Impact of Yeast Probiotics on Rumen Environment, and NDF and ADF Digestion

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Introduction

The yeast Saccharomyces cerevisiae has been used in ruminants for over 20 years. Globally, live yeast *Saccharomyces cerevisiae* promotes a better diet utilization by the animal: Julien et al. (2015) observed an increase of total organic matter (OM) digestibility in a range of 0.8 to 3.7 points for early-lactating dairy cows supplemented with probiotic yeast (Saccharomyces cerevisiae Sc47, Actisaf®, 10^{10} CFU/g, Phileo Lesaffre Animal Care, France). Regarding fiber degradation, Marden et al. (2008) stated that ACTISAF® supplementation in dairy cows suffering digestive trouble such as SARA definitely increase total fiber digestibility from 29.6% to 41.6%. Probiotic yeast effect at ruminal ecosystem level are mainly driving this impact at animal level.

Ruminal ecosystem

Ecosystem is a functional ecological unit endowed with a certain stability, constituted by a set of living organisms (the biocenosis) exploiting a given environment (the biotope or the milieu). This notion also integrates the interactions between the different species constituting the biocenosis and the interactions between these species and the environment. So there is an ecosystem whenever there is interaction between organisms and a milieu (Fonty and Chaucheyras-Durand, 2007). Therefore, the rumen is an amazing ecosystem: fermentation occurring in the rumen provide the ability to ruminants to produce human edible food. Given the high importance of the rumen fermentation, large part of nutrition research has been designed to optimize the system specifically to improve fibrolysis and microbial synthesis: a great deal of effort has been devoted to investigating methods for manipulating or "engineering" this complex ecosystem (Ungerfeld and Newbold, 2018).

Regarding rumen environment, pH has been identified as a key parameter of characterization of this milieu considering that bacteria composing the biocenosis present their own range of pH sensitivity. More specifically, ruminant depend on cellulolytic ruminal bacteria, but these bacteria cannot resist the low pH, pH sensitivity of cellulolitic bacteria dealing with alteration of enzymatic activity and/or growth (Russell and Wilson, 1996). Specifically, acidity in the reticulo-rumen during Subacute Ruminal Acidosis (**SARA**) has been clearly stated in last decades and threshold values of pH have been proposed considering that the functionality of many rumen bacteria is reduced when the pH drop below these levels (Plaizier et al., 2018). Indeed, background acid–base reactions are essential for the maintenance of all living organisms but also oxidation-reduction or redox potential (**E_h**) are also. Unlike in soil, redox potential has received little attention in rumen as pH was regarded as a master variable (Husson, 2013; Huang et al., 2018). In his review, Huang et al. (2018) put forward that in vivo measurement of ruminal E*h* are scarce mainly due to the difficulties of accurate measurement. By the way, as Husson (2013) for soil, Huang et al. (2017) give evidence that E*h* and pH are respectively and jointly major drivers of microorganism systems.

Redox potential for rumen environment assessment

Julien et al. (unpublished data) reported that positive E*h* values recorded in a buffered sterile rumen fluid, *i.e.* deprived of any living organism, revealed oxidative conditions (+ 270 mV). On the contrary, in vivo E*h* values ranged generally between −220 and −110 mV which confirmed that ruminal reducing conditions directly originated from microbial activity. Furthermore, considering that the evolution of pH with time around meal reveals ruminal metabolism, the simultaneous E*h* evolution seemed to reflect the varying energetic transfers involved (Julien et al., 2010).

A meta-analysis conducted by Huang et al. (2017) gave evidence that dietary characteristics affected ruminal pH but also ruminal E*h* such as NDF, starch or soluble sugars respective contents.

Even if ruminal Eh is not easy to assess in field conditions, it proved to be an endogenous parameter as meaningful as ruminal pH or fermentative profiles, allowing a different focus on rumen metabolism. As a consequence, it has been considered as a precious and interesting tool for investigations in probiotic yeast effect on ruminal ecosystem.

What about yeast impact on ruminal ecosystem

Probiotic yeast (Actisaf®) viability in rumen

It is already known that probiotic yeast is unable to colonize the digestive tract of ruminants, even if large proportion is alive. Monteils et al. (2006) demonstrated that Actisaf® numbers in the rumen, ileum and feces actually decreased to a negligible level 48h after administration of a single dose to dairy cows. However, viable cells recovered from ileal content indicated that Actisaf® could reach cow intestines alive. Actisaf® is not totally destroyed by conditions in the rumen, abomasum and duodenum and can survive in these parts of the digestive tract. Moreover, Julien et al. (2016) demonstrated that probiotic yeast ruminal concentration varied little, as demonstrated by CFU counts taken over 3 days after 18 days of daily supplementation, independently of the diet fed the cows. So it is conclusive that daily supplementation with probiotic yeast Actisaf® is essential to maintain a stable threshold concentration in the rumen ecosystem.

Probiotic yeast (Actisaf®) mode of action in ruminal ecosystem

Different hypotheses were put forward to explain the mechanisms involved in live yeast effects. Therefore, research works brought forward arguments to gain a better insight of the mode of action of live yeast: globally, by inducing higher reducing conditions in rumen (lower oxydo-reducing potential - E_h - values) and pH stabilization, live yeast prevented accumulation of lactate and allowed better fiber digestion for ruminants receiving a diet rich in high fermentative carbohydrates (Marden et al. 2008). This thermodynamic approach of live yeast effect in rumen was unique and still contributes to have a better insight in global rumen metabolism (Marden et al., 2009; Julien et al., 2010). Indeed, the quantitative analysis of the effect of probiotic yeast (Actisaf®) on ruminal redox potential in dairy cow shows that the E_h is a physicochemical parameter of interest for understanding not only the functioning of the rumen but also the ruminal action of the probiotic yeast (Huang et al., 2016). Regulation of ruminal by living yeasts is particularly effective when the risk of ruminal dysfunction is sufficiently high.

According to the results obtained by Marden et al. (2008) who compared live yeast and sodium bicarbonate ($NaHCO_3$), the E_h confirmed to be an important parameter complementing pH measurements. It allows a better understanding of the fermentative activity of the rumen and helps to clarify the mode of action of the probiotic yeast. Supplementation with $NaHCO_3$ and live yeast had the same ability to stabilize ruminal pH after feeding but $NaHCO_3$ had smaller effects than live yeast on ruminal E_h (Figure 1), fermentation, and total tract digestibility (Figure 2).

Figure 1: Effect of Actisaf® and sodium bicarbonate on rumen physicochemical parameters in 3 dairy cows suffering from SARA and allocated in a 3x3 Latin square design (Marden et al., 2008)

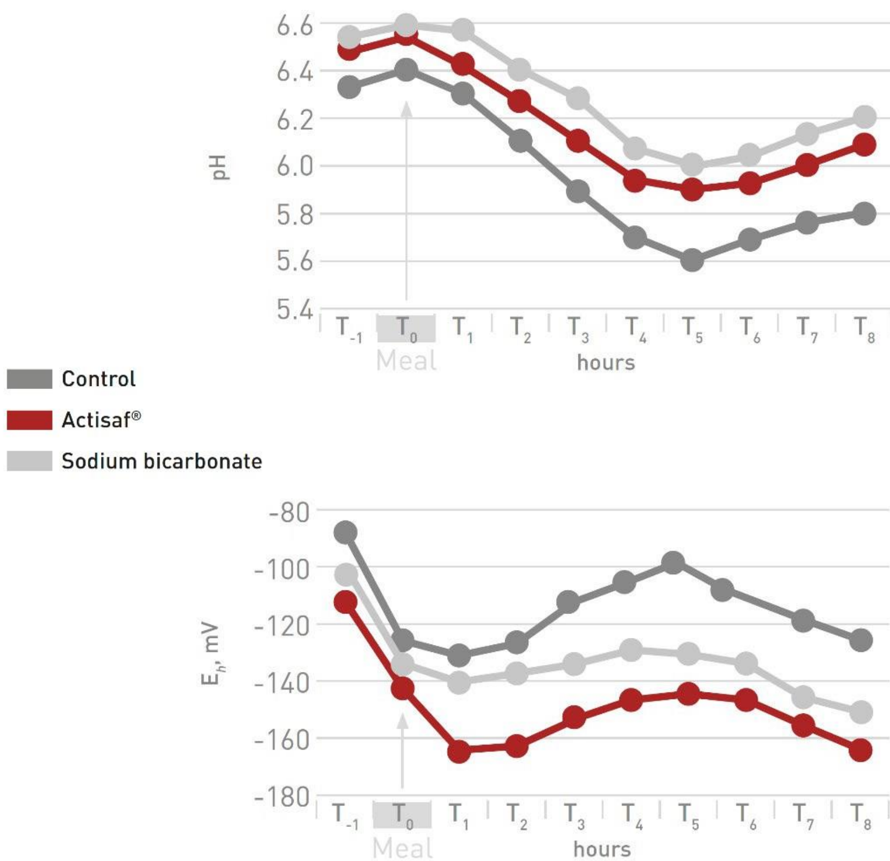
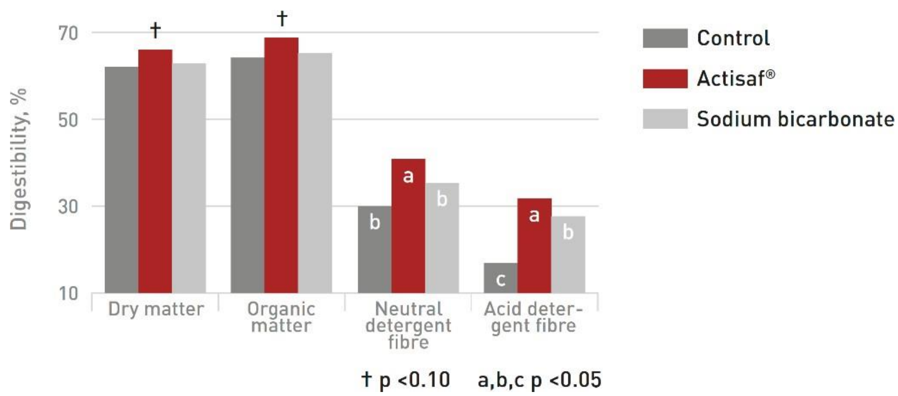


Figure 2: Effect of Actisaf® and sodium bicarbonate on total tract digestibility in 3 dairy cows suffering from SARA and allocated in a 3x3 Latin square design (Marden et al., 2008)



That clearly underlined that the mode of action of $NaHCO_3$ was only to buffer excess acid in the rumen whereas live yeast prevents the accumulation of lactate and allowed better fiber digestion by strengthening reducing conditions of ruminal environment.

In this same school of thought, Pinloche et al. (2013) verified that the effects of live yeast on physico-chemical (pH, Eh) and fermentative (volatile fatty acid and lactate) parameters were accompanied with a shift in the main fibrolytic group *Fibrobacter* and *Ruminococcus* and lactate utilizing bacteria *Megasphaera* and *Selenomonas* species. Also, Julien et al. (2012) confirming the role of probiotic yeast (Actisaf®) as potent microbiota modulator in ruminants considering that probiotic yeast supplementation might permit to decrease inter-individual variability of ruminal bacterial community suggesting a possible stabilizing effect of probiotic yeast (Actisaf®) on microbiota, at least among the 177 genus highlighted in this study.

Conclusion

Probiotic yeast Actisaf® can balance the rumen ecosytem, preventing rumen disorders and improving digestibility and performance in highly productive ruminant. Actisaf® can optimize the rumen environment by reducing the Eh, stimulating the growth and activity of obligate anaerobic bacteria such as lactate-fermenting bacteria and fibrolytic bacteria, leading to feed digestibility and animal performance improvement.

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