



## Gross energetics in the evaluation of the functioning of Instructional Dairy Farm at Pantnagar, India

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### ABSTRACT

Instructional Dairy Farm at Pantnagar University was studied for evaluating its energetic efficiency, an important measure to evaluate the functioning of a production system. The total organic inputs and outputs of the dairy farm were converted into their respective energy values. Of the total energy flows involved in the dairy farm, 72.6% was the input energy suggesting that most of the energy flow in the dairy farm takes place through feeds. Of the total energy output, dung accounted for 54.83% and milk 44.86%. Only 0.31% of the total output energy was contained in the new born calves. The energy balance of the dairy farm reflected that dung was the most important product, though milk was regarded as most valuable product as it is used for direct human consumption. Gross energetic efficiency of the farm worked out to be 37.7%. This reflects that 62.3% of the total energy was being used for non-productive purposes (methane production or others).

**Keywords:** Dairy farm, Energy, Energy efficiency, Input energy, Output energy

A traditional farming system in India has special place for livestock but not just for production purpose. It gives place even to the ‘useless’ animals for several intangible benefits, particularly for their role in the ecological integrity vital for sustainability of farming systems (Singh 1998, 2002a, 2020, Singh and Sharma 1990, 1998, Singh *et al.* 2001a, 2001b, 2017, Singh and Tulachan 2002, Singh and Gaur 2008). However, majority of animal scientists and policy makers seldom appreciate livestock contributions to ecological integrity (Singh 2019), which is perceived not through conventional economic analysis but through ecological economics. Working out energetics of livestock production is one of the ways to evaluate ecological economics of a production system.

Many workers, notably Singh (1998, 2002a, 2002b), Singh and Bohra (2005) and Singh and Gaur (2008), have presented the status and production performance of livestock in the Himalayas and have also suggested ways and means for increasing the livestock production. There are only fewer studies on the energetics of dairy farms. For example, Singh and Sharma (1993) worked out the energetics of crossbred dairy cows at a small dairy farm in the Himalayan environment and Singh *et al.* (2002) of dairy farms in the Tarai area of Uttarakhand. Thus, there is a big gap regarding the information on energetics, especially of large dairy farms.

A logical and objective method of evaluating the productivity and ecological attributes of livestock would

be to determine the gross energetic efficiency or the input-output ratio of consumption and production. The common denominator to which the input and output can be related with most accuracy is not economics, but the energetics (Singh and Sharma 1993, Singh *et al.* 2002, Rastogi *et al.* 2018).

Energetics, also related with energy economics, is the study of energy under transformation. The aim of energetics is the description of fundamental laws. The fundamental laws of thermodynamics can be treated as laws of energetics. In terms of dairy animals, the first law of thermodynamics can be stated as: Energy input must be equal to energy output plus or minus any change in body energy. Although energy can enter an animal's body via radiation (direct exposure to sun), convection (flow of heat from the air to the body) and conductance (flow of heat from a warm surface the animal comes in contact with), these inputs are usually quite minor, temporary and unrelated to the energy system functioning through the oxidation of nutrients. Therefore this discussion will assume the only energy input into the body of a livestock via diet (green fodder, dry fodder and concentrates). On the other hand, output is in the form of calf crop, milk and manure produced by livestock.

The second law can be explained as: No transformation of energy is 100% efficient and the inefficiencies are due to loss as heat. Energetics being dependent on the inputs and outputs of a dairy farm will be a useful indicator to suggest whether a dairy farm is sustainable or not. The purpose of this study is to present quantitative values which help in understanding the basic ecology of a large dairy farm. To that end, a gross energetic balance sheet has

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been presented taking a large dairy animal population as the basic unit of study. The gross energetic efficiency of livestock population is equal to the products derived from the livestock used by humans (in kcal) divided by the feed consumed by the livestock (in kcal).

This paper, attempts to evaluate the performance of one of the biggest dairy farms in Uttarakhand managed by the GB Pant University of Agriculture and Technology by applying the principles of energetics,.

MATERIALS AND METHODS

The present research was carried out at the Instructional Dairy Farm of Govind Ballabh Pant University of Agriculture and Technology based in Pantnagar, India for a year during 2018-2019. The total area of this farm is 515 acres. The primary information was collected on the pre-structured proformas. The information was collected on daily basis with the help of experts and working staff of the dairy farm. The required secondary data regarding aspects like population and composition of livestock in the dairy farm, feed composition and consumption, milk and dung production etc. were collected from the records of the Instructional Dairy Farm.

Among the dairy animals at the dairy farm were the cow breeds Sahiwal, crossbreds and Hill cows, and Murrah breed of buffalo. The diet provided to the dairy animals was rich in protein and fibre (wheat and rice straw, sorghum, berseem, oat, maize, and other feedstuffs). The variation in the diet depended on price and season. The annual average temperature was 21±1°C. Animals were randomly divided into 3 groups (dry animals, lactating animals, and calves) for convenience.

All the inputs and outputs were expressed on their dry matter basis. The energetic value of dry manure was considered to be 2.13 kcal/g as referred by Singh *et al.* (2002).

To calculate feed consumption, amount of feed given to an animal was subtracted from the leftover feed. The energetic value of a particular feed item was calculated according to its fat, crude protein, fiber and nitrogen-free extract content using available proximate analysis data from appropriate sources. Adding up the values of the individual content, i.e. fat, protein, and carbohydrate, the total energetic value of the feed items was determined.

Energy value of milk was based on its fat content. Total calves born in a year were enumerated. Energetic value of a newborn cow calf is 21,387 kcal (Singh and Sharma 1993). Multiplying total number of calves born at a dairy farm during a year by this figure would give energetic value of cattle calf crop. Energy value of a buffalo calf was adjusted to the approximate weight difference. A buffalo's body weight in the area was approximately by 1.25 times higher than that of a crossbred cow (Singh *et al.* 2002). The same factor was used for evaluating energy value for a buffalo calf, which was equal to 26736.25 kcal. Multiplying total number of buffalo calves at a dairy farm in a period of one year by this energy value would give energy value for the buffalo calf crop at the dairy farm.

RESULTS AND DISCUSSION

A dairy farm operates within an ecosystem/ agro-ecosystem. Dairy animals receive biomass energy from the ecosystem in the form of feed and fodder, use a proportion of this energy for their growth and maintenance, and convert the rest into useful products (e.g. dung/ manure, milk, calves, draft power, etc).

*Dairy farm inputs:* The population consisted of 338 cows, 77 buffaloes and 489 calves. These three categories were further divided into two, i.e. lactating and non-lactating cows/ buffaloes and female and male calves. Proportion of cows as well as of cow calves at the dairy farm was far more than that of the buffaloes. The female calves, both of cows and buffaloes, were in larger proportion than their male counterparts.

*Feed consumption and production:* The major constituent of the diet included wheat and rice straws. Other important feeds were mustard oil cake, berseem, sorghum, maize and sugarcane tops. A total of 10 different kinds of feeds were fed, but many of the feeds depended on seasonal availability (Table 1). The lactating animals received a more preferred diet as per the basic recommendations. The only input the dairy farm received was the feed (dry fodder, greens, and concentrate). Human labour was not taken into consideration, as feed was the only input which contributed to biomass.

Table 1. Feed availability during the year

Jan - Mar	Apr - Jun	July - Oct	Nov - Dec
Oat, Berseem, Hay, Wheat straw, Sugarcane tops, Maize, Napier and Jowar	Oat, Wheat straw, Sugarcane tops, Maize and Berseem	Jowar, Hay, Rice straw and Grasses	Oat, Berseem, Jowar, Sugarcane tops, Soyabean, Maize and Hay

The energy value of the rations provided to livestock was as referred by Singh *et al.* (2002) and Rastogi *et al.* (2018). To estimate total energy consumption, we multiplied mean daily consumption value to total number of animals for each category (Table 2).

Table 2. Total feed consumption at the dairy farm

Age class	Mean daily consumption	No. of livestock	Energy value, kcal
Adult female	13585 kcal/ female	415	5637775
Immature	9016 kcal/ calf	489	4408824
Total daily energy consumption by the population			10046599
Total yearly energy consumption by the population (10046599 kcal/day) × (365 days/year)			3667008635

*Dairy farm outputs:* Milk, dung/ manure, and calf crop were the main outputs of the dairy farm. Though only milk is considered for economic evaluation of a dairy

farm, dung and calves are also of great socio-economic importance. Meat production from a dairy farm is never imagined. Dairy farming in the Tarai area, as in most of the Indian region, carries a notion of sacredness. Cows are especially regarded as sacred. Animals have positive interaction with the environment. In recent years, dung produced at Pantnagar-based dairy farm is being used for the production of vermicopost. Sold in the market, the vermicompost fetches huge amounts of money, thus adding to large proportion to total economic returns from the dairy farm. Role of dairy animals in maintaining cyclic flow-pattern of nutrients is of critical importance for maintaining the productivity and sustainability of an agro-ecosystem.

Annual estimates of milk production were based on the official records maintained by the dairy farm officials. More than half of milk was produced by high-yielding breeds of cows (10-12 kg of crossbred, 6 kg of Sahiwal) because of a larger population than that of buffaloes. As much as 88.5% of milk was produced by cows. As many as 194 lactating cows were with their average yield of milk (8-9 kg/day per lactating cow) whereas 46 lactating buffaloes in the herd produced 5-6 kg of milk per day per head. Thus, a rough estimation of the total milk production by this animal population during the year of experimentation was calculated. The daily average milk production was 2143.866 kg for the entire population. Thus, the yearly production at the Instructional Dairy Farm would be 782511.09 kg of milk.

One kilogram of 4.5% fat milk is equal to 794 kcal (Singh *et al.* 2002). Multiplying total annual average milk production (in kg) by 794 kcal gave the annual output of milk in terms of calories. Therefore, the approximate calorific value of the total milk production by this animal population in 1 year would be:  $(782511.09 \text{ kg}) \times (794 \text{ kcal/kg}) = 621313805.50 \text{ kcal}$ .

Dairy manure contains essential plant nutrients that compose plant structure. These include nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), manganese (Mn) and copper (Cu) etc. The average daily dung production was calculated for the two different age and sex classes. These were converted to their respective energy values. These values were used to calculate the yearly output of energy in terms of dung, a highly valuable product used for improving soil fertility.

The values of dung production in kcal were derived using calorific values as referred by Singh and Sharma (1993) (Table 3).

Table 3. Total dung production in the dairy farm

Age class	Daily dung production	Number of livestock	Daily production (kcal)
Adult Female	2731 kcal/female	415	1133365
Immature	1937 kcal/calf	489	947193
Total energy of dung production by the population per day			2080558
Total yearly energy of dung production by the population $(2080558 \times 365)$			759403670

Numbers of all the calves born in a year were found out in the records of the dairy farm. Energetic value of a new born cow calf is equal to 21389 kcal as used by Singh and Sharma (1993) and Singh *et al.* (2002). Multiplying total number of calves born at the dairy farm during the year by this figure would give the total energetic value of the calf crop. Energy value of a buffalo calf was adjusted to the approximate weight difference. A buffalo's body weight in the area, as found in an earlier study by Singh *et al.* (2002) was approximately 1.25 times higher than that of a crossbred cow. The same factor was used for evaluating energy value for a buffalo calf, which was equal to 26736.25 kcal. Multiplying total number of buffalo calves at the dairy farm in a period of one year by this energy value would give energetic value for the buffalo calf crop at the dairy farm.

In the dairy farm, 152 calves of cattle and 41 calves of buffalo were multiplied by their energetic values to obtain total energetic value of calf crop. Total energy value of the calf crop at the dairy farm during the study period worked out to be 4347314.25 kcal. Energy values of cow and buffalo calves were 3251128 and 1096186.25 kcal respectively.

**Energy balance:** An energy balance sheet (Table 4) for the dairy farm presents total input and output energy values. We found that input energy in a dairy farm was much more than the total output energy. Dung contributed the highest amount of output energy ( $0.759 \times 10^9$  kcal), and the contribution of the milk to the energy flow valued at  $0.621 \times 10^9$  kcal. A fraction of the total output energy ( $0.0043 \times 10^9$  kcal) flowed through calf crop.

Of the total energy flow in the dairy farm, as much as 72.6% was the input energy. This would suggest that feed (the sole input) constituted major amount of energy in the annual dairy budget. Of the total output energy, dung accounted for as much as 54.83% and milk 44.86%. A small amount of energy (only 0.31%) was contained in the newborn calves (Fig. 1). The energy balance of a dairy farm, thus, suggests that, from the view point of energy output, the dung is the most important produce—in terms of total energy value and ecological contributions towards soil fertility amelioration and sustainability of agricultural production.

Table 4. Energy balance sheet of the Instructional Dairy Farm

Particular	Energy value, kcal/year	Energy value, kcal ( $\times 10^9$ )
Input	3667008635	3.667
Output		
Dung	759403670	0.759
Milk	621313805.50	0.621
Calves	4347314.25	0.004
Total output	1385064789.75	1.385
Maintenance, growth, and losses through gases and heat	2281943845.25	2.282

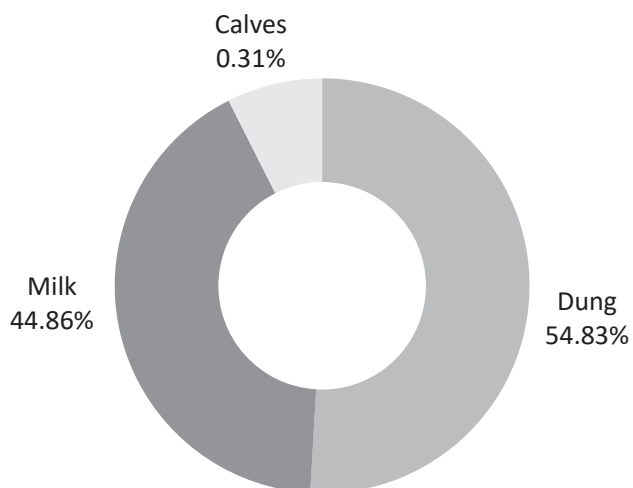


Fig. 1. Proportion of output energy values.

Energy in dung returns to the soil ecosystem through manure and a fraction of it is utilized by soil organisms in the detritus food chain and the rest is released into the environment. The detritus food chains are vital for the soil biodiversity to flourish. As the planet’s soil serves as the major sink of carbon, containing 2 to 3 times higher amount of carbon than the forests, soil fertility management would be instrumental towards enhancing carbon sequestration rates and, thus, playing crucial role in the natural phenomenon of climate change mitigation (Singh 2020). Humans consume milk energy and calves also consume a fraction of it. New borne calves retain a proportion of the output energy.

*Gross energetic efficiency:* Gross energetic efficiency is

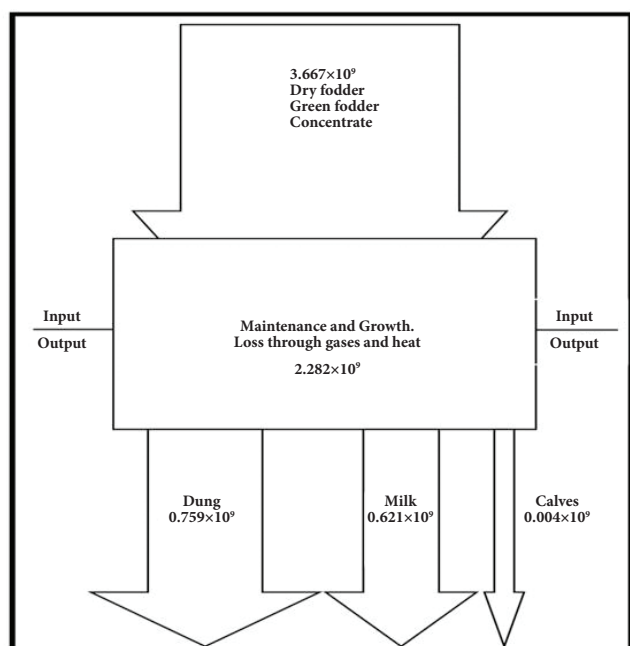


Fig. 2. Annual energy flows through the Instructional Dairy Farm (all figures are in kcal).

the percentage of the ratio of the total output energy, i.e. the calories derived from dairy animals having direct value for humans (e.g. milk for consumption and calves for sale and/ or further production) and for their environment (e.g. dung or manure for soil fertility maintenance), to the input energy, i.e. calories of total feed consumption by the dairy animals.

The gross energetic efficiency of the dairy farm studied was 37.77%. Energy used for maintenance and growth, which also included energy loss through gases like methane and heat, was  $2.282 \times 10^9$  kcal. This would suggest that a dairy farm was able to efficiently utilize only 37.77% of energy into useful production and the rest 62.23% was being used for non-productive purposes. A proportion of this energy would be lost through heat and gases. The energetic efficiency data emerged in this study are higher than in previous studies by Singh and Sharma (1993) and Singh *et al.* (2002) as energy input, such as in the form of human labour, have not been included in the analysis.

Energetic efficiency is an important indicator to measure the functional performance of a dairy farm in relation to the environment or the agro-ecosystem it operates in. The higher the value of the outputs obtained relative to those of the inputs the higher the energetic efficiency. Improvement in dairy farming efficiency will take place if we bring more of the dairy outputs into economic use. For example, milk is not the only usable dairy output. Dung and calves are also of great importance as we have analysed in this paper. Ecological valuation of dung, such as its contribution to soil fertility improvement translating into improved crop production, increased carbon sequestration through natural fortification of photosynthesis, proliferation of pedo-biodiversity, etc. would further help us in understanding contribution of dairy farming to ecological amelioration of the agro-ecosystems. An efficient and conservation-oriented management of natural resources would be phenomenal for ecologically healthy, vibrant and sustainable dairy farming.

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