Journal of Integrative Agriculture 2015, 14(3): 526–533

Available online at www.sciencedirect.com

ScienceDirect

REVIEW

Direct-fed microbes: A tool for improving the utilization of low quality roughages in ruminants

Mona M Y Elghandour[1], Abdelfattah Z M Salem[1], Jose S Martínez Castañeda[1], Luis M Camacho[2], Ahmed E Kholif[3], Juan C Vázquez Chagoyán[1]

[1] *Faculty of Veterinary Medicine and Animal Science, Autonomous University of the State of Mexico, Toluca P.O. 50000, Mexico*
[2] *Faculty of Veterinary Medicine and Animal Science, Autonomous University of Guerrero, Altamirano P.O. 40660, Mexico*
[3] *Dairy Science Department, National Research Centre, 33 Bohouth st. Dokki, Giza P.O. 12311, Egypt*

Abstract
For many years, ruminant nutritionists and microbiologists have been interested in manipulating the microbial ecosystem of the rumen to improve production efficiency of different ruminant species. Removal and restriction of antibiotics sub-therapeutic uses from ruminant diets has amplified interest in improving nutrient utilization and animal performance and search for more safe alternatives. Some bacterial and fungal microorganisms as a direct-fed microbial (DFM) can be the most suitable solutions. Microorganisms that are commonly used in DFM for ruminants may be classified mainly as lactic acid producing bacteria (LAB), lactic acid utilizing bacteria (LUB), or other microorganism's species like *Lactobacillus*, *Bifidobacterium*, *Enterococcus*, *Streptococcus*, *Bacillus*, *Propionibacterium*, *Megasphaera elsdenii* and *Prevotellabryantii*, in addition to some fungal species of yeast such as *Saccharomyces* and *Aspergillus*. A definitive mode of action for bacterial or fungal DFM has not been established; although a variety of mechanisms have been suggested. Bacterial DFM potentially moderate rumen conditions, and improve weight gain and feed efficiency. Fungal DFM may reduce harmful oxygen from the rumen, prevent excess lactate production, increase feed digestibility, and alter rumen fermentation patterns. DFM may also compete with and inhibit the growth of pathogens, immune system modulation, and modulate microbial balance in the gastrointestinal tract. Improved dry matter intake, milk yield, fat corrected milk yield and milk fat content were obtained with DFM administration. However, the response to DFM is not constant; depending on dosages, feeding times and frequencies, and strains of DFM. Nonetheless, recent studies have supported the positive effects of DFM on ruminant performance.

Keywords: direct-fed microbial (DFM), mode of action, ruminants

1. Introduction

The main goals of rumen microbial studies are to improve feed utilization, animal production and health, and animal food safety, which may be achieved by facilitating desirable fermentation, minimizing ruminal disorders, and excluding pathogens. For the past few decades, a number of chemical feed additives such as antibiotics, ionophores, methane inhibitors and defaunating agents have been used in rumi-

Received 3 September, 2013 Accepted 6 May, 2014
Correspondence Abdelfattah Z M Salem, E-mail: asalem70@yahoo.com

doi: 10.1016/S2095-3119(14)60834-0

nant nutrition to manipulate the microbial ecosystem and fermentation characteristics in the rumen and intestinal tract of livestock (Seo *et al.* 2010). Due to probable toxicity problems to the host animals, these feed additives are not routinely used (Salem *et al*. 2014a, b). Recently, a great awareness from public health aspects such as residues of these chemicals in milk and meat, and bacterial resistance to antibiotics as a result of increased use in the food chains prohibits their use as feed additives (Barton 2000). These supplements have been criticized by the consumers' organizations on the ground of product safety and quality. The consumers' demands have stimulated to search for natural alternatives to chemical feed additives. Supplementation with probiotics that can survive in the rumen has become a suitable alternative (Fon and Nsahlai 2013).

Therefore, this review summarizes the effects of direct-fed microbial (DFM) on rumen fermentation, methane inhibition, microbial populations and ruminant performance as growth, milk production and the efficiency of feed utilization.

2. Direct-fed microbial

The term "probiotic" is composed from two parts of Greek words: "pro" which means in favor and "biotic" which means life. The term probiotic has been defined as "a live microbial feed supplement, which beneficially affects the host animal by improving its intestinal microbial balance" (Fuller 1989). However, as pointed out by Vanbelle *et al.* (1990), many researchers accept that probiotic refers to "selected and concentrated viable counts of lactic acid bacteria *Lactobacillus*, *Streptococcus*". Moreover, Kmet *et al*. (1993) defined the term probiotics as "live cultures of microorganisms that are deliberately introduced into the rumen with the aim of improving animal health or nutrition". The Food and Drug Administration of USA has required feed manufacturers to use the term "direct-fed microbial" instead of probiotic (Miles and Bootwalla 1991) and has narrowed the definition to "a source of live, naturally occurring microorganisms" (Yoon and Stern 1995). Krehbiel *et al.* (2003) and Yang *et al.* (2004) defined the DFM as "alive, naturally occurring microorganisms that have been used to improve digestive function of livestock". The definition of DFM is very broad and may include specific and nonspecific yeast, fungi, bacteria, cell fragments, and filtrates (Sullivan and Martin 1999; Oetzel *et al*. 2007; Elghandour *et al*. 2014b). DFM grow in the rumen and beneficially modify its microbial ecosystem and/or fermentation characteristics. The intestinal tract may also provide a suitable habitat for DFM (Seo *et al.* 2010).

There are many different types of DFM being used in livestock production. They can be classified into three main categories; bacterial, fungal, and a combination of both. The bacterial DFM is the most common. The bacterial DFM strains may be classified as lactic acid producing bacteria (LAB), lactic acid utilizing bacteria (LUB), or other microorganisms. *Lactobacillus*, *Propionibacterium*, *Bifidobacterium*, *Enterococcus*, *Streptococcus*, and *Bacillus*, all of which are common microorganisms used in bacterial DFM for ruminants, in addition to other distinctive bacterial species such as *Megasphaera elsdenii* and *Prevotella bryantii* (Kung 2006; Seo *et al.* 2010). Development of this organism for ruminant animals should be continued with emphasis on optimizing dose and timing of administration. Success with such organisms could allow feedlot producers to decrease the time it takes to adapt cattle to a high concentrate diet. It could also be useful by reducing chronic acidosis in lactating cows (Kung 2006). The response to DFM was inconstant in ruminants; however, it has been positive in many experiments.

3. DFM mode of action

3.1. Bacterial DFM

The mode of action of DFM depends on many factors, such as dosages, feeding times and frequencies, and strains of DFM. Some of DFM act within the rumen while others impact the gastrointestinal tract (Puniya *et al*. 2015).

(1) Within rumen: The mode of action of different DFM sources within the rumen depends mainly on LAB and LUB. LAB might affect the rumen positively through preventing ruminal acidosis in dairy cows (Nocek *et al.* 2002) by facilitating the growth of ruminal microorganisms adapted to the presence of lactic acid in the rumen (Yoon and Stern 1995) and by stimulating LUB. LUB have been proposed as DFM that can decrease concentrations of lactate and maintain ruminal pH. *Megasphaera elsdenii* is the major lactate-utilizing bacterium in the rumen that prevents the drastic pH drops caused by accumulation of lactate in the rumen when fed a highly fermentable diet (Yang *et al.* 2004; Kung 2006) or prevents lactic acidosis in steers (Robinson *et al.* 1992). This bacteria simultaneously uses lactate, glucose, and maltose (Russell and Baldwin 1978) and would compete with lactate-producing organisms for substrate. During the feeding of readily degradable soluble carbohydrates, *M. elsdenii* seems to be the major ruminal lactate utilizer because *Selenomonas ruminantium* undergoes catabolite repression (Russell and Baldwin 1978) and is relatively acid-intolerant (Mackie and Gilchrist 1979).

Another bacterial species is the *Propionibacteria* which is naturally found in high numbers in the rumen of animals fed forage and medium concentrate diets (Kung 2006). Propionate is quantitatively the most important single precursor of glucose synthesis among volatile fatty acids (VFA), and tissue distribution of nutrient (Nagaraja *et al.* 1997). Certain