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Influence of mangosteen peel powder as a source of plant secondary compounds on rumen microorganisms, volatile fatty acids, methane and microbial protein synthesis in swamp buffaloes

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ABSTRACT

The objective of this experiment was to evaluate the effect of mangosteen peel powder (MSP) on rumen fermentation, nutrient digestibility and microbial population in swamp buffaloes (*Bubalus bubalis*) fed on a rice straw based diet. MSP is a fruit peel that contains plant secondary compounds (condensed tannins and saponins). Eight, rumen-fistulated 4-year old, male swamp buffaloes with 350 ± 4 kg live weight were randomly assigned to receive two dietary treatments (T1 = non-supplementation of MSP and T2 = supplementation of MSP at 100 g/(head × day)) according to a *t*-test design. All animals were fed concentrate mixtures at 0.5% of body weight and rice straw was fed *ad libitum* for 37 days with the first 30 days for feed adaptation and voluntary feed intake measurement, while the last 7 days were for samples collection. The results revealed that there was no difference between treatments on dry matter intake and nutrient digestibility by MSP supplementation ($P > 0.05$). Furthermore, MSP supplementation did not influence ruminal pH, temperature, ammonia nitrogen and blood urea nitrogen. Interestingly, propionic acid (C_3) production was significantly increased by MSP supplementation ($P < 0.05$) while total volatile fatty acids, acetic acid (C_2) and butyric acid were similar between treatments. Moreover, C_2:C_3 ratio was reduced by MSP supplementation. In addition, estimated rumen methane was significantly reduced by MSP supplementation ($P < 0.05$). Application of quantitative PCR to quantify cellulolytic bacteria (16S rRNA) targets revealed that MSP supplementation did not change population of *Fibrobacter succinogenes* and *Ruminococcus albus* ($P > 0.05$) while total bacteria population were significantly increased by MSP supplementation. The *Ruminococcus flavefaciens* and methanogens population were significantly decreased as MSP were supplemented ($P < 0.05$). Nitrogen intake, excretion (fecal and urine) and balance (absorption and retention) were similar between treatments whilst microbial nitrogen supply and efficiency of microbial protein synthesis were increased by MSP supplementation. In conclusion, supplementation of MSP as a source of plant secondary compounds exhibited no negative effect on feed intake, nutrient digestibility, ruminal fermentation characteristics, nutrient utilization and microbial protein synthesis. But rather,

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it could influence on rumen methanogenic population and hence, possibly mitigate methane production in swamp buffaloes fed on a rice straw based diet.

1. Introduction

Methane (CH_4) has a 21 times higher global warming potential than carbon dioxide (IPCC, 2007). It is estimated that the world's population of ruminants produces about 15% of total CH_4 emissions (Moss et al., 2000). Swamp buffaloes play a very important role in providing draught power, manure as fertilizer and meat for human consumption. Moreover, swamp buffaloes (*Bubalus bubalis*) are considered potentially the most efficient ruminant due to their ability to utilize low quality tropical feedstuffs (Wanapat et al., 2000). It has been reported that global CH_4 emissions by swamp buffaloes were 9.57 million tons per year (Steinfeld et al., 2006). As reported, CH_4 production resulted from fermentation of feed in the gastrointestinal tract of ruminants represents a substantial loss of 2–15% of gross energy intake (Johnson and Johnson, 1995), which reduces the potential conversion of feed energy to metabolizable energy. Hence, the inhibition of methanogenesis has long been considered from nutritional aspects, and more recently from the perspectives on greenhouse gas emissions. It is essential to control enteric methanogenesis to protect the environment and improve feed conversion efficiency in ruminants. Mitigation of CH_4 emission by rumen microbes using various chemical modifiers has been extensively investigated (Nagaraja et al., 1997). Manipulation of the rumen microbial ecosystem for enhancement of fibrous feed digestibility, fermentation efficiency, while reducing CH_4 emission by ruminants are some of the most important goals for animal nutritionists (Guglielmelli et al., 2010; Patra et al., 2006).

Whilst numerous chemical additives and antibiotics have been tested and used for this purpose, contemporary consumer demands orient towards the use of natural products to alter rumen fermentation. Plants containing bioactive products such as essential oils, saponins and tannins (Calabrò et al., 2011; Guglielmelli, et al., 2011; Wallace et al., 2002) with antimicrobial properties may be exploited in ruminant production to reduce CH_4 emissions. These compounds, called phytochemicals or plant secondary metabolites, describe non-nutritive plant metabolites which are essential for plant survival (*i.e.*, protection against herbivores, pests, microorganisms) and proper growth and reproduction (Greathead, 2003; Patra and Saxena, 2009). Some phytochemicals have a direct toxic effect on methanogens (*e.g.*, condensed tannins) or protozoa (*e.g.*, saponins) and, thus, have been tested as natural feed additives to decrease CH_4 production (*e.g.*, Kamra, 2005; Patra and Saxena, 2009; Wanapat et al., 2008). Condensed tannins and crude saponins have been shown to inhibit protozoa which cause the reduction of methanogens presumably by lowering the activity of protozoal associated methanogens (Guo et al., 2008). Another theory is that less H_2 is produced by lower numbers of protozoa, which can be used by methanogens for CH_4 production (Morgavi et al., 2010).

By nature, mangosteen (*Garcinia mangostana*), colloquially known as the queen of fruits, is a tropical seasonal plant species belonging to the members of the family *Clusiaceae* and the *Genus Garcinia*. Mangosteen trees thrive well in a warm and humid climate, ideally in the temperature range from 25 to 30 °C, with a height from 7 to 25 m. The fruit, capped by the prominent calyx at the stem end and with 4–8 triangular, flat remnants of stigma in a rosette at the apex, is round, dark to red–purple and smooth externally (Foo and Hameed, 2012; Palapol et al., 2009). Mangosteen fruit is primarily eaten fresh and available as food complements in desserts, salads, fruit cocktail, jam, juice combinations or can food processing industries (Lozano, 2006). Nevertheless, its wide scale implementations by the food manufacturing industries are deteriorated by the massive generation of peel and stem waste. For each kg of mangosteen harvested, approximately 0.6 kg of mangosteen peels can be obtained (Chen et al., 2011). Mangosteen peel is a fruit by-product and many researchers have been interested to use it as a dietary supplement to improve rumen ecology and rumen productivity. Mangosteen peel contains both condensed tannins and crude saponins, which can exert a specific effect against rumen protozoa, while the rest of the rumen biomass remains unaltered (Ngamsaeng et al., 2006). Ngamsaeng et al. (2006) found that supplementation with Mangosteen peel powder (MSP) decreased protozoa populations and the calculated CH_4 production. Supplementation of MSP as well as soap berry fruit pellet has been shown to alter rumen fermentation by lowering the protozoa population and CH_4 production (Poungchompu et al., 2009; Sliwinski et al., 2002). Ngamsaeng et al. (2006) suggested that supplementation of MSP (100 g DM/day) in cattle can increase rumen bacteria and decrease the protozoal population, and maintain the fungal zoospore population. However, the available data about manipulating ruminal fermentation of swamp buffalo is still limited. Therefore, the aim of the present study was to investigate rumen fermentation and microbial population in the rumen of swamp buffalo fed on rice straw as influenced by supplementation of MSP.

2. Material and methods

2.1. Animals, diets and experimental design

Eight, rumen-fistulated 4-year old, male swamp buffaloes with 350 ± 4 kg live weight were allocated into two groups and randomly assigned to receive two dietary treatments (T1 = 0 g/(head × day) of MSP and T2 = 100 g/(head × day) of MSP supplementation) according to a *t*-test design. All animals were fed concentrate mixtures at 0.5% of body weight offered in two equal portions at 07:00 and 16:30 h while rice straw was fed *ad libitum* for 37 days period. All buffaloes were placed in individual pens with