GM and Non-GM Rumen Microbes in Enhancing Animal Productivity

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Abstract

Rumen microbes has been extensively used for manipulating the rumen ecology. Genetically modified or non genetic modified are both the type of application for enhancing the ruminal fermentation and improving the performance of ruminants. Construction of genetic modified rumen microbes has been succeeded with adding the various kinds of traits, such as improving fiber digestion, detoxification or reducing methane production in the rumen. This modification strategy mainly targeted into the predominant ruminal bacteria including Butyrivibrio fibrisolvens, Streptococcus bovis and Prevotella ruminicola. However, directly introducing the GM microbes to the rumen ecology is very limited. Recombinant Butyrivibrio fibrisolvens which was transformed with fluoroacetate dehalogenase gene can protect the host animal from plant toxin poisoning. Since the usage of GM microbes has restricted in most countries for its potential risks, many research have been focused on another approach with Non-GM microbes. There are many researches for checking the effect of diverse Non-GM rumen microbes for enhancing the CLA production, mitigation of methane emission, and the possibility as probiotics through in vitro and in vivo. The results show that this alternative use of Non-GM rumen microbes can be an intense candidate for improving the animal productivity through manipulation of rumen ecology. We discussed about how the GM and Non-GM rumen microbes have been used during the last decade and its potential aspects to contribute to the animal productivity.

Keywords: animal productivity, genetic modified, rumen microbes

Introduction

Manipulation of ruminal fermentation has been one of the preferred methods in improving the performances of ruminant animals and rumen microbes have been extensively used for manipulating rumen ecology. The contribution of rumen microbes in its ecology has been partially defined with predominant rumen bacteria; *Butyrivibrio fibrisolvens*, *Prevotella ruminicola* and *Streprococcus bovis* which occupy a large population in the rumen and this fact allows them to be a proper target for genetic manipulation (Selinger *et al*., 1996; Ekinci *et al*, 2002). The leading purposes of genetic manipulation of predominant rumen microbes are increasing the fibrolytic activity, detoxification, limitation of protein degradation or improving microbial protein synthesis in the rumen (Forano and Flint., 2000). Although some successful evidences have been reported under in vitro conditions, efficacy of genetically modified rumen micobes has been marginal under in vivo conditions. Usage of non-GM rumen microbes can be an alternative way to avoid the potential risks of GM microbes. Some of recent areas of interest with non-GM rumen microbes are increasing the amount of CLA and mitigation of methane production. This paper will briefly discuss potentiality of GM and non-GM rumen microbes in enhancing animal productivity.

Genetically modified rumen microbes

The principal purpose which genetic modification has been intended during several decades is adding the beneficial traits (improvement of fiber digestion and amino acid synthesis, reduction of dietary protein degradation and alleviation of effect of toxic materials) (Gregg *et al*., 1994; Teather., 1985) into rumen microbes for their efficient fermentative action in the rumen. This modification strategy mainly targeted into the predominant ruminal bacteria including *B. fibrisolvens*, *S. bovis* and *P. ruminicola* (Forano and Flint., 2000). These efforts resulted in the construction of various kinds of GM microbes.

GM microbes often re-introduced into the rumen ecosystem for confirming the survival rate and capacity to be dominant in its environment but the period of survival was quite restricted, besides they usually do not maintain their recombinant traits (Kobayashi and Yamamoto., 2002; Krause *et al*., 2001). It is believed that foreign fibrolytic enzyme genes did not act properly in the rumen ecology. Inhibition by antibacterial-agent, bacteriocin, existed in the natural rumen ecology can be partly responsible for this. Despite non-significant impact on rumen fermentation and production with GM microbes, *B. fibrosolvens* transformed with fluoroacetate dehalogenase gene is regarded as one of positive examples (Gregg *et al*., 1998). Retaining the adequate population of recombinant bacteria to stabilize in the rumen is crucial factor for detoxification. In this experiment GM *B. fibrisolvens* maintained its population above 10^6 cells per ml and this was enough to detoxify the toxic molecule in the rumen ecology.

Despite successful expression of heterologous genes in the rumen microbes, the GM microbes have not been directly applied to the animal industry because of its potential risks. Possible gene transfer between rumen microbes and related environment or changes in the traits of rumen microbes are the most important factors for examination of GMO's risks Forano and Flint., 2000). Though the risks of GMO are vague, the acceptability of GMO by the public who directly consume the animal products is usually low. Due to the difficulty of public agreement on certain evaluation criterion, assessment of GMO's risk is not yet fully constructed. Because the advantage of genetic modification is distinct and efficient use of this technology can be beneficial to animal industry, scientific standard is needed for the proper utilization of GMO.

Non-GM rumen microbes

Since the usage of GM microbes has restricted in most countries due to their potential risks, many research have been focused on another approach with Non-GM microbes. Microbes isolated from the rumen could be re-introduced into the digestive tract of ruminants hoping to enhance digestive functions.

Major bodies of research results are with rumen bacteria. Isolated rumen bacterium *Pseudobutyrivibrio xylanivorans* Strain Mz5T was evaluated for its possible role in the rumen ecology through in vitro studies (ČEPELJNIK*et al*., 2003). This strain produced butyrate as a major product and fiber degrading enzymes, and bacteriocin were also synthesized. Characteristics of this strain such as providing enengy to the colonocyte and reducing pathogenic bacteria may facilitate it as a possible candidate for probiotics. *Propionibacteria* is also the available nominee for the probiotics. According to the research by Stein *et al* (2006) increased milk production and the molar percentage of propionate were detected in dairy cows after the treatment of *Propionibacteria*. Young calves are main targets of probiotics because this stage is important for infants to develop their pre-gastric fermentative organs which are required for the efficient degradation of forage. Dosing probiotic mixture compound which consisted of five rumen microbes increased ADG, improved fibrolytic action and decreased incidence of diarrhea in young Holstein calves (Aldana *et al*., 2009). Since dairy cows need proper controlling for parturition and calving, probiotic supplementation is in a position to alter the rumen fermentation. *Megasphaera elsdenii* is well-known lactate-utilizing bacterium and Aikman *et al*. (2011) inoculated this bacteria into the rumen for the purpose of reducing rumen acidosis at the postcalving period. Though ruminal pH did not show significant change, dosing the bacterium resulted in lower acetate : propionate ratio and less fluctuation of ruminal pH and other positive effects on the animal performance such as milk production and energy balance. Similar positive response to the addition of rumen fungi has been reported previously. Rumen fungi secrete various enzymes to degrade fiber components, and some studies tried to use rumen fungi as probiotcs. *Piromyces* sp. isolated from goat improved digestibility and total VFA production in vitro, but the same culture did not show any significant effect for heifers (Samanta *et al*., 2008a,b)

Interests in CLA which has beneficial effect on humen health have been increased from the decades upward (Wahle *et al*., 2004) and extensive research efforts have been made to elucidate the mechanism of CLA formation in the rumen and to find ways of enhancing the process. However, only a few studies looked at possibility of using rumen microbes to enhance CLA production in the rumen. Rumen protozoa are able to synthesize CLA by the isomerase activity though they cannot convert the CLA to others including vaccenic acid and stearic acid (Or-Rashid et al., 2008). Among the classified rumen bacteria, *Butyrivibrio fibrisolvens* which is prevalent in the rumen isomerlizes linoleic acid at a higher rate than other ruminal microbes (Maia *et al*., 2007). *B. fibrisolvens* MDT-5 isolated from rumen of goat by Fukuda *et al* (2006) was used as CLA enhancer in the rumen. The strain was believed to have high linoleic acid isomerase activity and no CLA reductase activity. By analogy with this successful result of MDT-5 which show increment of CLA in pet animals, there is possibility of obtaining beneficial effects by using the same strain with domestic animals, although it is uncertain with ruminants which already have CLA-producing bacteria in their own environment.

Methane is major green house gas produced by diverse activities including agriculture industry. Among the agriculture aspect, ruminants take the great possession of methane production through their enteric fermentation. Therefore reducing methane emmision by ruminants is emphasized. Present approaches can be classified into largely two strategies. First approach is through improving the quality of nutrition supplied to the animals, so that more product may be produced per unit of methane. Secondly, through the modification of rumen fermentation using various methods actual production of methane can be reduced in the enteric fermentation (Iqbal *et al*., 2008). Homoacetogens are able to utilize H_2 coming from fermentation of feeds in the rumen. Removing hydrogen from the mechanism which was naturaly used by methanogens to produce methane is beneficial for animals, because if homoacetogen convert the CO_2 to acetate with hydrogen, the acetate generates energy for the animal and contributes to the animal productivity. Lopez *et al.* (1999) defined the competition ability of homoacetogen incubated with ruminal fluid including methanogen in vitro. Without any additives, homoacetogens did not reduce methane production, though the amount of methane was reduced after treatment with 2-bromoethanesulfonic acid. Paul *et al*. (2011) reported about novel sulphate-reducing bacterium(SRB), *Fusobacterium sp*, and characterized its available role in mitigating methane production in vitro. Sulphate reduction could be better options for removing hydrogen from the rumen ecology because these bacteria could compete with methanogens and homoacetogens for utilization of H_2. After incubation with novel isolated SRB, concentration of methane was reduced and the population of SRB also increased. Much more information is needed to apply the same technology to practice.

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