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Energy footprint assessment of sheep meat produced under two different farming systems in Tunisia

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Abstract. Energy is a major input for sheep production due to the intensification and mechanization of production technologies. Energy efficiency is one of the key indicators for developing more sustainable agricultural practices. However, the analysis of energy uses in different sheep production systems are scarce. In this context, this study had been set out to measure energy footprint (EF) of sheep meat production in two farming systems in Tunisia; the mixed sheep-cereal farming system (prevailing in Northern Tunisia, mainly the regions of Beja, Jendouba) and the agro-pastoral farming system (prevailing in southern Tunisia mainly the regions of Tataouine and Kebili) where farmers rely on the purchase of livestock feedstuffs from local markets. This study further considers differences in the two production systems to explore the causes of variation of EF in sheep meat production. A total of 80 sheep farms, were investigated, using data on direct (fuel and electricity) and indirect (structures, machinery, feed, fertilizers, pesticides, and seeds) energy inputs. EF was expressed as mega joule (MJ) per unit of live weight (LW). Results show that the average EF of all evaluated farms was 1.58 MJ/ kg of LW. Farms in the North had the highest EF (average 2.18 MJ/ kg of LW) for which energy use is distributed as following: 65% feed production, 15% water pumping for livestock watering and irrigation, 8% animal housing and lighting and 12% for transport. While the lowest EF was obtained in farms located in the south averaging 0.98 MJ/ kg of LW for which the energy use during feed production, water pumping for watering and irrigation, animal housing and lighting and transport were 15, 25, 9 and 51%, respectively. It is concluded that sheep meat production in the agro-pastoral farming system in Southern Tunisia is less energy demanding than in the mixed sheep-cereal farming system in the North of the country. This can be explained by the fact that feed production has the largest share of the total energy used by Northern's farms. This means that efforts should be made to increase the energy efficiency of feed production and to increase feed use efficiency by animals.

Keywords. Energy footprint – Sheep – Mixed cereal-sheep system – Agro-pastoral system.

Évaluation de l'empreinte énergétique de la viande ovine produite sous deux différents systèmes de production en Tunisie

Résumé. *L'énergie est un intrant essentiel dans la production ovine en raison de l'intensification et de la mécanisation des technologies de production. L'efficacité énergétique est l'un des indicateurs clés pour développer des pratiques agricoles plus durable. Cependant, les analyses de l'utilisation énergétique dans différents systèmes d'élevage ovin sont rares. Dans ce contexte, cette étude a été conçue pour mesurer l'empreinte énergétique (EF) de la production de viande ovine dans deux systèmes d'élevage en Tunisie; Le système mixte céréales-élevage (prévalant dans le nord de la Tunisie, principalement les régions de Beja et Jendouba) et le système agro-pastoral (prédominant dans le sud de la Tunisie, principalement Tataouine et Kebili), où les agriculteurs comptent sur l'achat des aliments de bétail au niveau des marchés locaux. Cette étude considère également les différences dans les deux systèmes de production pour explorer les causes de la variation de l'EF dans la production de viande ovine. Au total, 80 exploitations ovines ont été étudiées, en utilisant des données sur les intrants énergétiques directes (carburant et électricité) et indirectes (structures, machines, aliments, engrais, pesticides et graines). EF a été exprimée en mégajoule (MJ) par unité de poids vif (LW). Cette étude montre que la valeur moyenne du EF de la viande ovine est 1.58 MJ / kg LW. Les fermes du Nord avaient la plus élevée EF (valeur moyenne de 2.18 MJ / kg de LW) pour laquelle la consommation d'énergie est distribuée comme suit: 65% de production des aliments, 15% de pompage d'eau pour l'abreuvement des animaux et l'ir-*

rigation, 8% de logement et d'éclairage pour animaux et 12% pour le transport. Cependant, l'EF la plus faible a été obtenue dans les fermes du sud et elle est d'en moyenne 0.98 MJ / kg LW pour laquelle la consommation d'énergie pendant la production des aliments, le pompage d'eau pour l'abreuvement et l'irrigation, le logement des animaux et l'éclairage et le transport étaient de 15, 25, 9 et 51%, respectivement. Il est conclu que la production de viande ovine dans le système agro-pastoral dus le sud Tunisien est moins exigeante en énergie que dans le système mixte céréales- élevage dans le nord du pays. Cela s'explique par le fait que la production des aliments correspond à la partie la plus importante de l'énergie totale utilisée dans les fermes du Nord. Cela signifie que des efforts doivent être faits pour améliorer l'efficacité énergétique de la production des aliments et l'efficacité de l'utilisation des aliments par les animaux.

Mots-clés. *Empreinte énergétique – Ovin – Système mixte céréales-élevage – Système agro-pastoral.*

I – Introduction

The population growth coupled with the rapid economic development place a heavy burden on natural resources through the increasing demand for agricultural products. In addition, the way in which we use natural resources is central to the challenge of improving food security across the world, particularly in developing countries (FAO, 2013; Wanapat *et al*., 2015). The challenge of providing sufficient food for everyone worldwide has never been greater. Livestock products and especially meat rely highly on natural resources and is responsible for high emissions of greenhouse gases (GHG) (Herrero *et al*., 2016). Fossil energy has been identified as a major input of livestock production systems. Furthermore, energy use is expected to increase globally from 46 to 58 percent between 2004 and 2030 (EIA, 2007). Energy footprint (EF) was proposed as a metric to measure the indirect and direct use of energy of a product. Fossil energy is used mainly for the production, transport, storage and processing of feed. Depending on location (climate), season of the year and building facilities, energy is also needed for the control of thermal environment (cooling, heating or ventilation) and for animal waste collection and treatment. Tunisia is one of the countries in the Mediterranean area having very limited energy resources. Small ruminants' production is the main source of income of many households in Tunisia. Therefore, producing more crops and livestock products with less energy has become a challenging demand by the government authorities. Several studies assessed the energy inputs of livestock products (Hartman and Sims, 2006; Meul *et al*., 2007; Thomassen *et al*., 2008; Kraatz, 2012; Pagani *et al*., 2016). However, assessments of EF of sheep meat are scarce. This study aimed to assess and compare the EF of sheep meat produced in Tunisia under two farming systems; the mixed sheep-cereal farming system (prevailing in Northern Tunisia, mainly de regions of Beja, Jendouba) and the agro-pastoral farming system (prevailing in southern Tunisia mainly Tataouine and Kebili). This indicator could help to identify hotspots of energy use and propose strategies to reduce energy consumption in sheep meat production. Additionally, select the more efficient farming system in term of energy use.

II – Methods and data

1. Study area and farming systems description

This study was carried out in two locations with two different production systems (Figure 1). The first location is in northern Tunisia (Beja and Jendouba governorates), and is characterized by an average annual rainfall ranging between 700 and 1200 mm. The average minimum and maximum temperatures are 5°C and 38°C, respectively. In this location, cereal cropping and sheep production are the main activities undertaken by farmers. The second location is in Southern Tunisia (Tataouine and Kebili governorates) characterized by an arid climate with an average annual rainfall less than 200 mm and the temperature varies between 15°C and 42°C. The agro-pastoral system is the dominant production system, and people get their incomes from small ruminant's production. This study was based on data from surveys conducted in 80 farms, from where sheep production is an important activity. This survey was also performed to determine diet composition, fodder crops types and energy costs.

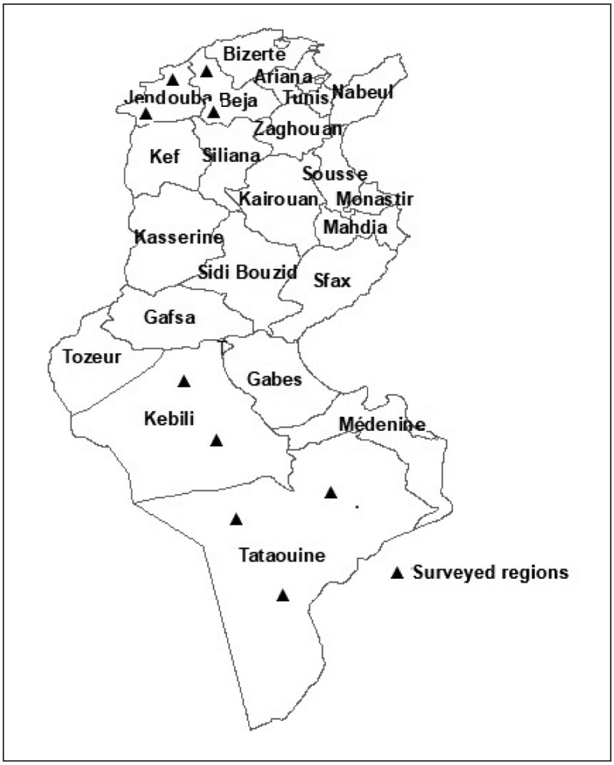

Fig. 1. Localization of the surveyed sheep farms in Tunisia.

2. The energy footprint accounting

In this study, a cradle to farm gate perspective was adopted. The system boundary included all direct energy inputs occurring at the farm level (fuels and electricity) and all indirect energy inputs immediately related to purchased animal feeds on the market. Data on direct energy inputs, structures, machinery, materials and feed were collected during field visits. The direct energy uses, which are recurring energy inputs, are those for pumping and operating the farm irrigation system, transport and feed production. For diesel engines, the energy input was calculated as (Khan *et al*., 2009; Pagani *et al*., 2016):

$$Ec = F_c * T_c * C_v * L$$

Where E_c is the energy output of the machine (kW h), F_c the fuel consumption of the machine (l/h), T_c the time consumed in operation (h), C_v the caloric value of the fuel (kW h/l), L is the actual fuel consumption over fuel consumed at rated power. For electric motors, the energy input was calculated by the product of rated power of the electric motor, operation time, and load factor. For operation performed by the contractor where the farmers paid for the energy applied, the energy consumption was calculated based on data from similar farms, but the charges were ascribed among operations based on the amount the particular farmer paid for a particular operation to the contractor (Khan *et al*., 2009). The energy footprint of sheep expressed on megajoule (MJ) and calculated as following:

$$EF_{sheep} = EF_{feed} + EF_{pumping\ drinking\ and\ irrigation\ water} + EF_{Lighting\ and\ housing} + EF_{transport}$$

III – Results and discussion

This study showed that the typical diet used in the north-located farms raised under the mixed sheep-cereal farming system includes 20 to 30% of concentrate feeds (commercial concentrate, barley and wheat bran). In addition, farmers rely on grazing on natural pasture, fallows and cereal stubbles in summer. Farms in southern Tunisia target sheep production under the agro-pastoral farming systems. Farmers in this region rely mainly on concentrate feeds (40 to 60%) and fodder crops mainly from the north region of Tunisia. Sheep flocks in this arid region are in most cases grazing on degraded rangelands. The energy footprint accounting of sheep meat in the selected farms averaged to 1.58 MJ/ kg of LW. Sheep meat produced on the north had the highest EF (2.18 MJ/kg of LW) compared to that produced in the south (0.98 MJ/kg of LW). This difference could be ascribed to the high use of energy during feed production on the farm scale. Moreover, Figure 2 shows that feed production in the northern farms represents the hotspot in term of energy use. While the transport of animal and feed reveals the highest consumption of energy in the Southern farms. These findings confirm that producing sheep meat under the agro-pastoral system consumes one time less energy than the mixed sheep-cereal farming system. Our study is the first assessing EF of sheep meat. Sheep meat is less intensive in term of energy use than dairy products (Koknaroglu, 2010; Mikkola & Ahokas, 2009). In order to reduce the EF of sheep meat it is suggested to improve the energy use efficiency of feed production in the Northern farms through for example the adoption of conservation agriculture. In the Southern part, Tunisia can invest more to take advantage from the renewable energy since our country has a good potential to produce solar energy which can be used to recompense the wasting of energy in feed transport.

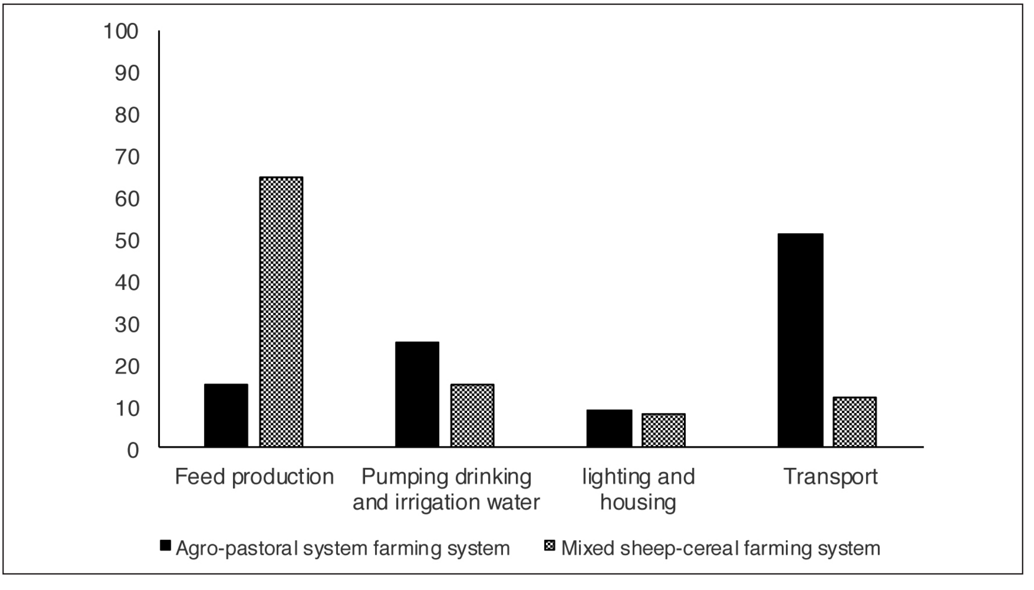

Fig. 2. Percentage of energy use per step of production in the agro-pastoral and the mixed sheep-cereal farming system in Tunisia.

IV – Conclusions

Our study shows that energy footprint is an important indicator for the assessment of energy use in livestock sector. The comparison of sheep farming systems in Northern and Southern Tunisia provides useful insights in terms of energy saving strategies for this sector. Energy efficiency intervention strategies should promote a sustainable agricultural mechanization through the adoption of conservation agriculture to save energy. Therefore, further research should focus on the reduction of farming dependency on fossil fuels through the integration of renewable energy sources in farm scale could lead to a transition to low carbon farms, driven by locally available resources such as biogas energy from manure and solar energy.

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