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Review

Silage processing and strategies to prevent persistence of undesirable microorganisms

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ABSTRACT

Year-round access to good quality forage is a physiological priority for ruminants and an economic priority for farmers. Ensiling is a method for preserving moist crops based on organic acid production by lactic acid bacteria under anaerobic conditions. However, silage can be a vector for undesirable microorganisms, impairing crop preservation, animal performance or the health of both animals and humans.

Major problems in silage processing are due to failure to apply good manufacturing practice (GMP). To improve silage preservation and guarantee the quality of this animal feed, silage additives such as chemicals, enzymes and bacterial agents can be employed.

The purpose of the present paper is to review existing information on the desirable and undesirable microorganisms involved in silage processing, and possible methods, using GMP or silage additives, of limiting silage degradation and its economic effects and health impact on animals and humans.

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1. Introduction

The livestock sector is one of the fastest growing segments of the agricultural economy, particularly in the developing world. As demand for meat and dairy products continues to increase, questions arise as to how this demand will be met and by whom. Access to a permanent forage base is a physiological priority for ruminants and an economic priority for farmers. Forage production is seasonal in many parts of the world, with surplus available during harvest and deficient in winter or in the dry season.

Ensiling is a crop preservation method based on natural lactic acid fermentation under anaerobic conditions (Gollop et al., 2005). Very different plant materials can be used for ensiling: grass, clover, alfalfa, barley, corn, wheat, sorghum (Ashbell and Weinberg, 2006) and various moist "by-products" of the food industry, such as apple pomace, beet pulp and brewer's mash (Ajila et al., 2012). The main purpose of ensiling is to keep forage available throughout the year for use as the main source of feed with high nutritional value for ruminants, thus improving the economic and environmental sustainability of production systems. The most important crops for ensiling are whole crop corn, alfalfa and various grasses (Weinberg and Ashbell, 2003).

Grass, alfalfa and corn silages are among the most widely used components of dairy cow rations due to their high nutritional value and high fiber content. In France corn silage is consumed by about 80% of dairy cows during the year (AFSSA, 2004) and in the US it is used extensively (Jokela and Russelle, 2003). In Denmark, output of corn silage increased by more than 70% between 1990 and 2008 and is equal to or greater than the output of grass silage (Storm et al., 2010). Worldwide, corn silage may constitute 50–75% of the diet (Driehuis et al., 2008) for a dairy cow consuming approximately 26 kg dry matter per day (Drackley et al., 2006).

The ensiling process involves many steps which should be timed and controlled carefully to ensure successful ensiling with minimal economic losses and health risks. The economic impact is difficult to assess as it involves various cost aspects in terms of veterinary and medical care, loss of raw material and reduced yield. Although humans, animals and their pathogens have coexisted for millennia, new health risks have emerged recently owing to the combination of rapid structural changes in the livestock sector, geographic clustering of intensive livestock production facilities near urban population centers and the movement of animals, people and pathogens between intensive and traditional production systems. For example, Bovine Spongiform Encephalopathy (BSE) or "the Mad Cow disease" is a progressive and invariably fatal neurodegeneration in cattle (Imran and Mahmood, 2011). The first case of BSE was recognized in England in 1986 and evolved to epidemic BSE has been shown to be naturally transmissible to a number of zoo species (Sigurdson and Miller, 2003), and BSE has also transmitted to humans in the form of a variant of Cruetzfeldt–Jacob disease (vCJD) (Bruce et al., 1997). Epidemiological analysis implicated a common extended source of infection, likely to be related to feed (bovine offals or mammalian-derived protein for ruminants feeding) (Hope, 2012).

Animal and human health could thus be threatened through direct illness or asymptomatic pathogen carriage. Microbial contamination can occur at a number of stages between farm and fork and intervention at the beginning of the food chain, looking at animal feedstuffs particularly, is an area of ongoing interest for reducing several risks. Due to the increasing use of silage around the world, it is necessary to ensure that the silage produced is of good final quality.

The purpose of the present paper is to review up-to-date information on microbial communities in silage, with a focus on corn silage, and possible techniques to limit silage degradation, its economic impact and its health impact on both animals and humans.

2. Silage processing and the roles of different bacterial groups

The ensiling process is defined as involving the following steps: harvesting the crop at the optimal stage of maturity, chopping, loading into a silo, compacting and sealing to exclude air, storing, and finally unloading for animal feeding. The four processing steps at which biochemical and microbiological incidents can arise are the aerobic, fermentation, storage and unloading stages (Ashbell and Weinberg, 2006). Fig. 1 summarizes the theoretical evolution of the main physico-chemical values and microbial populations in well-processed silage.

Optimum harvesting period to obtain the best nutritive value for herds varies across crops. Forage corn should be harvested at about the half milk line and ensiled at 30–35% DM (Ashbell and Weinberg, 2006). The bacterial flora of field grown corn consists mainly in *Paenibacillus*, *Flavobacteriaceae*, *Sphingomonas*, *Exiguobacterium*, *Rhizobiaceae*, *Acinetobacter* and *Buchnera* (Kadivar and Stapleton, 2003), but these bacterial population may vary according to geographic area, climate or growing stage. The low number of lactic acid bacteria (LAB) detected in fresh herbage may be due to inappropriate detection methods, or to viable but not culturable (VBNC) state of the cells in response to adverse environmental conditions. Once the plant material has been chopped and compacted into silos, important physico-chemical and microbial changes occur during storage.