POLJOPRIVREDNA TEHNIKA
Godina XXXII
Broj 2, decembar 2007.
Strane: 71 - 77

Poljoprivredni fakultet
Institut za poljoprivrednu tehniku

UDK: 631.1.017

DETERMINATION OF THE ENERGY DEMAND FOR LIVESTOCK BUILDINGS AT THE EXAMPLE DAIRY FARMING

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Abstract: The cumulative energy demand in dairy farming is strongly determined by feed supply and replacement. More than the half of the total cumulative energy demand is required for feed supply, about one quarter for replacement. The investigations aim at the development of a method for calculating energy balances in livestock farming; in this case especially on the parts livestock buildings and technical facilities in dairy farming. The specific cumulative energy demand per animal place and year calculated for the building and for the technical facilities is about 5% respectively. Different building shells cause only minor differences in the cumulative energy demand. Whereas the cumulative energy demand for a dairy cattle building without slurry channels and pits is about one third less than for a building with channels and pits. The cumulative energy demand for the technical facilities is about 60% less when sand is used as flooring material instead of a rubber mat.

Key words: *energy demand, dairy farming, animal husbandry.*

INTRODUCTION

In agriculture, we record a constantly growing consumption of raw materials and fossil energy due to the intensification and mechanisation of production technologies. In crop production, this involves direct and indirect energy inputs into the manufacturing and application of fertilizers and plant protection agents as well as machines and implements. In livestock keeping, direct and indirect energy inputs are caused not only by the supply of farm-produced or externally purchased feeding stuffs, air-conditioning, manure disposal and spreading of farm manure, milk production and storage, but also by buildings and constructions. So far, there is a poor knowledge of the energy efficiency of production technologies in livestock keeping, as well as their share in the total energy consumption of a farm and the influence of targets and the intensity of production on the energy efficiency. Nevertheless, any analysis and evaluation of environmental effects and the sustainability of farming systems must consider also the energetic aspects. Energy balancing allows characterising farming systems, overcoming labour bottlenecks and elaborating optimisation strategies.

Objectives

The investigations aim at the development of a method for calculating energy balances in livestock keeping. In this context, not only inputs and outputs are regarded in the form of a "black box" analysis, but rather the relationships between livestock keeping and soil and plant related to the farming via internal energy and mass fluxes. The methodology will be integrated into the "farm and environment management system REPRO (reproduction of organic soil matter)" (Hülsbergen, 2003). The REPRO software allows analysing and evaluating environmental impacts. Different from other approaches, it reflects a systematic consideration and description of interrelated mass and energy fluxes on the farm level.

Using vegetable as primary products, the procedure of forage preservation is analysed and the resulted amount of feed stuff is calculated. The energy efficiency can be calculated per initial product (original content of a feed-stuff) or per end product (preserved plants). The energy efficiency of an end product contains extra work cycles of preservation. Feed-stuffs are energy inputs of animal husbandry. Considering the procedure, feeding method and performance of fertiliser application in husbandry the required amount of organic and mineral fertiliser will be estimated. The produced fertiliser will be energetically assessed on the basis of their material composition. (Hülsbergen, 2003)

METHODS

Energy inputs in livestock keeping are ascertained on the basis of direct and indirect energy demands. Direct energy is used in form of fuel, oil and electricity (for example in feeding, milking and manure disposal). Indirect energy includes the energy input for manufactured machines and technical facilities (e.g. feeder-mixer wagons and milking parlours) as well as animal houses and storage facilities.

The VDI guideline 4600 "Cumulative Energy Demand – Terms, Definitions, Methods of Calculations" shall assist in making technological data available and comparable within a uniform framework. It allows the evaluation and comparison of products and services with respect to energy criteria (VDI-Richtlinie 4600, 1997). The method development of energy balancing in dairy farming is based on this VDI guideline.

The investigations are done at the example of dairy farming. At first a standard technology is defined. The decision for the design of the livestock building and the determination of the size of an excrement store depends on the livestock, feeding- and manure removal system.

The investigations are done for the example of a farm with 180 dairy cows and for the replacement on farm. Assumptions: a calving performance of 1.0 calf per year, about 50% of the calves are female, the 90 male calves will be sold after two weeks. The calving is continuous. The age of first calving is 25 months. For the calves as well as for the young cattle different livestock buildings are regarded. At the example of the described standard technology different livestock buildings and their components are analysed. The determination of the cumulative energy demand of the animal houses is based on a standard service life of 25 years. Differences consist in the shell of the buildings. The different building components are analysed separately, considering their different functions and materials they are made of. The energy demands are calculated on the basis of the mass of the separate components and the specific cumulative energy demand for these materials is generated by the database GEMIS.

The database GEMIS is used for calculations on the energy demand of different building materials. GEMIS is the acronym for Global Emission Model for Integrated Systems. The model can perform complete life-cycle computations for a variety of emissions, and can determine the resource use. In addition GEMIS analyses costs – the corresponding data of the fuels as well as data for energy and transport processes are included in the database. It offers information on energy carriers (process chains and fuel data) as well as different technologies for heat and electric power generation (www.gemis.de).

Additionally to the buildings and structures, the technical facilities are analysed. Calculations are based on a standard service life of 12 years for the technical facilities, only for the rubber mats or sand as cubicle flooring material a service life of 8 or3 years is assumed respectively.

RESULTS

The standard technology for dairy cattle has been defined for scenario estimations as follows: a cubicle housing system for 180 cows and liquid manure disposal. This keeping procedure was chosen because about 55% of the dairy cattle in Germany are being kept in such systems. (Statistisches Bundesamt, 2004) The cattle are fed with a total mixed ration by a feeder mixer wagon. In summer, the cattle are pastured half-day. The milk performance is 8000 kg FCM per cow and year and as milking equipment a herring-bone milking parlour is used.

The cumulative energy demand for the production of milk calculated for the described standard technology is about 2.7 MJ/kg FCM. Figure 1 shows the shares of the different sections of the procedure. More than the half of the total cumulative energy demand is taken by feed supply. It includes the whole energy expenditure of plant production. About one quarter of the total energy demand is required for the replacement, and about 10% for milking. The energy demand for buildings and structures, as well as for machines and technical facilities is about 5% respectively.

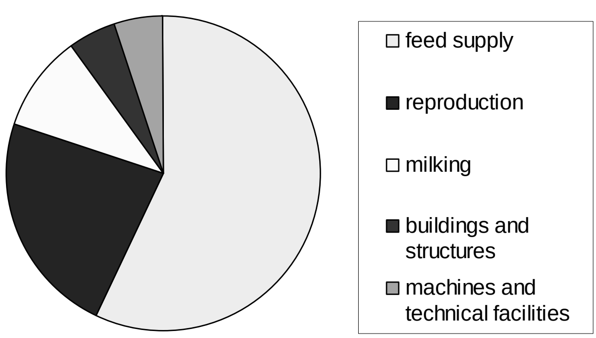

Figure 1: Share of the different sections of milk production of the cumulative energy demand calculated for the standard technology

The calculations for the cumulative energy demand for buildings are done for 4 different designed livestock building. The 4 variants of buildings have the same floors with slurry channels and milking house. Differences consist in the shell of the buildings. The variants are described as follows.

Variant 1 is a closed, cold / thermal non-insulated animal house common for newer cattle houses in Germany. The pillars and walls are made of wood, the roofing is made of fibre-cement plates with a light-band ridging.

The 2nd variant is an outdoor climate house becoming more and more common in Germany. One sidewall is completely open, the open gable is equipped with a wind protection net, the other walls are made of wooden space boards. The roof is similar to variant 1.

Variant 3 is a closed, warm / thermal insulated animal house as an example for a massive construction very common in Germany, especially for older buildings. Important characteristic features are the pillars of reinforced concrete, the exterior walls of concrete and a roof covered by fibre-cement plates. In difference to a thermal non-insulated animal house (variant 1), the building has an intermediate ceiling between roof and floor. This intermediate ceiling consists of fibre-cement plates and a thermal insulation.

Variant 4 is a light construction, completely different from the other variants. The building shell is made of a steel space structure covered by a canvas, and wooden sidewalls.

The cumulative energy demand of the four different dairy cattle houses described above is shown in figure 2. The closed, thermal non-insulated animal house and the outdoor climate house have the same energy demand, so they are summarised. The thermal insulated building has a slightly higher cumulative energy demand than the other three variants. It is caused by the massive construction with reinforced concrete pillars, the walls of concrete and the intermediate ceiling. The light construction has a slightly smaller cumulative energy demand than the other, because of its simple construction. The design of the floor has a much stronger influence on the cumulative energy demand of the building. The share of the slurry channels and pits is about one third of the total cumulative energy demand of the building.

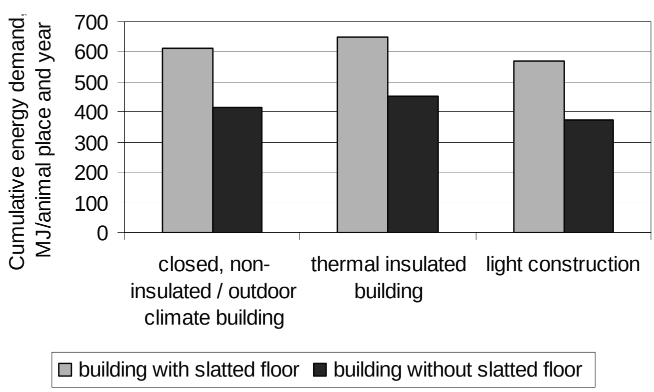

Figure 2: Cumulative energy demand of four different dairy cattle houses with two different manure removal systems respectively

The cumulative energy demand for the single components of the building shell in relation to the total cumulative energy demand of the building shell is shown in figure 3. In all variants about two third of the total cumulative energy demand of the building are caused by the floor. There are nearly no differences between the closed, thermal non-insulated and the outdoor climate building. But in comparison to the other variants there are appreciable differences between the building shells. The cumulative energy demand for the shell of the thermal insulated building is about 40% higher, that one of the light construction about 40% lower than that one of variants 1 and 2.

The specific cumulative energy demand per animal place and year calculated for the technical facilities is similar to that one of the buildings and structures. The specific cumulative energy demand of the single technical facilities in relation to the cumulative energy demand of the technical facilities in total is given in figure 4. The rubber mat takes more than 60% of the cumulative energy demand of the technical facilities, the cubicle about one fifth.

The cumulative energy demand for sand as cubicle flooring material is only one hundredth of that one for a rubber mat.

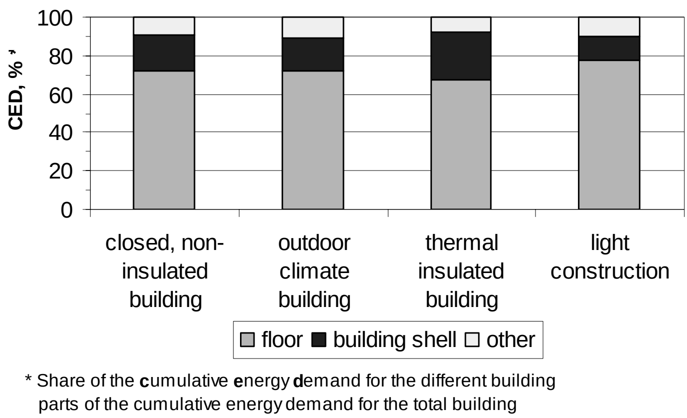

Figure 3: Share of the cumulative energy demand of the different components of the different dairy cattle houses in relation to the total cumulative energy demand of the building

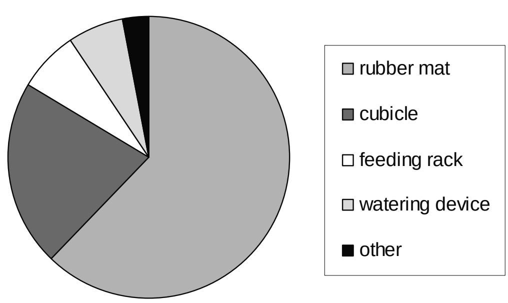

Figure 4:Share of the cumulative energy demand of the different technical facilities in relation to the total cumulative energy demand of the technical facilities

During the growth period the calves and the young cattle need different housing conditions. Because of reasons of the hygiene the young cattle should not be kept in the same livestock building like dairy cows. The keeping of the calves and the young cattle in different livestock buildings is from the hygienic point of view likewise advisable.

Although farmers use often old buildings as calf houses, for the investigations about the cumulative energy demand for the rearing of calves and young cattle only new livestock buildings are considered. The examinations of the cumulative energy demand for livestock buildings have shown that the building shell has only a slightly influence on the energy demand. Therefore the calculations were done for one typical style of construction.

The calf house as well as the young cattle house is a closed, cold, thermal non-insulated animal house, which is common for newer cattle houses in Germany. The pillars and walls are made of wood and the roofing is made of fibre-cement plates with a light-band ridging.

The accommodation of the calves occurs in three age classes. The calf house has 43 animal places. Calves up to two weeks are kept in calf pens. Subsequently the calves are kept in a group pen. The nesting area is bed with straw. The third rearing part is for the third and fourth month of living. It is a section with lying boxes and slatted floor and that means with liquid manure. The calves get used to lying boxes already in this age. The calf house includes two different systems of manure removal. The cumulative energy demand for the calf house is about 303 MJ/animal place and year.

The young cattle are kept in a cold animal house with lying boxes and slatted floor. The young cattle house includes three departments, because of the different age classes of the young cattle and has 132 animal places. The growing animals need different sizes of lying boxes. The cumulative energy demand for the young cattle house is about 444 MJ/animal place and year. The cumulative energy demand for a young cattle house without slurry channels and pits is more than 30% lower than for a building with slatted floor.

CONCLUSIONS

The cumulative energy demand in dairy farming is strongly determined by feed supply and replacement. More than the half of the total cumulative energy demand is required for feed supply, about one quarter for replacement.

The analyses of the cumulative energy demand for different dairy cattle houses inclusive the technical facilities show that only minor differences between different building shells are. The design of the floor has a much stronger influence on the cumulative energy demand of the building. About two third of the total cumulative energy demand of the building are caused by the floor. Half of that account for the slurry channels and pits. So the cumulative energy demand for a dairy cattle building without slurry channels and pits is about one third less than for a building with channels and pits.

The specific cumulative energy demand per animal place and year calculated for the technical facilities is similar to that one for the buildings. More than 60% of the cumulative energy demand of the technical facilities is taken by the rubber mat, about one fifth by the cubicle. The use of sand as cubicle flooring material necessitates only one hundredth of the cumulative energy demand of a rubber mat. So the cumulative energy demand for the technical facilities is about 60% less when sand is used as flooring material instead of a rubber mat.

The energy demand of the livestock buildings and technical facilities takes only a slight influence on the cumulative energy demand of dairy farming.

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ODREĐIVANJE ENERGETSKIH POTREBA U STOČARSKIM OBJEKTIMA

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Sadržaj: Na ukupnu potrošnju energije na farmama za proizvodnju mleka značajno utiče način snabdevanja hranom i izđubravanje. Više od polovine utrošene energije se odnosi na dobavljanje hrane i oko jedna četvrtina za izđubravanje. Cilj istraživanja je da razvije metod za proračun potrošnje energije u stočarskim objektima, u ovom slučaju posebno vezano za objekte i tehničke sisteme u objektima za proizvodnju mleka. Specifična potrošnja energije po mestu u objektu i godini izračunata za određeni tip objekta i tehničke sisteme je odprilike 5% redom. Različiti materijali objekta uzrokuju samo male razlike u ukupno utrošenoj energiji. Ukupna potrošnja energije za mlečna grla u objektima koji nemaju kanale za odvođenje osoke je za jednu trećinu niža od one u objektima sa odvodom osoke. Ukupna potrošnja energije za tehničke sisteme je oko 60% manja u slučaju da se za podni materijal koristi pesak a ne guma.

Ključne reči: *potrošnja energije, farme za proizvodnju mleka, stočarstvo.*