The Impact of Rumensin® on the Production of Biogas
- Literature Review -

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Introduction

Livestock producers have become increasingly interested in the use of anaerobic digestion to treat livestock manure. Anaerobic digestion relies on microorganisms to produce methane gas. It therefore seems reasonable to assume that manure containing compounds known to affect the growth of microbes could have an impact on methane production in a digester. Rumensin® (Elanco Animal Health, Greenfield, IN) is just such a compound. Livestock producers using Rumensin have questioned whether they should even consider the use of anaerobic digestion. This literature review is intended to shed light on this question.

Anaerobic Digestion

Anaerobic digestion (AD) is a process in which microorganisms break down organic materials in a non-oxygen environment. During this conversion of energy, biogas is produced. Biogas consists mainly of methane and carbon dioxide and it is the methane that has value as a source of renewable energy. The methane content of biogas is typically in the range of 55 to 65% (Polprasert, 2007). For a given input, it is possible to find a theoretical methane yield. For example, Moller et al. (2004) calculated this to be 468 L methane per kg volatile solids (VS) for cattle manure. In practice, the value would be somewhat less than this.

Besides this production of methane fuel, benefits of using anaerobic digestion include odour reduction and the destruction of volatile solids (Zitomer et al., 2007), reduction of pathogen levels, reduction of greenhouse gas emissions from the farm and the conversion of nitrogen in the digestate to an inorganic form that is more readily available to growing crops (DeBruyn and Hilborn, 2007).

In the design and setup of an anaerobic digester, a number a factors must be considered to ensure efficient gas production. Anaerobic microorganisms are sensitive to certain compounds or elements, such as heavy metals, phthalate esters, linear alkylbenzene sulfonates, antibiotics, etc. (Fountoulakis, et. al., 2008; Sanz et al., 1996; Lallai et al., 2002).

Temperature, nutrient availability and pH must all be controlled to ensure the stability of the bacteria culture. AD systems are normally designed to operate in one of three main temperature ranges: psychrophylic (15^{o}C to 25^{o}C), mesophylic (35^{o}C to 40^{o}C), and thermophylic (50^{o}C to 60^{o}C). These are based on the needs of the particular bacteria present. The operating temperature influences such factors as hydraulic retention times, costs and system construction (DeBruyn and Hilborn, 2007). For example, mesophylic systems will typically need a longer hydraulic retention time than thermophylic systems (DeBruyn and Hilborn, 2007).

Rumensin®

Many livestock farms use antibiotics and other products to promote growth and prevent infection and disease (Lallai et *al*., 2002**).** One widely-used product is Rumensin. Rumensin is a trade name for a generic brand of antibiotics known as monensin. These chemicals are classified as ionophores.

Ionophores have been used in the Canadian beef industry since 1977 **(**Duffield, 2001). They are also extensively used in the dairy industry. In 1982, 80% of all cattle in feedlots used monensin-supplemented diets (Varel, 1982). Ionophores are feed additives which alter ion transfer across cell membranes of specific rumen microorganisms **(**Duffield, 2001**)**. Monensin binds to the bacteria's membrane, causing potassium to exit and hydrogen to enter. The organism must then use energy to actively transport the incoming hydrogen out. This causes death or stunted growth to the organisms **(**Duffield, 2001**)**. Gram negative bacteria, which have a more complex outer membrane, are more resistant than gram positive bacteria. As a result, monensin selectively controls the gram positive populations (Duffield, 2001**)**. An alteration of these populations results in an increase in energy metabolism, improved nitrogen metabolism, modified volatile fatty acid production, changes in gas production, and it helps in controlling bovine coccidiosis **(**Duffield, (2001). Bovine coccidiosis is a lower bowel and rectum infection caused by the parasitic protozoa *Eimeria zuernii* and *Eimeria bovis* (Kennedy, 2007). The infection can lead to dehydration, weight loss, depression, diarrhea, and in some cases, death (Kennedy, 2007).

Typical feeding rates of Rumensin on lactating cows are between 11 and 22 grams per 454 kg of dry feed (such as silage or hay). At the 11 gram rate, a lactating cow can increase in size by 250 to 300 mg per day. The cost is $0.02 to $0.04 per cow per day, resulting in a 5:1 benefit to cost ratio (Hutjens, 2008). Dairy farms have measured increases in milk production of approximately one kg/day in lactating cows using Rumensin (Hutjens, 2008).

Concerns

Unaltered quantities of any additives may find their way into the animal feces **(**Hilpert, et *al*., 1984**)**. This generally depends on the stability of the additive/antibiotic used and the degree of its adsorption in the digestive tract. In the case of monensin, up to 40% of the amount added to the feed may be found in the feces in an unchanged form **(**Hilpert, et. *al.*, 1984**).**

Research Results

Several studies have been carried out that looked at the impact of monensin on methane production. Of these studies, a few have looked at methane production by the animal in response to a diet containing monensin (Thorton and Owens, 1977; McGinn, et *al.*, 2004; Sauer et *al*., 1998). In addition, several studies have been conducted in small vessel containers (e.g. serum bottles, fermentors), in the range of 50 mL to 4000 mL (Hilpert et al., 1984; Wildenauer et al., 1984; Varel and Hashimoto, 1982; Zitomer et al. 2007; and Van Nevel and Demeyer, 1977). No studies could be found that were carried out in full scale digesters.

Thorton and Owens (1977) measured the affect of variations in fiber diets on energy losses for six steers. Rations contained 12, 27 and 40% fiber. Rumensin was added to cattle feed before ingestion by the cattle. There was no loss of energy in the form of feces, urine and heat. However, energy loss as methane (measured for six hours after feeding) decreased by 10% at all three fiber levels (Thorton and Owens, 1977). While the study helped explain the improvement in animal performance by using Rumensin, it also suggested that Rumensin could inhibit the production of methane gas.

McGinn et al. (2004) also looked at gaseous emissions from cattle in response to feed additives. Their interest was in reducing greenhouse gas (GHG) emissions associated with cattle production (from the animals themselves). Monensin in the feed reduced the emissions of methane by 8.6%. Similarly, Sauer et al. (1988) found that a dairy cattle diet containing 24 ppm monensin (as Rumensin) decreased methane emissions from the cattle.

Several studies have been carried out that looked at potential impacts of Rumensin on methane production in an anaerobic digester. In all cases, the testing was done either in serum bottles or at a small “fermentor” scale. One such study was carried out by Hilpert, et al., (1984). In this study, municipal sewage sludge was the primary source of organic inputs and a range of agricultural products was evaluated. A single addition of monensin at a concentration of one mg /L led to a decrease in methane production of 50% in the first day. Higher rates of monensin led to a complete halt in gas production. The pH decreased rapidly and the concentration of volatile organic acids increased. When monensin was added continuously (and sludge was also added continuously), methane production returned to levels similar to the control after about 40 days. This suggested that either the monensin was broken down over time or that the microorganisms had adapted to the additions. A similar ionophore, lasalocid, did not cause a decrease in methane production, even at high concentrations (Hilpert, et al., 1984). In a similar study, Wildenauer et al. (1984) found that an addition of monensin at 2 to 5 mg/L reduced methane production to 45% of the control rate. Besides reducing methane production, monensin reduced acetate turnover rates and stopped propionate production and degradation. Only the short term effects were measured in this study – there was no attempt to quantify adaptation of microorganisms over time.

Zitomer et al. (2007) carried out anaerobic toxicity assays to establish the impacts on methane production of various sanitizers, cleaners, disinfectants and feed additives (Rumensin). All were products used on dairy farms and all were believed to be present in manure, at least in trace amounts. Several concentrations of each product were used, in order to determine the IC_{50} toxicity value – the level at which methane production has been reduced to 50% of the expected level. Of those products tested, Rumensin and Quaternary Ammonium Salt (QUAT) sanitizer resulted in the highest level of toxicity. Results for mesophilic and thermophilic conditions were similar (Zitomer et al., 2007).

In a study by Van Nevel and Demeyer (1977), rumen contents were extracted from a sheep, processed and placed into small incubation flasks (110 mL). The animal had been fed a diet of hay and commercial concentrates. Monensin was added to several of these flasks. The addition of monensin resulted in a decrease in methane production in a majority of the incubations. However, the differences were not statistically significant compared to the control (Van Nevel and Demeyer, 1977).

Varel and Hashimoto (1982) used 4 L fermentors (3 L working volume) operating at 35^{o}C and at 55^{o}C and using various hydraulic retention times. The study began using cattle manure that was free of monensin. The fermentors were fed once per day. Once methane production was established, manure containing monensin was added. The feed for the cattle supplying the manure contained monensin at a concentration of 29 mg per kg feed. Methane production dropped off within three weeks in both mesophilic and thermophilic ranges. However, after about six months, the organisms appeared to have adapted to the monensin, and methane production was similar to the control fermentors. The acclimation of organisms appeared to be similar for fermentors in both mesophilic and thermophilic ranges. Monensin in the manure led to lower pH values in the fermentors - 5.8 for monensin and 7.03 for the control. This low pH can potentially add further strain on the bacteria within a digester. The monensin fermentors also had a lower buffering capacity, which could lead to a lower stability at short retention times. The study included a comparison to similar ionophores, lasalocid and salinomycin. These materials caused no decrease in methane production (Varel and Hashimoto, 1982).

Conclusion

The focus of much of the research concerning Rumensin has been on the improved performance of the animal. There has also been some interest in reducing methane emissions from animals, as concerns over the production of greenhouse gases have increased. However, several studies have looked at the impacts of Rumensin on the production of methane in anaerobic digesters (or at least in fermentors and other systems meant to simulate AD systems). The main findings are as follows:

- Rumensin (a commonly used form of monensin) added to cattle feed leads to a decrease in the production of methane in the animal and an improvement in the performance of the animal (e.g. feed efficiency).
- The decrease in methane emission from the animal is seen as an advantage, as methane emissions from ruminant animals have been identified as a significant source of methane (a greenhouse gas) in the atmosphere.
- Not all Rumensin contained in livestock feed is used by the animal – a significant percentage exits the body in the animal feces.
- When manure containing Rumensin is first added to an anaerobic digester, the production of methane will drop. Rumensin initially inhibits the production of methane – it has an effect on the bacteria responsible for producing methane and it affects the production of volatile fatty acids (VFA's).
- Over time (e.g. up to six months), microorganisms in the digester can adapt and methane production should return to expected levels.

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