INTERNATIONAL JOURNAL OF HYDROGEN ENERGY XXX (2013) 1–9

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Influence of distiller's grains and condensed tannins in the diet of feedlot cattle on biohydrogen production from cattle manure☆

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ARTICLE INFO

Article history:
Received 22 January 2013
Received in revised form
3 July 2013
Accepted 5 July 2013
Available online xxx

Keywords:
Bioethanol
Biohydrogen
Condensed tannins
Dark fermentation
DDGS

ABSTRACT

Biohydrogen production from the manure of cattle fed diets containing corn dried distiller's grains with solubles (DDGS) diets was assessed. Four types of manure were obtained from cattle fed four diets (DDG, %of dietary dry matter): 0 (CK), 20 (DG20), 40 (DG40) and 40 plus 2.5% of dietary dry matter as condensed tannins (DG40CT) and evaluated for biohydrogen production using dark fermentation. Each treatment was evaluated in quadruplicate using 2 L continuously stirred biodigesters operating at 55 °C in batch culture with an organic loading rate of 20 g L^{-1} volatile solids and a total operation time of 4 d. Gas samples were taken daily to determine hydrogen production, and slurry samples were analyzed daily for volatile fatty acid concentration, total ammonia nitrogen, volatile solids degradation, and soluble ion concentration. The DG0 and DG40 treatments demonstrated the greatest hydrogen production, with DG40CT producing the least ($P < 0.001$). The inclusion of tannins in the diet of cattle had a negative effect on biohydrogen production from cattle manure, and thus the economic feasibility of using manure as a substrate in anaerobic digestion could be negatively impacted by the inclusion of tannins in the diet.

1. Introduction

Dried distiller's grains with solubles (DDGS) are an economically important co-product of ethanol production from corn and wheat [1]. Expansion of the bioethanol industry is ongoing, yielding 53 billion liters from the USA alone in 2011 [2]. In 2010/2011, approximately 40% of the corn harvest, or 128 Mt, was used for ethanol production [3]. Conversion of 1000 kg of corn into ethanol results in approximately 309 kg of DDGS (90% dry matter [DM]), resulting in production of ∼43 Mt DDGS annually [2]. Because DDGS contain 20–35% crude protein and energy values on par or greater than corn, they have become an important component of beef cattle feeds in North America. In fact, 38% of distiller's grains produced in the USA that are not exported are consumed by beef cattle [4]. The effects of feeding DDGS on growth performance of feedlot cattle have been studied

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http://dx.doi.org/10.1016/j.ijhydene.2013.07.014

previously [5–7]and inclusion of DDGS in the diet dramatically increased N and P excretion, presenting a significant challenge with respect to manure nutrient management [6,8,9].

Condensed tannins (CT), also known as proanthocyanidins, are polyphenolic secondary plant metabolites that have been studied as feed additives for beef cattle [10,11]. Feed proteins and CT form complexes in a pH dependent manner, reducing protein degradation in the rumen while allowing for greater protein adsorption in the intestinal tract [11]. Advantages of including CT in the diet include: increased protein deposition, reduced urinary N excretion, parasite control, and bloat safety [11]. However, CT are not adsorbed in the digestive tract and are excreted in modified forms in feces, where they may alter N availability in the feces and potentially alter the soil microbial community when manure is land-applied [12,13].

Renewable energy production and environmental sustainability are currently major issues being addressed through the development of technologies such as ethanol production. Another potential source of renewable energy is biohydrogen, which can be produced from organic wastes via mixed microbial fermentation. Capture of hydrogen and other gases produced during anaerobic digestion can reduce greenhouse gas emissions from manure and reduce the discharge of nutrients into the environment [14]. During anaerobic digestion, carbohydrates, fats and proteins are fermented into intermediates such as volatile fatty acids (VFA), alcohols and ammonia. Hydrogen is produced by the hydrogenase enzyme when VFA and alcohols are converted into acetate as a means to re-oxidise the electron carriers NAD^+ and ferredoxin [15]. Several factors influence the fermentative production of hydrogen, including microbial ecology, temperature, pH, partial pressure of hydrogen, as well as the concentration and characteristics of the substrate [16].

Fermentative hydrogen production is a renewable energy source that has the potential to be used synergistically in the lifecycle of DDGS, providing an environmentally sound method for manure management (Fig. 1). The production of hydrogen via fermentation of organic wastes such as cattle manure has been increasingly studied in recent years and could be used to dispose of manure derived from feedlot cattle [17–19]. Biohydrogen production using DDGS as a substrate has also recently been investigated [20]. However, the influence of feed ingredients such as DDGS and CT on biohydrogen production from manures has not been assessed. The objectives of this study were to: 1) compare biohydrogen production from manure arising from feedlot cattle fed DDGS versus manure from cattle fed a barley grain-based diet; 2) determine the effect of CT in the diet on biohydrogen production from manure; and 3) to assess a molecular technique for predicting biohydrogen yield from manure prior to fermentation.

2. Materials and methods

2.1. Materials

Cattle manure was obtained from a total of 8 pens housing crossbred steers involved in a DDGS feeding trial as described

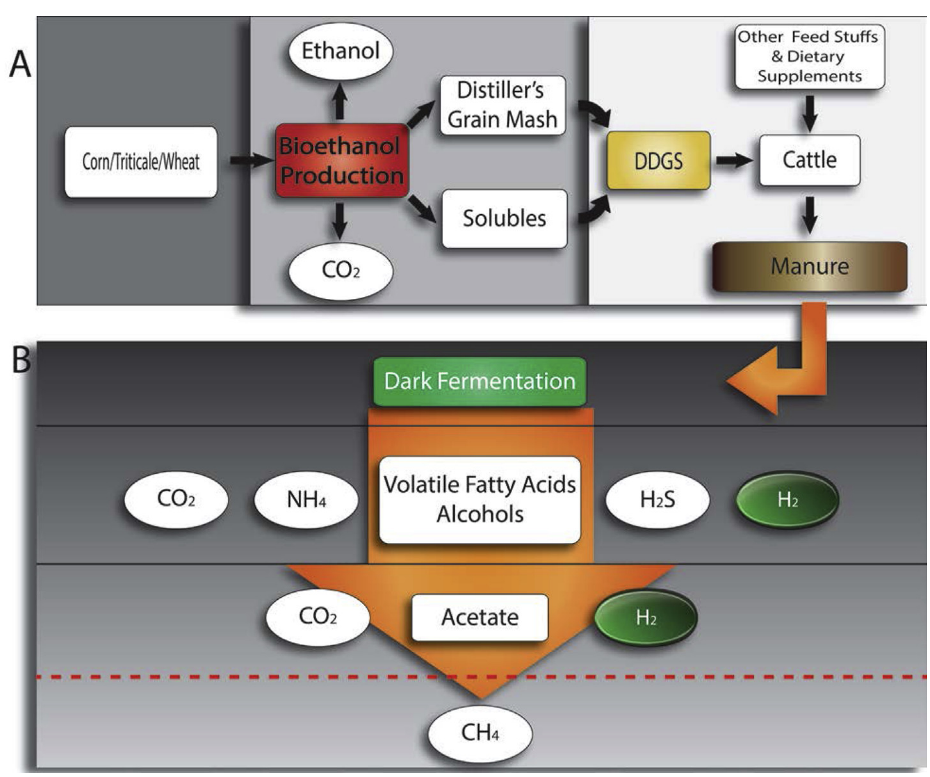

Fig. 1 – Schematic of bioethanol production from grains, resulting in dried distiller's grains with solubles (DDGS) which are fed to feedlot cattle (A). Manure produced from cattle is used as a substrate for biohydrogen production via anaerobic dark fermentation, which is a multi-step process involving substrate hydrolysis, acidogenesis, and acetogenesis (B). Under normal anaerobic conditions the final product is CH4, which is undesirable for biohydrogen production (dashed red line).

Please cite this article in press as: Gilroyed BH, et al., Influence of distiller's grains and condensed tannins in the diet of feedlot cattle on biohydrogen production from cattle manure, International Journal of Hydrogen Energy (2013), http://dx.doi.org/10.1016/j.ijhydene.2013.07.014