POTENTIALS TO ENHANCE THE NUTRITIVE AND HEALTH VALUE OF NATIVE GRAINS FOR RUMINANTS BY PROCESSING

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Abstract. Cereal grains such as maize, barley, wheat, sorghum, and triticale have become important components in the diets of high-producing ruminants. The physical characteristics of grains such as surrounding by a firm kernel coat, small particle size, and high specific density preclude efficient degradation and utilization of grains in ruminants, especially in cattle, which do not efficiently masticate them. Thus, if cattle eat unprocessed grains, these grains escape rumen degradation and leave gastrointestinal tract in undigested form. In order to improve the degradation of grains and optimize the feeding value of cereals in ruminants, grains typically are processed aiming to improve the access of microbial enzymes in the rumen. As different feed processing techniques can affect digestibility, the rate and site of digestion as well as the voluntary feed intake of forages, proper grain processing is a prerequisite to ensure high production efficiency of grain use and health in ruminants. This article deals with various grain processing methods in ruminant nutrition, focusing mainly on those that use chemical agents. The article highlights advantages and disadvantages regarding the use of those processing techniques in improving nutritive and health value of grains in ruminants.

Keywords: cereal grains, grain processing, chemical processing, organic acids, starch, phosphorus

Introduction

During the last 3-4 decades, the feeding practices of ruminants in many parts of the world have recognized important shifts. The traditional forage-only feeding has been more and more replaced by increasing the inclusion amounts of grains, which indeed have become an important dietary component, especially in high-producing ruminants. Compared to forages, cereal grains are less voluminous, highly palatable, safer from both availability and a hygienic point of view, and are also richer sources of energy. On the other hand, compared to forages, grains are rich in starch which is mostly highly digestible (Deckardt et al., 2013), low in fiber, and their feeding in large amounts is not without health risks in ruminants (Iqbal et al., 2009). Their inclusion in the diet in large amounts has facilitated increased energy intake, supporting high milk yields in dairy cows and rapid growth rates in growing ruminants. This has enabled intensive ruminant production systems all over the world, increasing both milk and meat production and the economic efficiency of ruminant production compared with forage-based extensive farming systems. On the other hand, however, the feeding of large amounts of grains has increased the incidence of gastrointestinal and metabolic disorders in ruminants (Deckardt et al., 2013).

Although processing is essential to maximize the utilization of grains by ruminants, extensive grain processing increases ruminal starch degradation, which may negatively affect feed intake as this process also enhances the risk of rumen fermentation disorders (Deckardt et al., 2013). Therefore, the development of effective processing methods for grains in ruminants aims at maintaining an optimal rumen metabolism (Iqbal et al., 2009). Slowing down the rate of ruminal degradation of starch-rich cereals may help reducing the starch availability for microbial degradation in the rumen and shift some starch digestion to the small intestine, a strategy that would help in minimizing the risk for rumen fermentation disorders, and hence improving the health values of grains for ruminants. Thus, processing of grains in ruminants should also target the ruminal fermentability and rumen health (Zebeli and Humer, 2016).

In addition, besides starch, many grains also are a good source of proteins and minerals, especially of phosphorus (P). With such large amounts of grains in the diet of ruminants, the nutritional needs of ruminants in P can be fully met by organic sources (Humer and Zebeli, 2015). However, in cereal grains 60-90% of P is stored as *myo*-inositol-hexakisphosphate (phytate). Although, in contrast to monogastric animals, ruminants can utilize the P stored as phytate almost completely, due to a high phytase activity of ruminal microbes, rumen degradation of phytate may be incomplete, lowering its availability for rumen microbes and the host ruminants (Humer and Zebeli, 2015). An improved utilization of proteins and especially of P from grains by processing of grains improves the nutritive value of grains and lowers inorganic P supplementation in high-producing ruminants.

Processing of grains in ruminants

Main methods used in grain processing in ruminants are physical and chemical methods, which can be applied singly or in combination (Campling, 1991). The former includes techniques that break the outer coat of the grain to allow access of rumen microorganisms and digestive enzymes, e.g. through grinding, rolling and crushing, as well as methods that affect the susceptibility to microbial attack in the rumen and enzymatic action in the intestine, e.g. through heating in addition to rolling to cause gelatinization of starch. On the other hand, some chemical treatments with alkali bring about an effect similar to that of rolling or crushing in enabling access of rumen microbes and digestive enzymes (Zebeli and Humer, 2016). In this regard, treating of whole grain with chemicals to increase digestibility of the kernel coat and

subsequently whole grain digestion within the rumen has been discussed as one strategy to reduce processing costs (for grinding) (Campling, 1991). The methods using chemical agents have also been suggested as a mean to slow down the rate of starch and protein digestion in the rumen to improve fibre digestion with potential beneficial effects on intake and production (Deckardt et al., 2013), which will be treated in more details in the sections below.

The use of sodium hydroxide, formaldehyde and ammonia

Sodium hydroxide (NaOH) is one of the first chemicals used in grain processing. Considerable research has been conducted on the NaOH treatment of grain, suggesting that digestibility, weight gain, and milk production on NaOH-treated whole grain can be similar to that on rolled grain, provided sufficient NaOH and processing time is applied (Kaiser, 1999; Zebeli and Humer, 2016). Treating grains with NaOH has been shown to result in slower ruminal starch and protein degradation as well as in decreased susceptibility to rumen acidosis (Dehghan-Banadaky et al., 2007). However, a number of practical considerations have limited the more widespread adoption of this technology on farms. For instance, negative side effects (e.g. nephrotoxicosis after prolonged feeding of high NaOH-amounts, soil salinification, risks for users as well as adverse effects on nutritional quality) preclude its application as routine technique in the practice (Zebeli and Humer, 2016).

Another chemical that has been widely used to treat milled grains long time ago is formaldehyde (HCHO), which retards the rate of digestion in the rumen of cereal starch and protein, without hampering total tract digestion and may have beneficial effects on forage intake (Campling, 1991; Dehghan-Banadaky et al., 2007). Nevertheless, also environmental and especially health issues have to be considered thoroughly when using HCHO as a chemical to treat feedstuffs for animal production. The HCHO has recently been classified as a potentially cancerogenic chemical (EU regulation 605/2014). Therefore, the use of this risky chemical in feed processing will be limited.

Treatment of grains with ammonia has been successfully used to render ruminal starch and protein degradation of grains, i.e., to decrease their rate of degradation in the rumen (Zebeli and Humer, 2016). In fact ammonia treatment offers a more practical alternative to NaOH, because of positive effects in enhancing the protein value of the treated grain, especially of maize. However, the digestibility and animal production responses have been highly variable in many studies (Dehghan-Banadaky et al., 2007), and research is required to identify effective ammoniation procedures.

The use of organic acids

In recent years there has been an increasing interest to identify new chemical grain processing techniques such as the treatment of grains with mild acids, in order to modify the chemical characteristics of the grain (Deckardt et al., 2013). Recent studies (e.g., Deckardt et al., 2014, Harder et al., 2015) investigated the effects of treating grains with two organic acids such as lactic or citric acid –acids that are widely used as a low-cost means of food preservation – by different industries (Figure 1).

Figure 1. **Treatment of crushed barley grain with citric acid and lactic acid leads to changes in color but also in chemical composition of the cereal (from the experiment of Harder et al., 2015)**

These studies have shown modulation of the chemical composition of barley treated with these acids (Deckardt et al., 2014; Harder et al. 2015). Feeding dairy cows barley grain steeped in lactic acid has been shown to exert some beneficial effects, such as decreasing the starch degradation rate in the rumen (Khol-Parisini et al., 2015; Figure 2), modify ruminal fermentation, and enhancing the energy status of the cows (Iqbal et al., 2009).

The decrease of the degradation of starch in the rumen results in more by-pass starch (i.e., starch that escapes fermentation in the rumen and is available for enzymatic degradation in the small intestine), a strategy which is considered helpful to prevent development of rumen fermentation disorders and enhance gluconeogenesis in ruminants (Deckardt et al., 2013). In contrast to the classical chemical processing techniques, that might even impede P utilization in ruminants, it has been observed, that lactic and citric acid treatments of cereals trigger the hydrolysis of native phytate (Khol-Parisini et al., 2015; Humer and Zebeli, 2015) and enhance ruminal P-disappearance (Figure 2), suggesting a potential of this technique for reducing inorganic P supplementation and P excretion in ruminants.

Conclusions

An ideal processing technique for grains in ruminants must be able to enhance nutritive value, ruminal tolerance, and the health value of the grain. In addition, processing methods need to be cost-efficient and safe for the users, animals, and the environment. Health aspects have become highly important in terms of lowering the risk of metabolic disorders and

promoting feed efficiency, but also in enhancing the nutrient utilization and reducing environmental pollution in ruminants. Depending on the feeding aim and ruminant species, every grain requires special attention in the choice of the processing method. Despite the progress made in using various processing methods in ruminants, the impact of grain characteristics, both physical and chemical, on the response to chemical treatments requires further research. Furthermore, the mode of action of the chemicals used in the host digestive tract remains to be clarified.

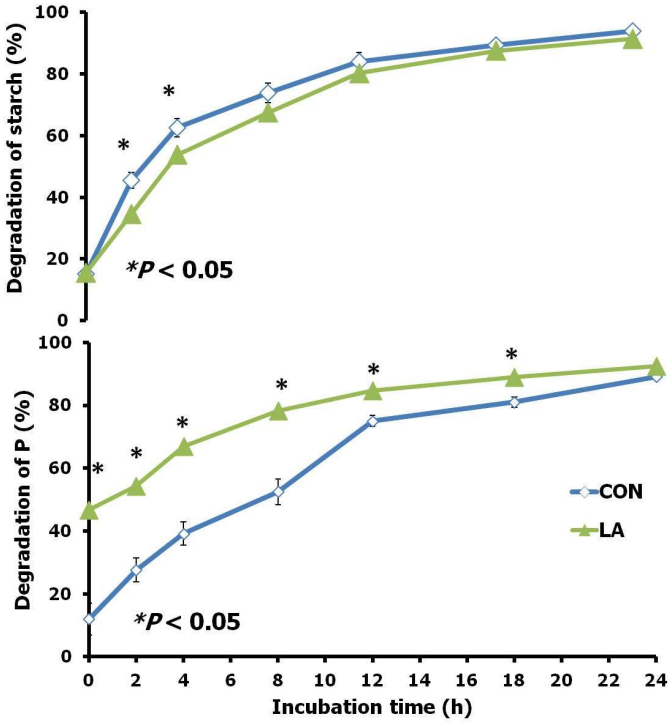

Figure 2. **Treating of barley grain with lactic acid (LA) lowered the *in situ* ruminal degradation of starch (top) and phosphorus (bottom) in LA-treated vs. untreated control (CON) barley samples (adapted from the study by Khol-Parisini et al., 2015)**

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