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Potentialities of biogas installation in South African meat value chain for environmental impacts reduction

V. Russo*, H. von Blottnitz

Chemical Engineering Department, EBE Faculty, University of Cape Town, 7701, Rondebosch, South Africa

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A B S T R A C T

Livestock farming in South Africa has expanded significantly, and thus there is a corresponding increasing need to properly manage the generated waste streams. Anaerobic digestion to produce biogas is becoming an increasingly popular technology choice for the treatment of organic wastes and wastewater. Energy production from the anaerobic digestion of manures and slaughterhouse wastes would reduce untreated waste disposal and provide additional income. This study investigated biogas plants potentialities to reduce emissions from poor waste management both at the feedlot and at the abattoir stage of the South Africa beef and pork value chain. Electricity generation from the biogas, and possibly usage of co-produced heat would further reduce GHG emissions by about 1.56 Mt CO_{2eq} per year, reducing the carbon footprints of beef and pork by 10% and 30% respectively. Even more significant reductions of both AC and EU impacts should be achievable by avoiding mostly landfilling of wastes and over-fertilization of soils. Furthermore, the produced biogas, burned for generating electricity and heat used within the industries themselves, might make them self-sufficient from the national grid. The nutrient-rich digestate would be similar in quantity to imported fertilizers, reducing the cost of importing and possibly generating additional income.

1. Introduction

Agricultural production is considered the “hotspot” in the life cycle of food products (Roy et al., 2009), and livestock farming is the world's largest user of natural resources. Worldwide, non-CO_2 GHG emissions from livestock sector have been estimated around 2.45 Gt CO_2-eq in 2000. Methane (CH_4) from enteric fermentation by ruminants was the largest source of GHG emissions (65%), whilst methane (CH_4) and nitrous oxide (N_2O) from manure management, and nitrous oxide (N_2O) from manure land application account for the 10%, 8,5%, and 20%, respectively. Cattle accounted for 77% of livestock GHG emissions; monogastrics (pigs and poultry) for 10%, mostly (56%) IS due to methane from manure management. Developing countries contribute 75% of global GHG emissions from ruminant and 56% of emissions from monogastrics; mixed crop–livestock systems produce the bulk of emissions from ruminants (61%), whilst grazing systems account for 12% of emissions (Herrero et al., 2013).

South Africa (SA) has acceded to the Kyoto Protocol (UNFCCC, 2007) and in more recent climate negotiations – Paris COP21 – SA indicated that its GHG emissions are expected to peak between 2020 and 2025, plateau for approximately a decade and decline in absolute terms thereafter. South Africa has committed to reduce GHG emissions by 34% and 42% against BAU (business-as-usual) emissions by 2020 and 2025 respectively (SA-INDIC, n.d). CH_4 emissions reduction will need to make a contribution to, since its impact is faster owing to the shorter lifetime and greater owing to its 34-fold higher global warming potential than CO_2 (Scholtz et al., 2013).

Stock farming is the most feasible agricultural activity in a large part of South Africa and the meat industry represents one of the most important agricultural sub-sectors (DAFF-Beef, 2014; DAFF-Broiler, 2014; DAFF-Pork, 2014). Significant methane (CH_4) gas emissions from ruminants and poor manure management have raised concern and warranted investigation into urgent mitigation methods. Moreover, untreated slaughterhouse wastes pose a high risk of pollution when they enter into a municipal sewage purification system due to the biological and chemical oxygen demand (BOD and COD); the problem is aggravated if that untreated waste stream directly reaches a river or a catchment (Meat Safety Act,

* Corresponding author.
E-mail address: v.russo@uct.ac.za (V. Russo).

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2000 (Act no. 40 of 2000)).

Anaerobic Digestion (AD) is nowadays widely used as a source of renewable energy and AD facilities can easily treat a wide spectrum of organic waste streams (e.g. municipal, agricultural or industrial wastes). The resulting product is a biogas, mostly formed by methane (CH_4) and carbon dioxide CO_2, which can be used directly as fuel, in combined heat and power (CHP) gas engines or upgraded to natural gas-quality bio-methane. The best option to recycle the nutrient-rich digestate by-product seems being that of using it as an organic fertilizer or soil conditioner, after being further treated (e.g. composting, solid-liquid separation). The benefits of resource recovery from waste streams also depend on the current economic context and establishing a defined market for value-added products (Amigun and Von Blottnitz, 2007; Amigun and Von Blottnitz, 2010; Amigun et al., 2008). Moreover, energy conversion of biomass reveals economic justification in case biomasses are spatially concentrated and available with continuity throughout the year.

A number of organic substances are anaerobically easily degradable without major pre-treatments. Animal manures are the most reported main substrate (Abubakar and Ismail, 2012; Ashekuzzaman and Poulsen, 2011; Petersen et al., 2007). They are usually used for diluting the co-substrate; Slaughterhouse wastes (SHW) have shown promising results, since they are rich in biodegradable organic matter. Both of these substrates overcome the seasonality of other agro-industrial wastes – they are produced all year round (Buendía et al., 2008; Cuetos et al., 2010; Ek et al., 2011; Hejnfelt and Angelidaki, 2009; Steffen et al., 1998). When combined with other co-substrates in so-called anaerobic co-digestion (AcoD) facilities, they can enhance methane yields and process stability (Alvarez and Lidén, 2008; Astals et al., 2014; Esposito et al., 2012; Hejnfelt and Angelidaki, 2009; Kacprzak et al., 2010; Luste et al., 2012; Palatsi et al., 2011, Yadvika et al., 2004).

Life cycle assessment (LCA) is a systematic approach, formerly developed for assessing environmental aspects and potential impacts associated with industrial production processes. Several recent LCA studies deal with the sustainability of a biogas plant (Dressler et al., 2012; Ishikawa et al., 2006; Lijó et al., 2015; Massaro et al., 2015; Patterson et al., 2011; Poeschl et al., 2012a, 2012b) and have shown that there is a large environmental improvement potential in redirecting waste streams of the agri-food sector from landfill disposal to energy production (Labutong et al., 2012; Patterson et al., 2011; Poeschl et al., 2012a, 2012b; Whiting and Azapagic, 2014) especially where an AD plant is combined with the biogas end uses in a CHP plant.

This study focused on the finishing (feedlots/housing) and slaughtering/rendering (abattoirs) phases of the South African livestock chain. Two different waste management scenarios for the beef and pork industries are compared: the current common practice and an improved scenario with AD plants to produce biogas and CHP plants to produce electrical and thermal power. The environmental impacts investigated were Global Warming Potential (kg CO2-eq.), Acidification (kg SO2-eq.) and Eutrophication (kg PO43-eq). The major benefits for the treatment of the meat industry wastes are avoided over-fertilization (mostly due to a surplus production of animal manure for the intensive animal farming activities), improving the fertilizer qualities of slurries (typically slurry produced in intensive livestock practices contains P, K and N with P and K having an equivalent fertilization value to those of mineral fertilisers, but the N content and fertilization value being lower than those of commercial fertilisers), reducing odours and pathogens and producing a renewable source of energy – the biogas (Alvarez and Lidén, 2008; Buendía et al., 2009; Holm-Nielsen et al., 2009; Nasir et al., 2012; Pagés-Díaz et al., 2014; Zhang et al., 2013).

2. Materials and methods

2.1. South African livestock value chain

Agriculture contributed 2.2% to the South African GDP (in 2013) and 5.2% to employment (StatsSA). Livestock farming is the most feasible agricultural activity in a large part of the country, since much of the land is unsuitable for rain-fed crop farming (only 12% available), but approximately 70% is suitable for grazing (Goldblatt, 2010); hence the meat industry represents one of the most important agricultural sub-sectors. Both the feedlot and abattoir industries have expanded in number and capacity and have become increasingly vertically integrated towards the wholesale level; animal-derived products contribute approximately 47% to the gross farming income and has consistently been on the rise since 2008/2009 to present (DAFF-Beef, 2014; DAFF-Pork, 2014).

South Africa and the world are consuming more meat. Davis et al. (2014) suggest in South Africa that this is because of increased spending power. The BFAP (2015) considered the trends in consumption of beef, chicken, sheep, pork and eggs in South Africa: for beef, chicken and pork consumption was on the rise since 2000 and is expected to increase further toward 2024 (See Fig. 1)..

In these study only the beef and the pork value chains were analysed for biogas opportunities and potential CO_2 reductions. The red meat industry is a predominant sub-sector in South African agriculture and it comprises both commercial (extremely efficient and developed) and small-scale farmers (communal subsistence producers).

The 80% of the total cattle heads are for beef cattle and the remaining 20% is for dairy cattle. Despite the primary beef cattle farming (cow-calf production cycle) being mostly extensive in South Africa, more than 75% of cattle slaughtered in the formal sector is finished in sophisticated feedlots on grain-based (maize) and its by-products (RMRD-SA), with the remainder of South African cattle raised on natural pastureland (DAFF-Beef, 2014). The South African pork industry is relatively large in terms of the overall South African agricultural sector: it contributes around 2.15% to the primary agricultural sector. Pork is produced throughout South Africa, but with Limpopo and North West provinces being the largest producers accounting for 44% of total production (DAFF-Pork, 2014). South African Pork production systems are mostly intensive and feed represents a crucial input from a producer's perspective: a typical pork farm has its modern plant on the farm for mixing the feed. Moreover, producers operate farrow to finish units, with breeding, weaning and finishing operations all being undertaken by the same grower. Production occurs in specialised housing which ensuring optimal growing conditions; grower pigs are fed for approximately 145 days in order to reach a live slaughter weight of approximately 100 kg (Davis et al., 2014).

Concentrated Animal Feeding Operations (CAFO) facilities are defined as Animal Feeding Operation where animals are confined for more than 45 day during the growing season, in an area that does not produce vegetation and comply with some certain size threshold. On CAFO farms the livestock are bred with modern industrial methods, which include making optimal use of space and other resources to maximise production. CAFO comprises watering and feeding facilities where livestock are kept in pens and fed grain-based diets, hay or silage. The major benefit of grain-based diets is that it is possible to finish livestock in a feedlot all year round. Table 1 reports the details on average entering weight (at feedlots) and carcass weight (at slaughterhouses) for beef and pork respectively.

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