Journal of the Saudi Society of Agricultural Sciences (2014) **13**, 139–147

King Saud University

Journal of the Saudi Society of Agricultural Sciences

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FULL LENGTH ARTICLE

Comparing methane emissions from different sheep-keeping systems in semiarid regions: A case study of Syria

Omar Hijazi [a,*], Werner Berg [a], Samouil Moussa [b], Christian Ammon [a], Kristina von Bobrutzki [a], Reiner Brunsch [c]

[a] *Leibniz Institute for Agricultural Engineering in Potsdam-Bornim, Department of Engineering for Livestock Management, Max-Eyth-Allee 100, 14469 Potsdam, Germany*
[b] *University of Damascus, Faculty of Agriculture, Department of Animal Production, Damascus, Syria*
[c] *Leibniz Institute for Agricultural Engineering in Potsdam-Bornim, Scientific Director, Max-Eyth-Allee 100, 14469 Potsdam, Germany*

Received 3 November 2012; accepted 20 January 2013
Available online 25 March 2013

KEYWORDS

CH_4 emissions;
Sheep-keeping systems;
Semiarid regions;
Syria;
Feedstuff components

Abstract Sheep husbandry represents a significant source of methane (CH_4) in semiarid grassland regions such as Syria. However, the contribution of sheep to CH_4 emissions in Syria is still unknown. This study was designed to quantify CH_4 emissions and identify possible mitigation strategies for their reduction. Methodology developed by the Intergovernmental Panel on Climate Change (IPCC) was used to estimate CH_4 emissions. A survey was conducted on 64 farms from different locations in Syria in 2009. Data were collected concerning sheep-keeping systems (SKSs), body mass, milk and wool yield, farm locations, feed rations, periods of grazing on the Steppe, the duration of pasturing on agricultural residuals and time periods when sheep were kept in stables. Using a linear statistical model, the influence of SKS, geographical region and sheep body mass on emitted CH_4 were analysed. The results showed that the geographical region, SKS and sheep body mass had significant effects ($P < 0.05$) on CH_4 emissions. According to the model, the mean values of estimated CH_4 emissions from extensive, semi-intensive and intensive SKSs were 26 ± 0.9, 22.5 ± 1.3 and 13.5 ± 1.7 kg/sheep year, respectively. In comparing differences between the least square means of CH_4 emissions, the extensive and semi-intensive SKSs produced 92% and 66% higher CH_4 emissions compared to intensive SKS. The differences in CH_4 emissions within the distinct SKSs were attributed to dietary composition. Extensive SKS used a less concentrated

* Corresponding author. Tel.: +49 1777568629.
E-mail address: omar1982hej@hotmail.de (O. Hijazi).
Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.jssas.2013.01.008

feeding regime (98 ± 17 day/year) than semi-intensive SKS (114 ± 47 day/year), and intensive SKS employed concentrated feeding year round. Furthermore, it was observed that sheep with the same body mass produced higher CH_4 emissions in extensive SKS than in semi-intensive and intensive SKSs. Moreover, the semi-intensive SKS occupied more natural pastures than extensive SKS, which caused an overuse of the Steppe. Therefore, an effective mitigation strategy involves the use of more digestible feed, which would be accomplished by increasing the quantity of concentrated feed. Owing to unfavourable farming conditions, low-cost nonconventional feeds such as the residuals of wheat and cotton should be used to improve sheep management practices to reduce Steppe overgrazing in the extensive and semi-intensive SKSs of Syria and other semiarid areas.

1. Introduction

The rangelands of the Arabian Steppe, which amount to half of Syria's land mass, are the main source of feed for domestic livestock, especially sheep and goats. In Syria, as in many other semiarid landscapes, rearing small ruminants is often the only possible enterprise for sedentary and nomadic populations because of the relatively unfavourable climatic conditions (Rahman, 2008). The Steppe is possible only to use as fed source for sheep husbandry. Ruminant livestock accounts for 35–40% of global anthropogenic methane (CH_4) emissions, which result from enteric fermentation and manure (Steinfeld et al., 2006). Methane is a potent greenhouse gas (GHG) with a global warming potential that is 25 times that of CO_2 on the basis of weight (Solomon et al., 2007).

Syrian flocks are mainly composed of multipurpose (milk, meat, and wool) Awassi sheep, a hardy, fat-tailed breed that is well adapted to local climatic conditions (Shomo et al., 2010). Sheep-keeping systems (SKSs) in Syria were classified as extensive, semi-intensive and intensive (Cummins, 2000). Extensive SKS are characterised by long-distance movement for grazing the rangeland of the Steppe. In addition to grazing, sheep are provided with concentrate feed within the semi-intensive SKS. The main purpose of intensive SKS is lamb fattening, where concentrate feed is mainly used. The major feeds in Syria are barley, maize, and cotton seed cake (Cummins, 2000). In 2005, sheep comprised approximately 75% of the meat and 25% of the milk supply in Syria (ACSAD, 2005). An increasing demand for these livestock products has resulted in higher flock sizes and rising CH_4 emissions (Aw-Hassen et al., 2008), while crop development has primarily occurred on marginal lands with low rainfall (Louhaichi et al., 2009). These practices have led to lower grain production for human consumption, animal feed deficits and the overgrazing-induced degradation of Steppe rangelands (Salkini et al., 2008). With respect to CH_4 emissions, Aluwong et al. (2011) reported considerable variation in values per tropical livestock unit (TLU, 250 kg body weight), between 21 and 40 kg of CH_4 per TLU per year. An enteric CH_4 emission represents an economic loss to the farmer in which feed is converted into CH_4 rather than into product output (Pelchen and Peters, 1998). Thus, improved productive efficiency in sheep husbandry should be achieved by changing feed utilisation and dietary supplements (Aluwong et al., 2011; Waghorn and Hegarty, 2011). Several CH_4 mitigation options for ruminants are summarised in a review by Martin et al. (2010) in which one option is breeding animals with lower enteric CH_4 emissions (Pinares-Patiño et al., 2011). Furthermore, various authors have indicated that using best management practices could significantly reduce CH_4 emissions per animal (Wiedemann Hartwell et al., 2010; Sejian et al., 2011). The level of CH_4 emission from enteric fermentation can be reduced by increasing dry matter intake in the form of high-grain feed, good quality forage and a carefully tailored roughage-to-concentrate ratio (Sejian et al., 2011; Zervas and Tsiplakou, 2012). Additionally, Grainger et al. (2008) reported that whole cottonseed appears to be a promising dietary supplement for CH_4 emission mitigation. However, grain needs for human consumption and the resulting competition with concentrate feed grain production should be considered.

The aim of this study was to compare different Syrian SKSs and their respective enteric CH_4 emission factors (EF) kg CH_4/sheep year, the difference of EF is because of the different GE intakes in each SKS which change according to animal needs. To estimate the CH_4 emissions it was applied recommendations from the Intergovernmental Panel on Climate Change (IPCC, 2006) (Tier 2) to specific farm management data that were obtained from a regional survey of 64 farms. Understanding the relationships between the sheep diets of different SKSs to enteric CH_4 production is essential for identifying viable reduction strategies. Moreover, it is important to produce definitive advice for enhancing rangeland management and minimising negative environmental impacts. Following these conclusions will make it possible to optimise land use and to balance the needs of humans and animals.

2. Materials and methods

2.1. Site description

This study was conducted at various farms across Syria (Fig. 1). The Syrian Ministry for Agriculture and Agrarian Reform (MAAR) divided Syria into five settlement zones according to agricultural activities and the amount of annual precipitation. The sizes of the five zones, along with their respective amounts of precipitation, are as follows: (1) 27,036 km^2: 350 mm/year; (2) 24,628 km^2: 250–350 mm/year; (3) 13,147 km^2: 250 mm/year; (4) 18,332 km^2: 200–250 mm/year; and (5) 102,034 km^2: 100–150 mm/year (MAAR, 2009). Settlement zone 5 is defined as the Steppe, which is located in the eastern part of Syria, represents 55% of the national territory and is the main region for sheep production. Zones 1 and 2 are wheat production areas, whereas barley is the dominant crop in zones 3 and 4 (Shomo et al., 2010). A total of 64 farms with different SKSs were surveyed in various Syrian governorates, and they are each marked with a sheep in Fig. 1. These farms were located within the governorates of