Energy, Nitrogen, and Phosphorus Balances in Grazing Cattle Fattening Systems

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ABSTRACT

The aim of this work was to check the balance of energy, nitrogen, and phosphorus in pre-fattening and fattening bovine systems at Turiguanó Livestock Breeding Company, in the province of Ciego de Ávila, Cuba. The botanical composition of the farms evaluated was determined, and the energy, nitrogen, and phosphorus balances checked. The annual energy, nitrogen, and phosphorus balances were negative on the experimental farms. New strategies are required to enhance energy and nutrients (nitrogen and phosphorus) use, and increase beef production during the final stage. Therefore, improvements in recycling, balance, and efficiency in the use of energy and these minerals are linked to increases in live weight/day, and better final weights during that stage.

Key words: *cattle, fattening, nutrients, recycling, efficiency*

INTRODUCTION

Increases in production, along with technical, technological, and management improvements have required farms to import raw materials by means of intensive use of balanced feeds, mineral salts, and chemical fertilizers. In that scenario, nutrients like phosphorus and nitrogen, secondary elements, and microelements, are widely utilized, since the naturally available sources in the soil are usually insufficient to meet forage and crop requirements (Pérez Infante, 2010; Guevara Viera *et al*., 2016).

Nutrient management is an area with an increasing interest, since it offers an alternative to reduce the pollution caused by nitrogen, phosphorus, and other minerals in livestock raising systems engaged in meat and milk production. In that sense, nutrient balances (the difference between income from input and output through the product) help understand dynamics, retention, and the recycling potential of the system itself. Additionally, the magnitude of the environmental costs (pollution, losses and/or transference of these nutrients out of the system), and economic (payments and their application within the system) can be estimated (Hristov, Hazen and Ellsworth, 2006; Martin, Díaz, and Hernández, 2007; Guevara Viera *et al*., 2016).

The balance of energy and other nutrients on a dairy farm is an agro environmental tool that allows management systems that reduce energy efficiency and the loss of elements into the environment (Roca *et al*., 2018). Nutrient inputs in terms of foods and fertilizers can be higher than milk, animals sold, and crop outputs. Therefore, mineral balance determinations are necessary on the local dairy farms, in order to introduce management improvements and enhance sustainability and efficiency.

The kind of regulations that could be implemented in Ecuador is still uncertain, so research is important to establish a coherent system. Relevant related information is essential to quantify the amount of nitrogen that inputs and outputs farms (MAGAP, 2013; Roca *et al*., 2018). Measuring the amount of nitrogen that is lost on a farm is a difficult task to fulfill on a routine basis, though not impossible, provided that strategies like volatilization, and inadequate or excessive use of fertilizers are implemented to estimate certain type of loss.

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Accordingly, nitrogen balance on a farm (total N input, minus total outputs as goods) is the most effective and practical way to estimate the amount of N that remains on the farm, which can be re-used, or that represents a potential hazard to the environment due to eutrophication (Pérez Infante, 2010; Guevara Viera *et al.*, 2016). Hence, the aim of this research was to determine the energy, nitrogen, and phosphorus balances in starting and final cattle fattening in grazing conditions, as a tool for management, which contributes to sustainability and efficiency.

MATERIALS AND METHODS

This study was conducted at the Turiguanó Livestock Breeding Company, in the municipality of Morón, Ciego de Ávila, Cuba, whose main goal is meat production. The company comprises an area of 7 218.88 ha, with 3 261.52 ha of farmland (2 557.57 ha of native grass, 572.26 ha of forage, and 131.69 ha of cropland).

A continuous grazing system was used throughout the year on a varied botanical composition that included native grass, like bahiagrass (*Paspalum notatum*); cultivated pastures, like common Bermuda grass (*Panicum maximum*), African Bermuda grass (*Cynodon nlemfuensis*); tree species, like algarroba (*Prosopis juliflora*), gliricidia (*Gliricidia sepium*), Guásima (*Guasuma ulmifolia*), and leucaena (*Leucaena leucocephala*); some creeping native legume species, like *Desmodium*, *Centrosema,* and *Calopogoneum*; and undesirable species, like sickle bush (*Dichrostachys glomerata*), needle bush, (*Acacia farnesiana*), and paspalum (Paspalum virgatum).

Windmills were used to pump water to round tanks with surrounding troughs for animal consumption. The data collected from the farm were used to check out the energy and protein balances, one liter was assumed as equivalent to a kilogram of the product. The estimations were based on conversion tables for product energy, according to Funes-Monzote and Monzote (2013). The balances were performed according to the method used by Guevara, De Armas, Guevara, and Curbelo (2006) for energy, nitrogen, and phosphorus. The inputs and outputs of energy, nitrogen, and phosphorus were determined, and the outputs were subtracted, which resulted in the balance figure of each nutrient.

The protein equivalent coefficient of plant and animal products for human consumption, previously implemented by Funes-Monzote and Monzote (2013) was used. It was multiplied by the kilograms produced, which output the system, including the 6.25 nitrogen equivalence to determine N. The sustainability indicators determined were energy balance, nitrogen balance, and phosphorus balance.

The step methodology described by García-Trujillo and Corbea (1982) was utilized to determine the botanical composition of the farms in the study. Molasses was used as energy concentrate, and Norgold was included as a protein concentrate, along with mineral salt, to provide supplementary nutrition to animals. Molasses was supplied at a rate of 2.0 kg per animal, Norgold was administered 1.0 kg/a/day, and the mineral salt was given at a rate of 0.1 kg/a/day.

RESULTS AND DISCUSSION

Table 1 shows the negative value of energy balance on the farm. The inputs were way above the outputs. The concentrated feed supplied and fuel consumption were the two most significant input products. These farms do not require physically exhausting labor, like hand weeding control, reaping to preserve hay, or ensilage; forage is not cut or carried. Hence, labor energy is not relevant to estimate balance. Energy expenses in terms of medication, and molasses were lower within the livestock system.

Table 1. Energy balance (MJ/year) in the fattening system

Concept	Energy (MJ/ year)
Beef (MM MJ/year)	2 829 656
Fuel (MM MJ/year)	4 349 920
Medication (MM MJ/year)	12 410 770

Molasses (MM MJ/year)	8 645 954
Human labor (MM MJ/year)	9.4
Feedstuffs (MM MJ/year)	13 546 370
Total energy that inputs the system (MM MJ/year)	38 953 024
Total energy produced that outputs the system (MM MJ/year)	2 829 665
Total output energy from the system (MM MJ/year)	2 829 655
Edible energy (MM MJ/year)	2 829 655
Number of people per ha fed in a year (#)	18 339
Energy balance (MM MJ/year)	(- 36 123 368)

A favorable balance was achieved by Guevara, De Armas, Guevara, and Curbelo (2006) on a very diversified system. The system used in the current study was not as diversified. The number of people fed per hectare in terms of edible energy was higher than the one found by Guevara, De Armas, Guevara, and Curbelo (2006), and by Funes-Monzote and Monzote (2013). The balance carried out by these authors was positive due to the large contribution of energy provided by plants in the system studied. However, in the current study there were some deficiencies; for instance, energy input was only supported by the beef produced, since no other productions contributed to further improvements.

Grazing cattle in the tropics usually means multiple nitrogen and other mineral deficiencies, since pastures and forages seldom meet the requirements of these nutrients. Such nutrient deficit in the grass is closely related to the soil features. Nitrogen is a fundamental component in the diet of animals, especially the ones with elevated needs of production (growth, lactation, and gestation) as the basic element for protein synthesis (Ayanz, 2006).

Table 2 shows the negative nitrogen balance. Funes-Monzote and Monzote (2013) claimed that the nitrogen issue in cropping and cattle raising systems is one of the most difficult ones to solve, provided it is not done through the well-known alternative of large-scale nitrogen fertilizer use. One of the most viable ways to solve this critical situation is the inclusion of legume species in areas with graminaceae, due to their high protein level, digestibility, and acceptable mineral composition. Equally important is the fixation of air nitrogen, which benefits quality and production of the graminaceaous (Guevara Viera *et al.*, 2016; Roca *et al.*, 2018).

Table 2 Nitrogen balance (kg/ha/year) in the fattening system

Concept	Nitrogen (kg/ha/year)
Total N_2 that inputs the system (kg)	51.44
N_2 that is output through beef (kg)	86.64
Edible protein (kg)	503.90
Protein per ha year (kg)	121.72
People/ha that can be fed with animal protein (#)	32.57
N_2 balance (kg/ha/year)	(-35.20)

The tropical-humid soils generally lack phosphorus, which is a critical element for plant growth and development (CIAT, 2013). Table 3 shows the balance of phosphorus, whose deficiency may reduce cell growth, decrease flowering and fruiting, and reduce the total number of seeds and their size. It also acts directly on carbohydrate use and root growth, particularly small lateral and fibrous roots.

Table 3. Phosphorus balance (kg/ha/year) in the fattening system

Concept	Phosphorus (P/ha/year)
Total P that inputs the system (kg)	16.01
Total P that outputs the system (kg)	24.49
People/ha who can use P produced in the system/requirements	105.1
Balance P (kg/ha)	(-8.48)

IICA (2009), in the Manual of Good Practices of Cattle Raising (beef), states total average of 0.70% phosphorus in 45-90 kg live weight calves, and 0.4% in balanced feedstuffs in beef cattle.

Because of the importance of phosphorus in cattle systems, the nutrient balances will provide information about the potential of environmental hazard, which might become critical indicators of sustainability for cropping and cattle raising systems. This balance will help recommend the best global improvement strategies based on determination of their mineral cycle (NRC, 2010; Pérez Infante, 2010; and Bargo, 2014).

Mineral balances, especially nitrogen and its derived use efficiency, are relevant for related estimations of grazing dairy cattle. These minerals are usually found as part of protein formation, nitrogen, and calcium and phosphorus salts, and in other nutrients, which are essential for life (NRC, 2010, CIAT, 2013; and Crespo, 2015).

Throughout the world, large areas with phosphorus deficiency are covered with balanced feedstuffs, whole and organic fertilizers, and direct mineral supplementation, which is a right and very safe practice (Kristensen, Mogensen and Knudsen, 2011; Bargo, 2014; and Guevara Viera *et al.*, 2016). Only the presence of indicators like energy balance demonstrates the potential to turn more energy into output beneficial products.

The energy-nitrogen-phosphorus triad is a comprehensive indicator of dairy systems, which is influenced by a number of factors, such as the physical characteristics of every system, climate, cattle ecosystem, season of the year, management of agrotechniques and fertilization, and other inputs used to produce forages, extra nutrition to grass, and the animal type (Pérez Infante, 2010; Bargo, 2014).

CONCLUSIONS

New strategies are required to enhance energy and nutrients (nitrogen and phosphorus) use, and increase beef production during the final fattening stage. Therefore, improvements in recycling, balance, and efficiency in the use of energy and these minerals are associated to increases in live weight/day, and better final weights for processing during that stage.

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