Iranica Journal of Energy & Environment 3 (3): 213-224, 2012
ISSN 2079-2115
IJEE an Official Peer Reviewed Journal of Babol Noshirvani University of Technology
DOI: 10.5829/idosi.ijee.2012.03.03.0924

BUT

Assessment and Optimization of Energy Consumption in Dairy Farm: Energy Efficiency

Paria Sefeedpari

Department of Agricultural Machinery Engineering,
Faculty of Agricultural Engineering and Technology, University of Tehran, Karaj, Iran

(Received: April 9, 2012; Accepted: June 29, 2012)

Abstract: Energy is considered as an important production factor in many systems and therefore should be managed in parallel with other main production resources including land, labor and capital. In this paper, the energy efficiency scores of some selected dairy farms, using the non-parametric data envelopment analysis approach was assessed. The results for efficient farmers based on two DEA models showed that with an energy conservation policy, farmers can perform better in stock farming. The total energy consumption was 72.8 GJ/cow and the top two energy consuming inputs as feed intake and electricity drew the fact that promoting input utilization efficiency seems critical. The mean technical efficiency score of 0.88 made this ample need more apparent. Machinery, electricity and feed were suggested as the main inputs for optimization due to their high contribution in energy saving (46 and 36%, respectively). The least amount of ESTR (Energy Saving Target Ratio) for human labor indicated that it is employed efficiently. By practicing efficiently, dairy farmers are potentially capable of reducing their energy consumption by 16.8%. In this study, adopting new methodologies, cutting the excess use of inputs such as feed stuffs through using standard feeding rations and providing consultancy and extension programs are recommended.

Key words: Energy efficiency; Data envelopment analysis; Dairy farming; Feed intake

INTRODUCTION

A dairy farm unit is both an energy consumer and an energy producer; since the use of different energy inputs would lead to produce energy outputs (in the form of milk and cow manure). All farm operations including feed preparation, feeding, milking and transportation require energy inputs in various forms and varying magnitude. The pattern of utilizing energy inputs is almost linked with the amount of their uses, equipment and machinery and the herd size [1].

Nomenclature

BCC	=	Banker-Charnes-Cooper (DEA model)
CCR	=	Charnes-Cooper-Rhodes (DEA model)
CRS	=	Constant returns to scale
DEA	=	Data envelopment analysis
DLP	=	Dual linear programming
DMU	=	Decision making unit
EI	=	Energy intensity
EP	=	Energy productivity
ER	=	Energy ratio
ESTR	=	Energy saving target ratio
LP	=	Linear programming
PTE	=	Pure technical efficiency
SE	=	Scale efficiency
TE	=	Technical efficiency
VRS	=	Variable returns to scale

Iranian dairy sector needs taking a serious look at the ways of energy expenditure and improving efficiency on farms to reduce their ongoing costs and accordingly improve their bottom line. A wrong belief among farmers causing the inefficient use of energy sources is the excess use of resources to get higher productivity, particularly when they are priced low, free or available in plenty [2]. Energy consumption in developing countries has been increasing rapidly due to recent economic growth and development [3].

Efficiency is defined as the ratio of the sum of weighted outputs to the sum of weighted inputs. It can also be defined as the ratio of the actual output to the optimal output. The input and output weights are evaluated for each unit in order to maximize its relative efficiency [4]. Efficiency analysis is now a popular way

Corresponding Author: Paria Sefeedpari, Department of Agricultural Machinery Engineering,
Faculty of Agricultural Engineering and Technology, University of Tehran, Karaj, Iran.
E-mail: paria.sefeedpari@gmail.com

which has been applied by different authors in different fields such as stock farming [5-7]. One of the well-established methodologies to evaluate the relative technical efficiency (TE) of some entities by some mathematical programming models is Data Envelopment Analysis (DEA). These peer entities are called Decision Making Units (DMUs). It is a non-parametric approach which does not impose any prior assumptions on the underlying functional relationships between inputs and outputs [8]. In addition, DEA is a data oriented frontier analysis technique that floats a piecewise linear surface to lie on top of the empirical observations [9].

Data envelopment analysis is widely used in agricultural enterprises benchmarking and specifically, energy use modeling and improving energy efficiency of dairy farms in recent years. In an earlier and related study, DEA was applied to estimate the technical efficiency of input use in I rrigated dairy farms of Australia [10]. Also, Barnes assessed the technical efficiency scores of Scottish dairy farms by applying the non-parametric method of DEA [11]. Technical efficiency of Austrian dairy farms was determined using data envelopment analysis [12]. Similarly, Mbaga *et al.* [13] assessed the TE of Quebec dairy farms. Binici found the production efficiency of 132 dairy farms in Burdur province of Turkey [6]. Technically, allocative and economic efficiencies were investigated in the survey carried out by Sharma *et al.* in swine production in Hawaii [14]. More previously, Cloutier and Rowley provided a comparison between the distribution of efficiency scores within Canadian dairy farms between 1988 and 1989 based on a sample of 187 farms. The results showed that efficiency in 1989 has increased compared to 1988. Also, larger farms were more likely to appear efficient than smaller ones [15].

Based on literature, there was no study on improving energy efficiency with application of DEA in dairy farming enterprises in Iran. With a growing number of studies using DEA, a study of this field would be useful and timely. This study aimed to fill this gap. Therefore, this research, for the first time, was undertaken to specify the energy use pattern of dairy farms, analyze the efficiencies of farmers, rank efficient and inefficient ones and to identify target energy requirements and wasteful uses of energy from different inputs for milk production in Tehran province of Iran.

MATERIAL AND METHODS

Selection of Case Study Region and Data Collection: This study was conducted in Tehran province of Iran. Tehran is located within 35°34' and 35°50' north latitude and 51°02' and 51° 36' east longitude [16]. The amount of produced milk in the first three month of 2010 production period was announced to be 265,501 tons. Tehran province was argued because a big share of milk production in Iran comes from this province. Inputs such as human labor, machinery, fossil-based fuels (including gasoline, diesel, kerosene and natural gas), electricity and feed intake and the yield value of milk have been used to calculate the total energy inputs and output equivalents. The calculated equivalents were employed to assess the energy indices as energy ratio, energy productivity, net energy, etc.

Data used in this study were collected through personal interviews with dairy farmers in their farms during the spring of 2011. The required sample size was determined using simple random sampling method. The equation is as below [17]

$$n=\frac{N\times s^2\times t^2}{(N\text{-}1)d^2+\left(s^2\times t^2\right)} \tag{1}$$

Where n is the required sample size, N is the number of dairy farms producers in target population, s is the standard deviation, t is the t value at 95% confidence limit (1.96) and d is the acceptable error. The permissible error in sample size was 5% (with 95% confidence). Thus, the number of sample size was 35. Hence, based on the number of milk producers in the region, 35 farmers from the population were randomly selected.

Some assumptions were essential due to have a much more precise computation such as the period for which energy consumption was estimated. A lactation period of a cow is 305 days and cows are dry about 60 days. Therefore, input consumptions assigned to a production year were considered. More specific information about the target farms and cows are given in Table 1.

Energy Equivalents of Inputs and Output: The culled data were used to calculate the quantity of different energy inputs utilized per cow including: human labor, machinery, fossil-based fuels (including gasoline, diesel, kerosene and natural gas), electricity, feed intake and the milk yield as output. With the purpose of analyzing the farmers' performance from the viewpoint of energy use efficiency, the energy equivalents were calculated by multiplying the amount of energy use of inputs with their corresponding energy equivalent coefficients [18]. Energy equivalent coefficient of inputs is defined as the energy used from primary production to the end user [19]. This can be measured differently from one input to another input. For example, the energy coefficient equivalent of fuels

Table 1: Characteristics of the dairy farms and cows of the studied area

Breed of cows	Holstein	Average milk yield (kg/day·cow)	26.5
Average No. of cows per farms (head)	129	No. of lactations (times per day)	3
Lactation period (days)	305	Average feed intake of lactating cow (kg/day·cow) (DM*)	19
Drying period (days)	60	Average feed intake of dry cow (kg/day·cow) (DM)	35

* Dry matter

Table 2: Energy coefficients, energy inputs and output

Inputs (unit)	Energy equivalent (MJ/unit)	Reference
A. Inputs		
Human labor (h)	1.96	[22]
Machinery		
(a) Tractor and self-propelled (kg a*)	9-10	[21]
(b) Stationary equipment (kg a*)	8-10	[21]
(c) Implement and machinery(kg a*)	6-8	[21]
Fossil fuels		
(a) Diesel (l)	47.8	[21]
(b) Gasoline (l)	46.3	[21]
(c) Kerosene (l)	36.7	[21]
(d) Natural gas (m^3)	49.5	[21]
Electricity (kWh)	11.93	[23]
Feed		
(a) Concentrate (kg)	6.3	[24]
(b) Silage (kg)	2.2	[25]
(c) Alfalfa (kg)	1.5	[26]
B. Outputs		
Milk (kg)	Calculated	

a*:Economic life of machine (year)

and electricity means their heating value (enthalpy) and the energy needed to make their energy available directly to the farmers (mining, refining and transporting). For machinery, the energy used in producing the raw materials, the quantity of energy required in the manufacturing process, the transportation of the machine to the consumer and fourth, the energy sequestered in repairs are considered. Average values for energy coefficient of chemicals include production, formulation, packaging, transportation and application. The energy equivalent of human labor is the muscle power used in field operations which comes from metabolic energy of the food consumed. Also, it is suggested to consider energy involved in all processes in which the food industry, transportation and distribution take part [19,23]. For feed input energy coefficient the calorific value of the feed type is not considered here and we are of the opinion that the referred numbers in Table 2 for feed rations are the energy intensities indicating the energy consumed in the production process of cows' feed.

Assuming that the energy consumed for the production of the tractors and agricultural machinery is depreciated during their economical life time, the embodied energy in agricultural machinery was calculated [20]; therefore, the machinery energy input was calculated using the following Eq. [21]:

$$ME=\frac{G\times M_p\times t}{T} \qquad (2)$$

Where ME is the machinery energy per cow (MJ/cow); G is the material mass used for manufacturing (kg); M_P represents the production energy of material (MJ/kg), t is the time that machine used per cow (h/cow) and T is the economic life time of machine (h). It is essential to state that the expended time of each machine per head of cow was considered to calculate the energy used for each machine per head of cow.

The energy equivalent coefficients of various inputs derived from previous researches in similar conditions are illustrated in Table 2. Moreover, the energy content of milk as the main product of each dairy farm was calculated considering the milk ingredients and the energy conversion factors of them including protein, fat and carbohydrate as 17, 37 and 17 MJ/kg, respectively [22].

Energy use of water provided for cows can be calculated using two methods. In some cases farmers and researchers can measure the fossil fuel or electricity use of pumping systems. Otherwise, water energy consumption can be estimated measuring required energy for pumping water (during the whole useful life time of the well) from wells, water transformation and the fuel or electricity inputs. Due to this, to calculate the energy consumption of water production, the following equation can be utilized

[23]. It should be noted here that in present study, measuring fuel use of diesel pumps was possible for us and the energy use was directly estimated considering the diesel consumption and its energy coefficient equivalent.

$$DE \frac{Q\rho gh}{10^6 \eta_1 \eta_2} \tag{3}$$

Where Q is referred to discharge flow rate per cow in a lactation period (365 days) ($m^{3/cow}$), ρ is the density of water (kg m^3), g is the acceleration due to gravity (m/s^2), h is the net head between the upper and lower water levels (m) and η_1 and η_2 are pump efficiency (0.7-0.9) and overall efficiency of conveyance and application in electrical motors (0.18-0.2), respectively. Subsequently, DE represents the energy consumption of water (MJ/cow).

Following, different indices of energy consumption including energy ratio, energy productivity, energy intensity and net energy were calculated using the following equations [24,29]:

$$Energy\ Input-Output\ Ratio = \frac{Energy\ Output\left(MJ/cow\right)}{Energy\ Input\left(MJ/cow\right)} \tag{4}$$

$$Energy\ \text{Productive} = \frac{\text{Milk}\ Output\left(kg/cow\right)}{Energy\ Input\left(MJ/cow\right)} \tag{5}$$

$$Energy\ \text{Intensity} = \frac{\text{Milk}\ Input\left(MJ/cow\right)}{Energy\ Output\left(kg/cow\right)} \tag{6}$$

$$Net\ Engery = Energy\ Output\left(MJ/cow\right) - Energy\ Input\left(MJ/cow\right) \tag{7}$$

Data Envelopment Analysis Technique: The DEA technique, first introduced by Charnes *et al.* [30] has been broadly applied to the efficiency (productivity) measurement of many organizations in public and private sectors. Data envelopment analysis assesses the relative eficiency of a decision making unit (DMU) as the ratio of the sum of its weighted outputs to the sum of its weighted inputs allowing the DMUs to freely allocate weights to their inputs/outputs [31]. In this case, DMUs are dairy farmers and input variables are energy inputs used by dairy farming (MJ/cow), as were estimated through the mentioned methods and the single output parameter is defined as the milk energy (MJ/cow) for each DMU. It is worth mentioning that the inputs consumption, accordingly their energy equivalents and the output quantity (milk yield) were computed for a period of 365 days in which cows are dry and milking.

In DEA, efficient DMUs are those with the highest level of productive efficiency. DEA encompasses various kinds of models for evaluating the performance of different DMUs. Different researchers have developed some optimization models based on the return to scale parameter known as CCR (or CRS) and BCC (VRS). CCR model demonstrates constant returns to scale while BCC permit the existence of variant returns to scale. A unit can be made efficient by two analyses (input orientation and output orientation). In the input-oriented case, the DEA method determines the frontier by making the maximum possible reduction in input use, with the constant output level, for each unit. The output oriented case in DEA method would find the maximum possible increase in output production, due to fixing the input level. In fact, the input-oriented is commonly utilized in DEA applications because efficiency profitability depends on the efficiency of operations. Besides that, a farmer is able to take the control of inputs rather than output level more easily.

The VRS model, developed by Banker *et al.* [32], decomposes technical efficiency into pure technical efficiency and scale efficiency for management factors and scale factors, respectively. Therefore, pure technical efficiency is the technical efficiency that has the effect of scale efficiency removed; while scale efficiency (SE) measures how efficiency scores vary between CRS and VRS and seizes the impact of scale size on the productivity of the DMU. The relationship between technical efficiency and pure technical efficiency to calculate scale efficiency is presented as below [39]:

$$\text{Scale efficiency} = \frac{\text{Technical efficiency}}{\text{Pure technical efficiency}} \tag{8}$$

Firstly, we specify the model by assuming that each DMU_j has multiple inputs, $x_{i,j}$ and multiple outputs, $y_{k,j}$. A relative efficiency measure can be explained by [33]:

$$TE_j = \frac{u_1 y_{1j} + u_2 y_{2j} + \ldots + u_n y_{nj}}{v_1 x_{1j} + v_2 x_{2j} + \ldots + v_m x_{mj}} = \frac{\sum_{r=1}^{n} u_r y_{rj}}{\sum_{s=1}^{m} v_r x_{sj}} \tag{9}$$

Where, TE_j is the technical efficiency score given to unit j; x and y denote input and output and v and u symbolize input and output weights, respectively; s is the number of inputs ($s=1,2,.\ m$), r is number of outputs ($r= 1,2,\ldots n$) and *j* represents *jth* DMUs (*j=1,2,. k*). In solving an optimization problem, each DMU_j sets its own weights to maximize its efficiency subject to the condition that all efficiencies of other DMUs remain less than or equal to 1 and the values of the weights are greater than or equal to 0 [34]:

$$\text{Max}: q = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}}$$
$$s.t \qquad (10)$$
$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1,\ j = 1,2,\ldots,n$$
$$u_r \ge 0,\ v_i \ge 0$$

Using a linear programming (LP) problem, Eq. (10) can equivalently be written as follows [34]:

$$\text{Maximize } q = \sum_{r=1}^{n} u_r y_{ri}$$
$$\text{(i)} \sum_{s=1}^{m} v_s x_{si} = 1,\ i = 1,2,\ldots,k \qquad (11)$$
$$\text{Subject to (ii)} \sum_{i=1}^{n} u_r y_{ri} - \sum_{s=1}^{m} v_s x_{si} = 0$$
$$\text{(iii)}\ u_r \ge 0,\quad r = 1,2,\ldots n$$
$$\text{(iv)}\ n_s \ge 0,\quad s = 1,2,\ldots m$$

Where θ is the technical efficiency. Model (10) is known as the input-oriented CCR DEA model introduced by Charnes *et al.* [30]. The CCR model (represented by Eq. (10)) assumes constant returns to scale (CRS), which is only appropriate when all DMU's are operating at an optimal scale and the production possibility set is formed without any scale effect [35].

If the constant return to scale surface is estimated, the measure of the relative farm performance is called the Technical Efficiency (TE), [36] (as it was mentioned above) and the Pure Technical Efficiency (PTE), if the variable return to scale surface is evaluated [36,37]. The pure technical efficiency which separates both technical and scale efficiencies, can be expressed by Dual Linear Program (DLP) as [38]:

$$\text{Maximize} \quad z = uy_i - u_i$$
$$\textit{Subjected to} \quad vx_i = 1 - vX + uY - u_o e \le 0 \qquad (12)$$
$$v \ge 0.\ u \ge 0 \text{ and } u_0 \text{ free in sign}$$

Where *z* and u_0 are scalar and free in sign. *u* and *v* are output and inputs weight matrixes and *Y* and *X* are corresponding output and input matrixes, respectively. The letters x_i and y_i refer to the inputs and output of i_{th} DMU.

The results obtained from standard DEA models divide the DMUs into two sets of efficient and inefficient units. It is possible to rank inefficient units according to their efficiency scores; while, DEA lacks the capacity to discriminate among efficient units. In this study, the benchmarking method was applied to subdue this problem. Accordingly, an efficient unit which is referred as a useful target for many inefficient DMUs and so appears frequently in the referent set, is highly ranked [40, 41]. To analyze the efficient and inefficient DMUs, t he energy saving target ratio (ESTR) was calculated as follows [42]:

$$\text{ESTR}\ (\%) = \frac{(\textit{Energy Saving Target})}{(\textit{Actual Energy Input})} \times 100 \qquad (13)$$

Where energy saving target is the reduction amount in input energy use without decreasing the output level and *j* indicated the *jth* DMU. ESTR which is the indicator of energy efficiency, typifies the inefficiency level regarding energy saving and energy consumption for each DMU. Whereas the minimum value of ESTR is zero, its corresponding percentage would be zero to 100. The best DMU with respect to energy use efficiency is the one with ESTR score of 0. Otherwise, the quantity of ESTR more than zero determines a conduct on energy saving and energy use for the specific DMU. Hence, the higher ESTR value, the more energy use management is required [42].

In order to calculate inputs and output energy, the collected data were inserted to Excel 2007 spreadsheet. To perform DEA models (CCR and BCC) for estimating the efficiency scores and determining the amount of energy loss and energy saving of inefficient DMUs, the Frontier Analyst software was applied.

RESULTS AND DISCUSSION

Analysis of energy input and output in dairy farming The collected data via face to face questionnaire approach from 35 dairy farms in 2011 were analyzed with respect to energy use pattern and the results are presented in Table 3. It is stressed that one production period of 365 days including the dry and lactation periods of cows was considered in our energy use calculations. The results revealed that 72.81 GJ/cow was consumed as the total energy input and the majority of this was

Table 3: Energy inputs and output equivalents of dairy farms (MJ/cow)

Item	Total energy equivalent (MJ/cow)	Percentage (%)
A. Inputs		
Human labor	402	1
Machinery	1641	2
Fossil fuels	7467	10
Electricity	25217	35
Feed intake	38089	52
Total energy input	72816.7	100
Total energy output	17598	

* Indicates standard deviation for energy inputs (MJ/cow) and yield (kg/cow).

Table 4: Energy indices in milk production process

Item	Unit	Average
ER	-----	0.26
EP	kg/MJ	0.12
EI	MJ/kg	9.48
NE	MJ/cow	-55217.3

consumed by feed intake in dairy farms of Iran. After feed intake, electricity with 25.217 GJ/cow had the highest contribution in energy input consumption. Fossil-based fuels were belonged to the third rank (12%). Considering the observations at farms, electricity was the only force to run the equipment of dairy farms as milking machines, cooling and feed preparation equipment while fossil-based fuels were spent in feed preparation and feeding operations, heating and cow manure gathering from the farm surface and deposal of that in the surroundings with tractor. Moreover, labors' houses used diesel fuel and other fossil-based fuels for heating and other household tasks since in most cases natural gas pipelining had not been exerted in the target area. In order to improve the dairy farming sustainability and reduction of fossil-based fuels consumption, it is strongly recommended that the energy costs is reduced and energy efficiency would increase with replacing alternative energy sources such as natural gas and renewable energy resources like solar energy or biogas.

In some previous studies, researchers calculated energy consumption of some inputs in dairy farms; Koknaroglu calculated the total cultural energy expended in dairy farming including cultural energy expended for feed, dairy operations, transportation and machinery and equipment as 19,700 MJ/cow [43]. More energy usage in dairy farms of Iran could be attributed to less energy conservation and energy use pattern analysis by policy makers. Also, Moitzi *et al.* concluded electrical energy is consumed more in small-scale dairy farms while in large-scale ones, electricity use is diminishing and feed energy increases [44]. This is in agreement with the results of this study due to large-scale size of our target farms. In another study, Meul *et al.* reported the total energy input was 36,372 MJ/ha for dairy farms in 2000-2010 in Flanders and diesel fuel use took the major part of direct energy use [26].

The different energy indices as energy ratio, energy productivity and net energy were calculated and the results are given in Table 4. The overall milk yield per lactation period (365 days) in the studied farms was 8,227 kg/cow, relatively larger than lactation milk yield which previously was reported as 4,506.71 kg/cow in Turkey [45]. Energy use efficiency (Eq. (4)) was found to be 0.26, indicating the inefficient use of energy in the dairy farms of Tehran province. Although, the more energy ratio amount shows the better production system in view of energy use but its verification becomes more obvious when we compare the results of various studies. Due to the energy ratio reported by others [43] we can confirm that our value is low. It is suggested that the energy ratio can be increased by the following ways:

- Raising the crop yield by reducing the losses;
- Decreasing energy inputs consumption by optimization methods.

The average energy productivity was calculated to be 0.12 kg/MJ, showing that using 1 MJ of energy would result in 0.12 unit outputs. The negative value of net energy (-55217.3) means that energy is being lost in milk production in Iran. The results of energy indices calculation can only be compared with Koknaroglu, which resulted in energy ratio of 0.7 and energy productivity of 0.9 kg/MJ in dairy farms of Turkey [43]. Moreover, energy intensity showed a range of 1.7 to 2.1 MJ /kg depending on different milk yields in another study [46].

Efficiency Estimation of Farmers: Fig. 1 exhibits the results for the application of the input-orientated BCC and CCR models. The BCC-I (Input-oriented BCC) model showed that out of 35 dairy farms considered as the DMUs, 21 farms (60%) were pure technically efficient. Moreover, 18 farmers (51%) were technically efficient; hence they had the technical and pure technical efficiency score of one. So, there was no need to reduce their corresponding energy use. This is evident that the use of BCC model provides a higher number of efficient farms due to its less feasibility unit. On the other hand, technically and pure technically inefficient farms with the score range of 0.9 - 1, were 2 and 3 of overall farmers, respectively. These amounts for the range of 0.8 - 0.9 were

5 and 6 of farmers, respectively. Moreover, the technical efficiency estimation under different DEA models showed that 2 dairy farmers had an efficiency score of less than 0.5 under CCR model while there was no farmer in this range for BCC model.

Dagistan *et al.* showed that between 100 small-scale dairy farms there were only 13 and 46 technically and pure technically efficient farmers [47]. In another study carried out by Silva *et al.* a few farmers were found to be efficient as the result of DEA with input oriented model method in Portugal [48]. Table 5 summarizes the dispersion of statistic results for the three calculated efficiencies. The average value of technical, pure technical and scale technical efficiencies were 0.88, 0.93 and 0.95, respectively. The technical efficiency varied from 0.43 to 1 with the standard deviation of 0.16 between the farmers, indicating that the whole farmers are not familiar with the correct production techniques or they do not apply them properly. We obtained relatively higher mean scale efficiency (95%, Table 5) compared to previous reports in similar studies in Australia (88%), Turkey (72%) and Scotland (84%) [11,47, 49].

Ranking Analysis: In this part, benchmarking approach was applied to rank efficient dairy farms. This was done with respect to the number of times an efficient DMU appears in a referent set [50, 51]. The results obtained from the analysis showed that DMUs 26, 14, 4, 8 and 28 appeared 14, 11, 10, 9 and 7 times in referent set, respectively (Table 6). While the referent set is composed of the efficient units which are similar to the input and output levels of inefficient units, efficient DMUs with more appearance in referent set are known as the superior unit in the ranking. The results are beneficial to inefficient farmers to manage their energy sources usage in order to attain the best performance of energy use efficiency.

Comparison of Input Use Pattern of EfFIcient and InefFIcient Farmers: The amounts for different input use of 10 superior referred and inefficient farmers (based on CCR model) are presented in Table 7. As it is obvious, for all inputs, inefficient farmers consume more than efficient ones and the output derived from efficient dairy farms is more than inefficient ones. Machinery, electricity and fossil fuels (with 41.5, 24.3 and 23.9 % differences, respectively) are the most significant energy inputs required to be optimized in the selected dairy farms. The lack of enough information for farmers, existence of some wrong beliefs among farmers that feeding more will result in better milk yield, poor extension programs to educate dairy farms due to the importance of their occupation, inappropriate plan of buildings and corrals and finally implementing depreciated and energy-intensive equipment were observed at inefficient dairy farms. A careful examination of the similar research showed no study on dairy farming efficiency analysis with respect to energy consumption.

Energy Saving from Different Energy Inputs: Table 8 tabulates the optimum energy requirement and saving energy of dairy farming based on the results of BCC model. In the last column the percentages of ESTR are given. The results showed that feed intake plays an important role in energy optimization. ESTR estimation results indicated that 40.35% of machinery and equipment, 19.36% from fossil fuels, 15% from human labor, 17.17% from electricity and 14.48% of feed intake could be saved. This is accomplished by following the stated recommendations in this study. Moreover, the percentages of ESTR for total energy input was calculated as 16.8% which implies that with respect to energy saving comments in this study, on average, 16.8% (12234.69 MJ/cow) from total input energy could be saved with the constant milk yield level.

Various energy inputs contribution share in the total input saving energy is illustrated in Fig. 2. Evidently, the share for feed intake input is highest (46%) followed by electricity (36%). The less than 1% contributions of human labor input are used efficiently by almost all the DMUs. In fact, by improving energy inputs usage, it is possible for dairy managers to achieve a better energy use pattern and update their energy efficiency in comparison with other DMUs.

Table 5: Descriptive statistics for efficiency scores of dairy farms

Particular	Technical efficiency	Pure technical efficiency	Scale efficiency
Mean	0.88	0.93	0.95
Std. Deviation	0.16	0.12	0.11
Minimum	0.43	0.52	0.44
Maximum	1.00	1.00	1.00

Table 6: Ranking 10 superior referred dairy farmers in Tehran province, Iran

Rank	Farmer No.	Frequency in referent set	Rank	Farmer No.	Frequency in referent set
1	26	14	6	3	7
2	14	11	7	11	6
3	4	10	8	31	5
4	8	9	9	1	3
5	28	7	10	27	2

Table 7: Amounts of energy inputs and output for 10 superior referred farmers and inefficient farmers (MJ/cow)

Item	10 superior referred farmers	Inefficient farmers	Difference (%) B - A)*100/ B
A. Inputs			
Human labor	372.59	376.87	1.13
Machinery	1288.58	2202.67	41.5
Fossil fuels	5902.57	7471.76	21
Electricity	18014.14	23796.38	24.3
Feed intake	31662.03	41621.93	23.9
Total energy input	70458.87	75587.26	6.8
Total energy output	17879.06	16579.39	-7.8

Table 8: Energy requirement in optimal condition and saving energy for milk production

Item	Optimal energy requirement (MJ/cow)	Saving energy (MJ/cow)	ESTR (%)
Human labor	341.64	60.31	15
machinery	978.82	662.01	40.35
Fossil fuels	6021.49	1445.82	19.36
Electricity	20887.65	4328.96	17.17
Feed intake	32575.34	5513.71	14.48
Total	60790.51	12234.69	16.8

Table 9: The actual energy use and target energy requirements for individual inefficient milk producers based on the results of BCC model

		Actual energy use					Target energy requirement					
DMU No.	PTE	Fossil fuels	Electricity	Machinery	Human labor	Feed	Fossil fuels	Electricity	Machinery	Human labor	Feed	ESTR (%)
5	0.88	7210	17139	920	294	39878	4537	13611	731	233	31670	22.6
7	0.78	7221	15907	1294	247	47623	5092	11217	706	245	33584	29.9
9	0.52	10857	48263	4091	502	49219	5255	17750	953	243	23823	57.6
10	0.98	5661	21433	1199	178	49384	1574	9159	494	76	16730	64.3
12	0.97	2994	25963	5008	821	33794	1958	12770	429	135	22098	45.7
18	0.73	8825	23493	1955	434	41705	5974	15905	983	294	28235	33.1
21	0.89	9563	37428	5362	498	45122	7898	21075	1389	411	37265	30.9
22	0.64	8758	35519	6067	941	40707	5206	17061	1514	559	24201	47.6
23	0.84	7725	14618	1757	289	47053	4340	12022	793	238	38182	22.5
24	0.98	5087	17705	1784	245	37735	4639	16932	917	235	36087	6.4
25	0.81	7152	16234	1855	305	45334	4518	12950	806	243	36163	23.2
30	0.81	5130	15738	1338	262	44536	3888	11927	702	198	33753	25.2
32	0.87	4264	19909	992	271	36488	3669	17131	837	233	31398	14.4
35	0.79	6981	19004	923	361	46182	5404	14711	714	274	35749	22.9

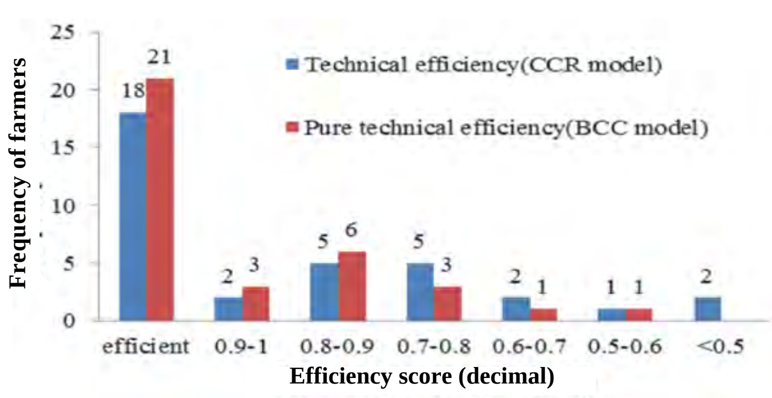

Fig. 1: Distribution of dairy farmers based on efficiency scores

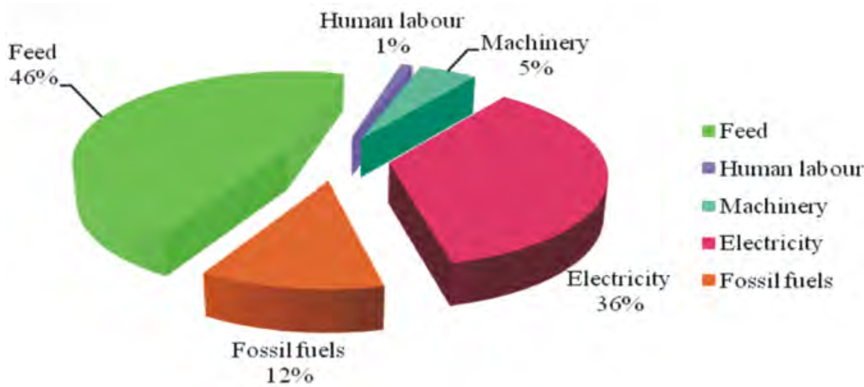

Fig. 2: Distribution of saving energy from different sources

Setting Realistic Input Levels for Inefficient Farmers: Pure technical efficiency, actual energy input use and their corresponding target energy requirements for inefficient farmers are represented in Table 9. The quantity of optimum energy requirements are derived from the results of this study. They are calculated for the purpose of making inefficient farmers aware of the amount of reduction in energy inputs consumption without decreasing the milk yield level. As it can be seen in the last column of Table 8, the percentages of energy saving for 17 inefficient farmers are given. The maximum and the minimum energy saving values (64% and 6%) indicated that farmer 10 and farmer 24 are respectively the worth and the best inefficient dairy farmers. It is worth stating that after a complete survey, we arrived at the conclusion that DEA analysis and energy efficiency analysis are not well documented in the literature. Hence, the results were not compared with any other research.

To give a summing up, dairy farming is one of the main energy consuming sectors in Iranian agriculture. The high requirement of energy inputs such as feed stuff, electricity and fossil-based fuels drew our attention to calculate the energy efficiency of dairy farming in Tehran province of Iran. The results revealed that there is a high potential for improving the present situation of milk production from the viewpoint of energy use. As it was observed during the process of data gathering, developing strategies such as adopting new methodologies, heightening agricultural extension programs and supervising systems including energy auditing concluding in the increase of farmers knowledge about dairy production systems and encouraging them to minimize their energy use, could be useful to provide a more sustainable agricultural production system in the target area.

CONCLUSION

This study was carried out in Tehran province of Iran in order to optimize energy use pattern of dairy production through DEA approach in some industrial dairy farms. Our results suggested that energy consumption in some of them is not efficient. The feed intake and electricity usage was considerably higher than other inputs and the energy ratio value represented that dairy farms are not efficient in the selected area. DEA models including input oriented CCR and BCC were applied to examine the energy efficiency of different DMUs. Consequently, 18 farmers out of 35 selected dairy farmers were technically efficient and 21 of them were efficient in BCC model. According to the results derived in this study, feed intake had the highest contribution in energy optimization. Based on the results the following suggestions are proposed:

- Energy auditing especially at inefficient dairy farms, cause to involve farmers in optimizing the use of inputs, cutting the costs and finally enhancing their viability among milk producers.
- Feeding cows regarding standard dairy ration patterns in order to achieve a reduction in energy wasting of feed intake.
- Educating inefficient dairy farmers for changing their wrong attitudes towards energy source use by establishing exemplary dairy farms and performing other extension programs.
- Finally, use of non-parametric method of DEA is recommended as a tool for benchmarking and improving energy use efficiency in stock farming production systems.

REFERENCES

1. De, D., R.S. Singh and H. Chandra, 2001. Technical impact on energy consumption in rainfed soybean cultivation in Madhya Pradesh. Appl. Energy, 70: 193-213.
2. Singh, G., S. Singh and J. Singh, 2004. Optimization of energy inputs for wheat crop in Punjab. Energy Conv. Manag., 45: 453-65.
3. Iwaro, J. and A. Mwasha, 2010. Implications of building energy standard for sustainable energy efficient design in buildings. Int. J. Energy Environ. 1(5): 745-756.
4. Mukherjee, K., 2008. Energy use efficiency in the Indian manufacturing sector: an interstate analysis. Energy Policy, 36(2): 662-72.
5. Asmild, M., J. Hougaard and D. Kronborg, 1999. A method for comparison of efficiency scores: A case study of Danish dairy farms. In Helles *et al.* (eds), Multiple use of forests and other natural resources, Dorfrecht: Kluwer Academic Publishers, pp: 220-227.
6. Binici, T.,V. Demircan and C.R. Zulauf, 2006. Assessing production efficiency of dairy farms in Burdur province, Turkey. Journal of Agricultural and Development in the Tropics and Subtropics, 107: 1-10.
7. Moreira, V.H., López, B.E. Bravo-Ureta, A. Arzubi and E. Schilder, 2006. Multi-output technical efficiency for Argentinean dairy farms using stochastic production and stochastic distance frontiers with unbalanced panel data. Economia Agraria, 10: 97-105.
8. Seiford, L.M. and R.M. Thrall, 1990. Recent developments in DEA: The mathematical programming approach to frontier analysis. J. Econom., 46: 7-38.
9. Cooper, W.W., L.M. Seiford and J. Zhu, 2010. Data envelopment analysis. History, Models and Interpretations. Handbook on Data Envelopment Analysis. 71: 1-39. Springer., DOI: 10. 1007/b105307.
10. Fraser, I. and D. Cordina, 1999. An application of data envelopment analysis to irrigated dairy farms in Northern Victoria, Australia. Agric. Syst., 59(3): 267-82.
11. Barnes, A., 2006. Does multi-functionality affect technical efficiency A non-parametric analysis of the Scottish dairy industry. J. Environ Manage., 80: 287-94.
12. Kirner, L., M. Ortner and J. Hambrusch, 2007. Using technical efficiency to classify Ausrtian dairy farms. Die Bodenkultur, Austrian Journal of Agricultural Research, 58: 15-24.
13. Mbaga, D.M., R. Romain, B. Larue and L. Lebel, 2003. Assessing technical efficiency of Quebec dairy farms. Canadian Journal of Agricultural Economic, 51: 121-137.
14. Sharma, K.R., P. Leung and H.M. Zaleski, 1999. Technical, allocative and economic efficiencies in swine production in Hawaii: a comparison of parametric and nonparametric approaches. Agricultural Economics, 20: 23-35.
15. Cloutier, L.M. and R. Rowley, 1993. Relative Technical Efficiency: Data Envelopment Analysis and Quebec's Dairy Farms. Canadian Journal of Agricultural Economics, 41: 169-176.
16. Anonymous, 2010. Annual agricultural statistics. Ministry of Jihad-e-Agriculture of Iran; http://www.maj.ir (in Persian).
17. Kizilaslan, H., 2009. Input-output energy analysis of cherries production in Tokat Province of Turkey. Appl. Energy, 86: 1354-8.
18. Mousavi-Avval, S.H., S. Raflee, A. Jafari and A. Mohammadi, 2011. Energy efficiency and cost analysis of canola production in different farm sizes. International Journal of Energy and Environment, 2(5): 845-52.
19. Mousavi-Avval, S.H., S. Rafiee, A. Jafari and A. Mohammadi, 2011. Optimization of energy consumption for soybean production using Data Envelopment Analysis (DEA) approach. Appl. Energy, 88(11): 3765-72.
20. Beheshti Tabar, I., A. Keyhani and S. Rafiee, 2010. Energy balance in Iran's agronomy (1990-2006). Renew. Sustain. Energy. Rev., 14(2): 849-55.
21. Gezer, I., M. Acaroglu and H. Haciseferogullari, 2003. Use of energy and labor in apricot agriculture in Turkey. Biomass Bioenergy, 24: 215-9.
22. Anonymous, 2002. Summary edition of the Composition of Foods (Food Standards Agency), The Composition of Foods, Sixth summary edition. Cambridge: Royal Society of Chemistry.
23. Kitani, O., 1999. CIGR Handbook of Agricultural Engineering, Energy & Biomass Engineering. Vol. 5. ASAE publication, St Joseph.
24. Pishgar Komleh, S.H., A. Keyhani, S. Rafiee and P. Sefeedpary, 2011. Energy use and economic analysis of corn silage production under three cultivated area levels in Tehran province of Iran. Energy, 36: 3335-41.
25. Ozkan, B., H. Akcaoz and C. Fert, 2004. Energy input-output analysis in Turkish agriculture. Renew Energy, 29: 39-51.

26. Meul, M., F. Neven, D. Reheul and G. Hofman, 2007. Energy use efficiency of specialised dairy, arable and pig farms in Flanders. Agriculture, Ecosystems and Environment, 119: 135-144.
27. Wells, D., 2001. Total energy indicators of agricultural sustainability: dairy farming case study. Technical paper. Ministry of Agriculture and Forestry, Wellington. ISBN: 0-478-07968-0, http://www.maf.govt.nz.
28. Sainz, R.D., 2003. Livestock-environment initiative fossil fuels component: framework for calculation fossil fuel use in livestock systems. http:// www. fao. org.
29. Mandal, K.G., K.P. Saha, P.L. Gosh, K.M. Hati and K.K. Bandypadhyay, 2002. Bioenergy and economic analyses of soybean-based crop production systems in central India. Biomass Bioenergy, 23: 337-45.
30. Charnes, A., W.W. Cooper and E. Rhodes, 1978. Measuring the efficiency of decision making units. Eur. J. Oper. Res., 2: 429-44.
31. Allen, R. and E. Thanassoulis, 2004. Improving envelopment in data envelopment analysis. Eur. J. Oper. Res., 154: 363-379.
32. Banker, R., A. Charnes and W. Cooper, 1984. Some models for estimating technical and scale inefficiencies in data envelopment analysis. Manage. Sci., 30: 1078-92.
33. Cooper, W., L.M. Seiford and K. Tone, 2004. Data envelopment analysis, a comprehensive text with models, applications, references and DEA- solver software. Massachusetts, USA: Kluwer Academic Publishers.
34. Gelan, A. and B. Muriithi, 2010. Measuring and Explaining Technical Efficiency of Dairy Farms: A Case Study of Smallholder Farms in East Africa, The 3rd Conference of African Association of Agricultural Economists Africa and the Global Food and Financial Crises, 19 - 23 September 2010, Cape Town, South Africa at The Westin Grand Cape Town Arabella Quays.
35. Coelli, T. and S. Perleman, 1999. A comparison of parametric and non-parametric distance functions: With application to European railways. Eur. J. Oper. Res., 117: 326-339.
36. Iraizoz, B., M. Rapun and I. Zabaleta, 2003. Assessing technical efficiency of horticultural production in navarra, Spain. Agricultural Systems, 78: 387-403.
37. Llewelyn, R.V. and J.R. Williams, 1996. Nnonparametric analysis of technical, pure technical and scale efficiencies for food crop production in East Java, Indonesia. Agricultural Economics, 15: 113-126.
38. Nassiri, S.M. and S. Singh, 2009. Study on energy use efficiency for paddy crop using data envelopment analysis (DEA) technique. Appl. Energy, 86: 1320-5.
39. Pishgar Komleh, S.H., M. Omid and A. Keyhani, 2011. Study on energy use pattern and efficiency of corn silage in Iran by using Data Envelopment Anal ysis (DEA) technique.International Journal of Envi Ronmental Sciences, 1(6): 1094-1106.
40. Mousavi-Avval, S.H., S. Rafiee, A. Jafari and A. Mohammadi, 2011. Improving energy use efficiency of canola production using data envelopment analysis (DEA) approach, Energy, 36: 2765-72.
41. Mousavi-Avval, S.H., S. Rafiee and A. Mohammadi, 2011. Optimization of energy consumption and input costs for apple production in Iran using data envelopment analysis. Energy, 36: 909-916.
42. Hu, J.L. and C.H. Kao, 2007. Efficient energy-saving targets for APEC economies. Energy Policy, 35: 373-82.
43. Kaknaroglu, H., 2010. Cultural energy analysis of dairy cattle receiving different concentrate levels. Energy Conv. Manag., 51: 955-8.
44. Moitzi, G., D. Damm, H. Weingartmann and J. Boxberger, 2001. Analysis of energy intensity in selected Austrian dairy farms with focus on concentrate level in feeding. Bulletin UASVM Agriculture, 67(1): 194-97.
45. Demircan, V., T. Binici, H. Koknaroglu and A.R. Aktas, 2006. Economic analysis of different dairy farm sizes in Burdur province in Turkey. Czech J. Anim. Sci., 51(1): 8-17.
46. Kraatz, S., W. Berg and R. Brunsch, 2009. Factors influencing energy demand in dairy farming. South Afr. J. Anim. Sci., 39: 139-140.
47. Dagistan, E., B. Koc, M. Gul, O. Parlakay and M.G. Akpinar, 2009. Identifying technical efficiency of dairy cattle management in rural areas through a non-parametric method: a case study for the east Mediterranean in Turkey, Journal of Animal and Veterinary Advances, 8: 863- 7.

48. Silvam, E., A. Arzubi and J. Berbel, 2004. An application of Data Envelopment Analysis (DEA) in Azores dairy farms. New Medit, 3(3) :39-43. Ciheam, Italy. Direct.bl.uk/ research/ 0B/ 55RN157036063. html.
49. Kompas, T. and T.N. Che, 2004. Production and technical efficiency on Australian dairy farms. Asia pacific school of economics and government, working papers. The Australian National University 2004; 20. http://www. crawford. anu. edu. au/ degrees/ idec/working_papers/IDEC04-1.pdf.
50. Adler, N., L. Friedman and Z. Sinuany-Stern, 2002. Review of ranking methods in the data envelopment analysis context. Eur. J. Oper. Res., 140(2): 249-65.
51. Mousavi-Avval, S.H., S. Rafiee, A. Jafari and A. Mohammadi, 2011. Energy storage in field operations of sunflower production using data envelopment analysis approach. International Journal of Energy and Environment, 2(5): 933-44.