsequent improvement in digestibility.

In vivo, trials demonstrate the positive effect of S. cerevisiae CNCM I-1077 on NDFd of more than 300 different forage samples, including: corn silage, straw, rye grass hay, alfalfa hay, annual rye grass (pasture), meadow hay, grass silage, etc.

Saccharomyces cerevisiae CNCM I-1077 is found to increase NDF digestibility by 4-8 units, depending on the type of forage and on its own degradability.

Overall, combined data trials indicate a 3% improvement of feed efficiency with the live yeast supplementation, with higher effect under rumen challenged conditions (up to 7% increased feed efficiency, corresponding to a 6:1 up to 9:1 return on investment for the producer under these challenging situations (Fig. 3).

Defining 'fibre':

Different criteria can be measured:

- NDF: Neutral Detergent Fibre. NDF analysis represents total fibre without pectin, which is solubilised into the neutral detergent solution: it contains all the lignin, cellulose, and hemicellulose.
- uNDF: undigested NDF, is the measured part of undigestible forage. It is used to estimate NDF digestibility (NDFd) that is available for digestion.

The difference between what is not digestible and total NDF is the digestible portion of the NDF available for the animal (pdNDF).

Conclusion

Fibre represents the majority of milk energy for dairy cows. Fibre degradability is linked:

- To the quality of the plant material, which depends on both the crop inherent characteristics and its growing environment.
- To the fibre digestion process once it is fed to the animal (mainly located in the rumen).

So, the degradation of fibre is influenced by farming practices and rumen dynamics. Indeed, the rumen can be pictured as an engine that, thanks to its unique microbiome, turns fibres into milk energy.

Management and feeding practices that ensure optimal rumen environment (pH, microbial balance) and function can help that improve the efficiency of the 'rumen engine' for optimal farm revenue. ■