

Energy balance of the local system of fattening bovine production in Tecpatán, Chiapas, México

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The energy balance of two systems of fattening cattle production in Tecpatán, Chiapas, México is described. It is shown that the studied animal husbandry systems, which purpose is meat production, are energetically efficient with values of 4.53 and 4.99 MJ, produced for each unit of consumed energy for both productive units. Likewise, these systems develop an energy potential that does not fulfill the diet of a person, and its production of animal protein satisfies the requirements of six people per hectare a year. From the economical point of view, the animal husbandry systems of meat production have a benefit/cost relation of 1.56 Mexican pesos per each invested peso, which indicates this practice is economically possible for the producers from the area of study.

Key words: *animal husbandry, energy analysis, approaching methodology*

The Mexican animal husbandry occupies around 110 millions hectares. From them, 28.3 % belong to tropical areas, mainly distributed in the states of Veracruz, Tabasco, Chiapas, Tamaulipas and San Luis Potosí (Espinosa *et al.* 2000, Magaña *et al.* 2005 and INEGI 2012). The cattle from these areas is produced mainly for double purpose. There are also calves used for fattening which mainly depend on the extensive grazing.

The main varieties of grass used in the diet of these animals are *Panicum maximum*, *Cynodon plectostachyus* and *Brachiaria brizantha*, among others (Ruiz *et al.* 2004). The Cebu x Swiss and Cebu x Simmental breeds are the most used due to their rustic qualities and their adaptation to the weather. Calves are commercialized when they are nine months old, with an average weight of 160 kg (Orantes *et al.* 2010). During the fattening stage, which lasts from 6 to 10 months, they reach 360 kg of average fattening weight, and 480 kg of complete fattening weight (Vite *et al.* 2007).

The energy analyses are very important for the evaluation of the sustainability of agricultural systems (Mora *et al.* 2006). There are many researches related to this subject, among them the studies of Refsgaard *et al.* (1998), Ozkan *et al.* (2004), Bonel *et al.* (2005), Teixeira *et al.* (2005), Pimentel *et al.* (2005), Zak *et al.* (2006), Denoia *et al.* (2006), Meul *et al.* (2007), Mrini *et al.* (2008), Pimente and Willianson (2008), Pimentel (2009) and Denoia and Monticos (2010).

The agricultural and livestock production can be considered as a process of energy conversion, where the solar energy, through the photosynthesis, is transformed

into food for the human beings, and in forage for animals (Denoia and Monticos 2010). Nevertheless, the modern agriculture needs the contribution of fossil energy in all the production stages, like the direct use of energy for agricultural machinery, irrigation, crops operations and harvest (Denoia and Monticos 2010).

The sector of animal husbandry, and especially the ruminants, is considered as one of the most important contributors to the release of greenhouse gases (GHG), with 18% of the global net emissions, mainly of: carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O). All these gases are generated by ruminant fermentation and animal faeces (Blanco *et al.* 2011 and Indira and Srividya 2012). It has been stated that if the supplies of concentrated food increases, the production of GHG also increases, as well as the energy expenses. Due to these conditions, the intensive management of pastures and the use silvopastoral systems are recommended (Carmona *et al.* 2005).

The irrational use of the energy is a subject related to climate change and accumulation of GHG. The energy consumed in the agricultural systems comes from the animal and human work, the organic matter, the industrial consumables, and the sun. A part of this energy is transformed into product and the rest disappears in the process (Funes *et al.* 2009). The comprehensive organic systems with a great diversity try to take good advantage of the energy benefits of the system. This way, they try to minimize the losses during the development of the productive activities and to favor the interrelation between the productive components and the internal

recycling of nutrients (CEDECO 2006).

Even though during the last years there have been important increases in the yield of most of crops, the energy efficiency of the systems has diminished because the use of energy has increased in a higher rate regarding the yields (Hetz *et al.* 1994).

The meat production in the tropical areas, based on traditional systems which are built by the experience of the producer, leads, occasionally, to the investment of more energy than the required for the good functioning of the system. For instance, the over grazing occurs due to the inappropriate management of the stocking rate, and, consequently, concentrated food has to be bought. As a result, the emission of GHG is higher. According to Espinoza (2000) and Vilaboa *et al.* (2009), the climate features, the animal management, the breed, the modernization rate, as well as the social and economic environment of the producer, are determining factors for achieving a good exploitation of resources, a productive efficiency and a consistent sustainability.

The economic and energy efficiency of the system of fattening cattle production is analyzed in this study. Its goal is to contribute to the knowledge of the traditional systems of animal husbandry in Mexico.

Materials and Methods

Location of the study area. The research was carried out in the cooperative farm Miguel Hidalgo, Tecpatán municipality, Chiapas State. Two representative farms of the area were selected, and their main activity is the system of fattening cattle production. Semi-structured interviews and field tours were carried out for data collecting. According to the recommendations of Funes *et al.* (2009), the patterns related to the energy efficiency were: hours of human work (h/ha), consumed energy (MJ), productive yield (t/ha), produced energy (MJ/ha), produced protein (kg/ha), produced animal protein (kg/ha), people fed with energy (p/ha), people fed with proteins (p/ha), energy cost of protein (MJ/kg), energy productivity of work (h/MJ), protein productivity of work (h/kg) and energy balance.

Energy analysis. The analysis method of Meul *et al.* (2007) was used. The incomes and expenditures of energy were considered, which were characterized by flows of physical matter and consumables used for the production. The methodology of Funes *et al.* (2009) was applied, which consisted on the documentation of the necessary elements for calculating the energy efficiency. This methodology includes the area of the productive system, kind and amount of food, products, and direct or indirect energy expenses of the production (animal and human workforce, use of fuel, fertilizers and other consumables). The approach for the energy balance used in this study does not consider the ecological costs from the solar energy, dissipated heat or the energy degraded in the system.

The energy efficiency was calculated through the formula of Funes *et al.* (2011):

$$E_e = \frac{\sum_{i=1}^S m_i e_i}{\sum_{j=1}^T I_j \times f_j} \quad Ec.1$$

Where:

Ee= Energy efficiency;

S = Number of products;

M = Amount of the product (kg);

E = Energy content of the product (MJ/kg);

T: Number of consumables;

I = Amount of consumables (kg);

F = Energy required to produce a supply (MJ/kg).

The indicators related to the productivity of the system were quantified, like the amount of produced energy (MJ/ha/year) and protein (kg/ha/year) and the amount of people that could support the system, according to the average demand of protein and energy of a person per year (Funes *et al.* 2011). The contents of energy and protein of animal and plant origin used for the calculation were taken from Gebhardt *et al.* (2007). The energy equivalences for calculating the expenses in direct or indirect consumables were stated by García (1996) and Funes *et al.* (2011).

The calculation of the amount of people that can be fed according to the energy requirements was performed through the use of the formula of Funes *et al.* (2011):

$$P_e = \frac{\sum_{i=1}^S m_i \times \frac{r_i}{100} \times e_i}{R_e} \quad Ec.2$$

Where:

Pe: people supported on the bases of produced energy;

mi: production of each product (kg);

ei: energy content of each product (MJ);

A: area of the farm (ha);

Re: energy requirement of a person (kg/ha).

For calculating the amount of people that can be fed, according to the protein requirements, the formula of Funes *et al.* (2011) was applied:

$$P_p = \frac{\sum_{i=1}^S m_i \times \frac{r_i}{100} \times p_i}{R_p} \quad Ec.3$$

Where:

Pp: people supported on the bases of produced protein

mi: production of each product (kg);

pi: protein content of each product (MJ);

A: area of the farm (ha);

Rp: protein requirement of a person (kg/ha).

Analysis of the benefit/cost relation. For calculating the benefit/cost relation, the productive units (PU) were considered as closed systems, which only considered the incomes and costs of the system. The calculation was carried out by this formula:

$$BCR = \frac{\text{Income}}{\text{Costs}}$$

Where:

Incomes: Incomes from the animal sales

Costs: Sum of the production costs

The expenses in each area of the production system were considered in order to obtain the total costs. The total incomes were obtained from the sale of calves. The benefit/cost relation was obtained from the incomes and expenses. Besides, the utility in each production system was calculated. The Mexican peso was taken as reference for all the calculations.

Results and Discussion

Table 1 shows the energy expenses of human and animal work in each studied PU. Although the characteristics of the production systems are similar, there are works in each PU that require more or less energy expenses, due to the specific characteristics of the production system or the skills of the producer. This coincides with the reports from Torres and Torres (2004), who mention the existence of many factors that favors the differences in the energy expenses.

Generally, there are works that mark the differences in the energy expenses from both PU. Some of these are the grass cutting, gathering of animals, transportation of the producer to the farm and mineral salts supply. All these works determine human energy expenses of 105.5 MJ for PU-2, which represented an 82.5 % of the total energy expense of this unit. The marked difference in the energy expenses, due to the supply of mineral salts, lies on the amount of hours spent in that work, which is 208 h higher in PU-2.

In the case of shoeing activities, the producer of PU-2 did not spend time because this activity is combined with the gathering. However, this activity in PU-1 is carried out with fire and it takes two hours with two people. Another case is the grass-cutting activities, which is less

used in PU-1 because of the management of *Brachiaria* pasture. This requires less paid work per hectares. The use of *Pennisetum* pasture is different because it allows a higher growth of weeds and more paid works.

The transportation to the farm is another different characteristic in both PU. As it can be observed in table 1, the energy expense is higher in PU-2 because the producer has to spend two hours walking to the farm. On the other hand, the producer from PU-1 does not have to move to the farm because he lives in it.

The water availability involves more or less energy. For instance, PU-1 does not need to spend time for water supply because there are streams which the animals use for drinking water. However, the workers of PU-2 have to take care for the water supply and keep the water troughs filled. The difference regarding the animal energy expenses lies on the use of a horse for the activities of gathering and transportation of the animals for sale.

Table 2 shows the structure of the energy expenses for both PU. The consumption of white salt represents the highest contributions to the energy expenses regarding the total consumed consumables in each PU, with more than 65 % of the total expenses.

Both PU showed that the energy production was higher than the energy expenses, which had an impact in a balance of energy higher than the unit (table 3). Although there are variations, which differentiate an activity from the other regarding the energy expenses, the meat yields per hectares in both PU even the energy expenses. Then, the energy efficiency turns to be high and similar to the values reported by Cieza and Flores (2007). These authors state that when the exploitation of the pastures increases, the energy efficiency grows with it, because the pastures make use of the energy that comes directly from the sun. This energy is transformed

Table 1. Energy expenses of the work in the two PU of fattening calves from the cooperative farm "Miguel Hidalgo" in Tecpatán, Chiapas.

No.-	Work	Energy expenses (MJ)			
		PU-1		PU-2	
		Human	Animal	Human	Animal
1.-	Grass-cutting	44.68	0.00	50.24	0.00
2.-	Cutting hedge	4.65	0.00	5.57	0.00
3.-	Fence keeping	7.45	0.00	6.99	0.00
4.-	Collecting	6.28	45.22	13.94	0.00
5.-	Shoeing	0.71	0.00	0.00	0.00
6.-	Parasites removal	0.92	0.00	0.25	0.00
7.-	Vaccination	0.46	0.00	0.46	0.00
8	Transportation to the PU	0.00	0.00	12.06	0.00
9.-	Mineral salts	5.15	0.00	29.31	0.00
10	Water supply	0.00	0.00	0.92	0.00
11	Dipping	6.03	0.00	6.03	0.00
12.-	Sale	1.84	13.40	2.09	0.00
Total		78.17	58.62	127.87	0.00

Table 2. Structure of the energy expense of the consumables for two PU of fattening cattle in the cooperative farm "Miguel Hidalgo"

Consumables	PU-1		PU-2	
	MJ	%	MJ	%
Insecticides	93.79	31.68	87.76	31.03
White salt	202.23	68.32	195.03	68.97
Total	296.02	100.00	282.79	100.00

and transferred to the bovines that turn it into meat, which represents low human energy expenses and low consumables expenses.

The results of this study are superior to the results stated by Guevara *et al.* (2006), who informed an energy efficiency of 2.8 in forest and animal husbandry systems. Valdés *et al.* (2009), in a study of the energy balance carried out in 20 farms located in the Western area of Cuba, demonstrated that the energy balance of these farms influences on the use of external consumables which were obtained to promote the animal production.

When comparing both productive units, the energy yield and the energy intensity were the same. However, the energy efficiency was superior in PU-2 due to the superior yield of meat production per hectare and to the inferior energy consumption of this unit (table 4).

The yield of meat production per hectare was superior in PU-2. The amount of animals in each PU and the daily liveweight gain mark these differences in both units. These values were inferior to those informed by Macedo *et al.* (2008), who reported yields of 351 kg of meat.

These data indicate that the calf meat production in both PU does not supply the energy needs of a person in a year. However, from the protein point of view, six people per hectare can be fed annually. Funes (2000) reported a similar result in a mainly animal husbandry system in Cuba. Nevertheless, this result differs from those stated by Guevara *et al.* (2006), who found the ability of feeding 1.4 people/ha in a forest and animal husbandry system, but this system also produces plant protein.

Funes *et al.* (2011), in a recent study carried out in Cuban farms, informed ranges of energy productivity that allow to feed from 0.3 to 21.1 people/ha. The protein productivity allows feeding between 1.7 and 38.4 people/ha, with the diversified management of these farms.

The energy cost per kilogram of protein was similar in both PU. This results from the similarities of the energy contribution from the production of energy from the meat, and the energy consumption in the two productive units. In both PU the energy production was higher than the energy consumption, which has an impact on the energy efficiency of the productive units. This result was influenced by the achievement of a closed cycle and by the proper exploitation of the natural resources which guarantees an adequate use of the nutrients and the energy of the system (Schiere *et al.* 2002). This does not mean that all the energy incomes and expenses involved in the studied productive systems were considered, mainly those related to the ecological costs (open systems) (Naredo 2003 and Martínez 2005).

Table 5 shows different indicators used as base to calculate the economic efficiency based on the

Table 3. - Energy analysis in the two productive units.

Indicator	MU	PU-1	PU-2
Meat production (45% of yield)	kg	301.50	306.00
Energy production	MJ	1961.19	1990.50
Total of direct energy used	MJ	432.94	398.64
Energy intensity	MJ/kg	6.50	6.50
Energy yield	kg/MJ	0.15	0.15
Energy efficiency		4.53	4.99

Table 4. Parameters related to the energy efficiency.

Indicator	PU-1	PU-2
Hours of human work per ha	74.68	70.04
Productive yield, kg/ha	301.05	306.00
Produced energy, MJ/ha	1961.19	1990.50
Produced protein, kg/ha	62.41	62.41
Energy cost per kg of protein, MJ/kg	31.44	31.90
Energy productivity, h/MJ	0.038	0.035
Protein productivity, h/kg	1.20	1.13
People fed with energy/ha/year	0.46	0.47
People fed with animal protein/ha/year	6.11	6.12

benefit/cost relation of meat productions. Both PU had a positive balance regarding the incomes and expenses, which demonstrated the economic feasibility of this practice. The evident resemblance between the amounts of animals from both farms is because of the surface of each farm. According to Vargas *et al.* (2011), this surface determines the size of the cattle herd and is directly related to the dimensions of the farm. Nevertheless, there are some variations in the selling price of the farm, regarding the moment of the sale.

The weight gains are different in each productive unit, where PU-2 was superior (667 g/d) to PU-1 (643 g/d). However, both had inferior results to those stated by Rebollar *et al.* (2011), who published a weight gain of 1900 g/d, in stabulated fattening systems. The selling price also varies, because the producer from PU-1 sells the animals at \$ 21.00, and the producer from PU-2 sells them at \$ 23.00, because this unit sells the animals directly to the principal gatherer. Orantes *et al.* (2010) stated similar information and confirmed that the gatherer may earn up to \$ 2.00 per kg of liveweight in the calves selling. This aspect, as well as the highest liveweight achieved in PU-2, did not influenced on the benefit/cost relation to be higher in PU-2. This is caused, mainly, by the highest production cost of the PU-2, which has more calves.

Rebollar *et al.* (2011) referred sale prices in the state of Mexico for the fattening cattle, between 21 and 21.5 \$/kg. However, in the case of the purchase, these prices decreased to 17 and 18 \$/kg of liveweight.

Espinosa *et al.* (2000) obtained similar results. The profits achieved in both units confirm the stated by Riggs (2001), Velázquez (2002), and Medina and Rodríguez (2005). These authors declare that the most important thing in these productive systems is to recognize that the animal husbandry business has to leave profits because its survival depends on them.

In a study about competitiveness and profitability in fattening bovines from the state of Mexico, Rebollar *et al.* (2011) informed that the animal husbandry of bovines in this region is an efficient and profitable activity for producers of herds with more than 50 head of cattle. This is explained by the high incomes received from the sale of animals. In the case of this study, although the herds from both productive units are small and the level of liveweight gains are below those informed, this activity continues to be a feasible economic option for the producers of the studied area.

Macedo *et al.* (2008) carried out a research in Mexico about the protein, energy and forage balance from a production system of cattle with double purpose. They found that the profitability of the production system, measured with the benefit/cost relation, was 1.02 and it is balanced. Therefore, any changes to improve the production system should be carried out using management practices or introducing technologies with an immediate benefit that surpasses its implementation

Table 5. Behavior of costs, profits and the relation benefit/cost in the studied productive units.

PU	Animales	Weight, kg		Precios		Expenditures		Incomes		B/C Rel	
		Initial	Final	Buy	Sale	Production cost	Calves buy	Total expenditures	Calves sale		Profits
PU-1	18	200	335	\$18.00	\$21.00	\$16.578.00	\$64.800.00	\$81.378.09	\$126.630.00	\$45.251.91	1.56
PU-2	20	200	340	\$19.00	\$23.00	\$24.412.72	\$76.000.00	\$100.412.72	\$156.400.00	\$55.987.28	1.56

The economic data are expressed in Mexican pesos.

cost.

It is necessary, for further studies, to deal with costs from the point of view of an ecological economy, which suggests the use of biophysical indicators in the assessment of the sustainability in the traditional economy, using financial indicators. These indicators offer criteria and points of reference to the management of useful ecosystems, in relative terms more than in absolute terms, and allow the comparison between situations and systems, in time and space (Carpintero 2005).

The animal husbandry systems for meat production in the cooperative farm Miguel Hidalgo, Tecpatán municipality, Chiapas, are energetically efficient, with energy contributions that surpass almost five times the energy consumption. These systems develop a potential of energy and of animal protein production that allow the feeding of 0.5 and 6 people per hectares, respectively.

These animal husbandry systems are sustainable and economically closed and produce with a benefit/cost relation of 1.56 per each invested peso. This indicates that this practice is feasible from an economical point of view for the producer of the area in study, depending on the meat production yield, the liveweight in the moment of sale, and the selling price.

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