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Estimation of the water footprint in the production of beef from European cattle in Mexico

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ABSTRACT

Objective: To determine the water footprint of beef from Charolais cattle subjected to stable production and an established diet.

Design/Methodology/Approach: The water footprint was estimated using the methodology proposed by Hoekstra, in which the water footprints of the ingredients of the feed consumed are added to the total volume of water that the animal drank during its life.

Results: The estimated water footprint for beef in this research was 2,972.4 liters per kg, including the blue and green water footprint.

Study Limitations/Implications: The calculation of the gray water footprint is not included, although it is an indicator of the specific zone.

Findings/Conclusions: There is a difference between the water footprint obtained in this study and the footprint reported in the references, perhaps as a result, among other reasons, of the differences in diet and breed of the animals studied.

Keywords: beef, intensive production, European cattle, water footprint.

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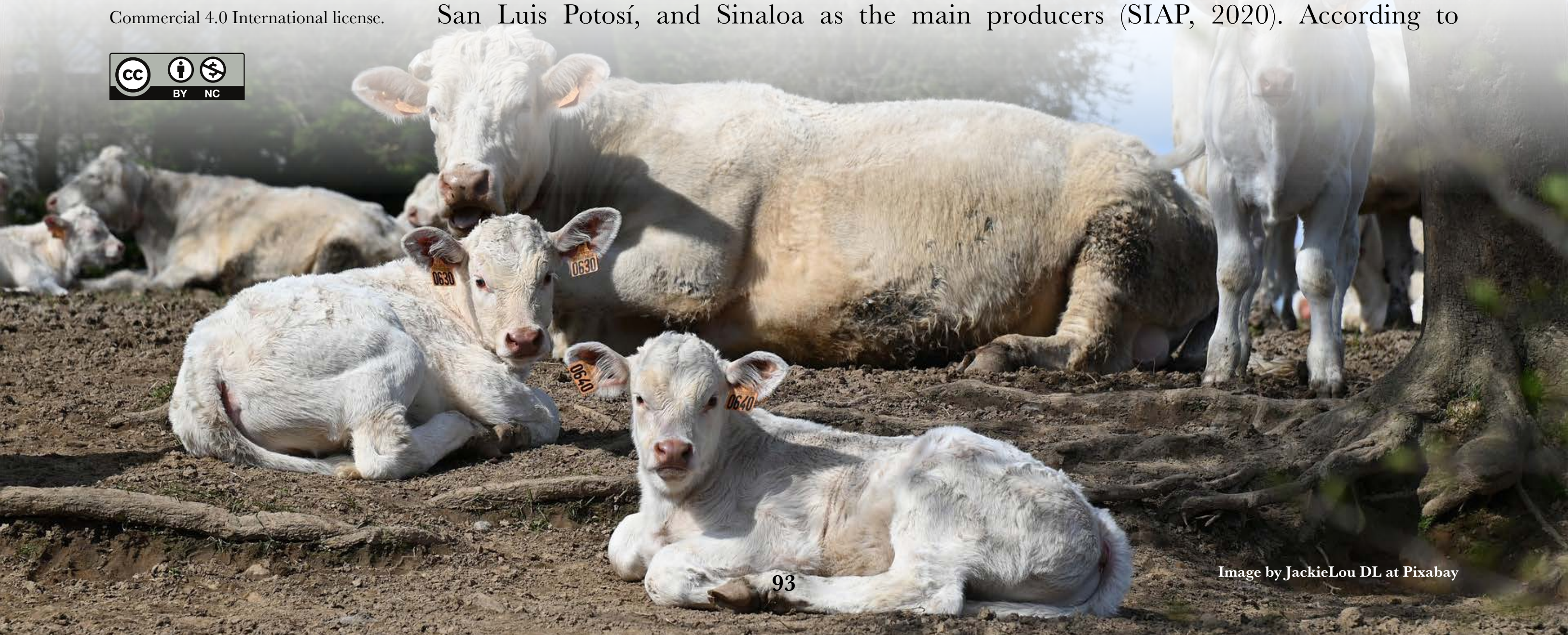
INTRODUCTION

The production and consumption of beef in the world has increased in recent years (FAO, 2021), as well as the concern of consumers about the deterioration of the environment and water resources.

Mexico is the 6th producer of beef worldwide, with the states of Veracruz, Jalisco, San Luis Potosí, and Sinaloa as the main producers (SIAP, 2020). According to



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SEMARNAT (2018), agriculture and livestock account for 76% of the consumptive use of water in Mexico.

There is concern about climate change and its effects —including the increase in temperature, changes in the climate, and floods—, which have consequences for future generations, as well as potential health impacts (Oltra *et al.*, 2009). This situation has motivated researchers to identify indicators that monitor the effect of human activities on natural resources and the environment.

In this context, indicators of environmental impact and of the use of natural resources have been developed for the production of meat products. One of these is the water footprint (WF). WF is defined as an "indicator that shows the human appropriation of water resources. It refers to the total volume of fresh water used to produce something, whether it was incorporated into the product, evapotranspired by a crop, returned to another basin, or used by a body of water to assimilate the pollutant load" (Vázquez del Mercado and Lambarri, 2017). There are three types of WF: blue, green, and gray.

The water footprint has been estimated for several products, including: forage crops and their productive efficiency (Ríos *et al.*, 2015); the production of sugarcane cultivation (Cossio *et al.*, 2019; Garay *et al.*, 2022); bovine milk in Mexico (Flores *et al.*, 2017; Navarrete *et al.*, 2019); onion and tomato under irrigation conditions (Peñaloza *et al.*, 2020); the slaughter of already fattened cattle (Zambrano *et al.*, 2018); and various products of animal origin produced in different parts of the world (Esquivel and Salgado, 2020; Gerbens *et al.*, 2013).

Hanemann (2006) points out that water has an economic value, which may or may not be equal to its price; therefore, determining the water footprint is an useful way to know how much water is used in a production process. With that purpose in mind, the water footprint of beef from Charolais cattle subject to stable production and an established diet was determined.

MATERIALS AND METHODS

The state of Querétaro, Mexico, is the eighth largest beef producer nationwide. It produces 34,426.27 tons of beef with a production value of $2,503,438 pesos. The state has 18 municipalities, out of which the main producers are Ezequiel Montes, Querétaro, and San Juan del Rio (SIAP, 2022). This research used data from the municipality of Ezequiel Montes, given its importance for livestock production. This municipality is part of the Administrative Hydrological Region (RHA) IX Golfo Norte (Municipality of Ezequiel Montes, 2020). This region has medium water stress, an average rainfall of 855.3 mm per year, and excellent water quality overall (SEMARNAT, 2018).

An intensive beef production system was the subject of this study. The young bulls are placed in a confined area until they reach an optimum market weight; with this purpose in mind, they are provided a diet designed for weight gain (Callejas *et al.*, 2017). The breed chosen for the study was Charolais, which has the best productive behavior in relation to daily weight gains (Parra *et al.*, 2011; Bautista *et al.*, 2019).

The beef production and cattle fattening data were obtained from SIAP (2022); meanwhile, the forage ingredients and water consumption data were taken from information for Mexico and are assumed to be homogeneous for the entire region (Rios *et al.*, 2015). The methodology applied to determine the WF of cattle in fattening was proposed by Mekonnen and Hoekstra (2012) and modified for this study.

First, the expression of the final product (FP) per animal is calculated as follows:

$$FP = \frac{P}{Pop}$$

Where P is the total annual production of beef in the state (kg/year) and Pop is the total population of cattle in the state.

Feed conversion efficiencies (FCE) are then estimated:

$$FCE = \frac{FC}{FP}$$

Where FC is the feed consumption per head (kg of dry mass/year/animal) and FP is the final product produced per head (kg of product/year/animal).

Then the total amount of feed consumed (Feed) is calculated:

$$Feed[n] = FCE \times P$$

Where $Feed$ is the total amount of feed consumed (ton/year) in the state, FCE is the feed conversion efficiency (kg of dry mass of feed/kg of product), and P the total amount of beef product (ton/year) in the state.

Subsequently, the WF of the feed consumed is determined with the following formula:

$$WF_{feed} = \frac{\sum_{p=1}^{n}\left(feed[n] \times WF_{prod}[n]\right)}{Pop}$$

Where $feed$ represents the annual amount of feed ingredient [n] consumed (ton/year), WF_{prod} [n] is the WF of feed ingredient [n] (m^3/ton), and Pop is the number of animals slaughtered per year in the state.

The WF of an animal is expressed as proposed by Mekonnen and Hoekstra (2012):

$$WF = WF_{feed} + WF_{water} + WF_{serv}$$

Where WF_{feed} is the water footprint of the feed consumed, WF_{water} is the total water that the animal drank during its life, and WF_{serv} is the water used in the farm service and corresponds to the gray water footprint (which was not considered for this study). The water footprint of an animal and its three components can be expressed in terms of m^3/

year/animal. When they are added over the lifespan of the animal, they are expressed as m^3 animal^{-1}.

RESULTS AND DISCUSSION

During the 120-days fattening period, the animals are constantly offered a sufficient volume of fresh and clean water. The volume that animals drink depends on the temperature, the environment, their body weight, and the dry matter content of the feed (NRC, 1996). The average temperature in the municipality of Ezequiel Montes was 16.7 °C. Meanwhile, the average weight gains for each period were the following: 316.8 kg at reception; 352.5 kg at the beginning, and 445.5 kg at finishing.

The average daily consumption per head of cattle in fattening was 38.9 L. Additionally, the total water consumed per head of cattle (4,664.4 L) was determined for the total days of fattening.

One feed formula was considered for each stage of fattening. All three formulas had the same ingredients and variation in the amounts administered. The amount of feed consumed by cattle in fattening depends on the weight of the animal and its weight gain. Table 1 shows the feed consumptions calculated considering the average weights and average weight gains.

The animals consume the calculated kilograms of feed per day, plus the barley straw that is added directly to the feeder every day. Table 2 shows the total feed consumption per period; these data were used to calculate the amount of ingredients consumed in each period, taking into account the formula used in each one.

The total feed consumption for each period and the quantities of ingredients that make up the formulas were used to calculate the total consumption of ingredients for each fattening period (Table 2). During the entire fattening period, 88,460.6 t of feed were consumed, plus 9,492.1 t of barley straw, giving a grand total of 97,952.7 t of feed for the total number of heads of cattle. The water footprint was determined for the following ingredients used in the formulation: corn silage (forage corn), corn stubble (corn for grain and stubble), sorghum (sorghum for grain and stubble), soybean (soybean for grain), alfalfa hay (alfalfa for fodder), and barley straw (barley for grain and straw). Table 3 shows the results obtained in this research. The water footprint of the beef is 2,972.4 L kg^{-1}.

Mekonnen and Hoekstra (2012) report that the global average of WF for beef in extensive, mixed, and intensive production systems is 15,400 L kg^{-1}, while the global

Table 1. Information on weight and food consumption

Periods	Average weight (kg)	Average daily gain (kg))	Consumption of dry food per day (kg)	Dry matter (%)	Food/day (kg)
Receive	316.8	1.6	7.818	73.19	10.682
Start	352.5	1.8	7.773	78.61	9.889
Ending	445.5	1.9	9.182	81.2	11.308

Source: Table developed by the authors.

Table 2. Food consumption by period and total. Source: self made.

Fattening periods	Duration of the period (days)	Feed consumption/ day/head (kg)	Feed consumption per period and total (t)
Receive	21	10.682	15,101.40
Start	21	9.889	13,980.30
Ending	78	11.308	59,378.80
Total			88,460.50

Table 3. Water footprint per kg of Charolais breed beef. Source: self made.

Total weight gain per head (kg)	Average daily gain (kg)	Total feed intake per head (kg)	Feed conversion (kg)	Feed conversion Carcass weight per head (kg)	Live weight (kg)	Carcass yield Meat (%)	Water Footprint (L kg^{-1})
220	1.833	1455.31	6.615	322.4	520	62	2,972.4

average in intensive production systems is 10,244 L kg^{-1}. For their part, Esquivel and Salgado (2020) determined that the average WF for production in an intensive system in the United States is 4,552 L kg^{-1}; this result is closer to that obtained in this research. For references purposes, in the Comarca Lagunera region of Mexico, the WF is 13,570 L kg^{-1} (Navarrete *et al.*, 2019).

The WF has a geographical and temporal component, which, in the case of beef production, is closely related to the diet. A better diet, a better choice of fattening breed with more productive efficiency, and the climate affect the magnitude of WF. A lower WF allows allocating water for other uses. Taking into account that the economic value of water is generally represented as monetary units, an efficient use of water increases overall productivity (Garay *et al.*, 2022).

CONCLUSIONS

This research contributes to understanding the issue of water footprint in production of beef. The volume of water necessary to produce one kilogram of beef was estimated and it matches the estimate of the blue and green WF. The gray water footprint must be incorporated into the analysis. This fact explains the lower magnitude of the WF with respect to that obtained for stabled cattle in the United States. The context of each research must also be incorporated in the analysis, including the following and other differences: the conditions of the study area, feed cultivation practices, difference in diets, weight gain, feed consumption, and animal carcass yield.

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