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Effect of Herd Size on Sustainability of Dairy Production

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Abstract: Data obtained by conducting a survey on 132 dairy farms selected by the stratified random sampling method was used to assess effect of farm size on Cultural Energy (CE) expenditure of dairy cattle production. Dairy cattle farms were divided into three groups according to farm size. Accordingly farm groups were assigned as group 1 (farms that had 1-2 lactating cows, 53 farms), group 2 (farms that had 3-5 lactating cows, 51 farms) and group 3 (farms that had more than 5 lactating cows, 28 farms). Total cultural energy expended included cultural energy expended on feed, dairy operations, transportation, machinery and equipment. Cultural energy expended on feed was similar for farm groups ($p>0.05$) and it constituted more than half of the total cultural energy. As farm size increased cultural energy required producing a kg of milk decreased and group 3 had lower CE requirement than other farm groups ($p<0.05$). Cultural energy expended (Mcal) per Mcal protein energy output was lowest for group 3 ($p<0.05$). Efficiency defined as Mcal input/Mcal output was better for group 3 and differed from other farm groups ($p<0.05$). Results show that as farm size increases efficiency of converting cultural energy into milk increases. Thus in order to be more sustainable in dairying farm size should be increased without interfering cattle performance.

Key words: Cultural energy analysis, dairy cow, farm size, sustainability

INTRODUCTION

Rapid population growth in the world brings together some risks of adequate and balanced nutrition. This situation requires rational use of resources in the world. It is possible to say that except some countries there is still deficiency of animal origin protein intake in the world. Thus it is necessary to develop policies increasing animal origin protein intake of population. To meet the basic food needs of our expanding human population, a productive, sustainable agricultural system must become a major priority (Pimentel *et al*., 1998).

Sustainable agriculture defined as an integrated system of plant and animal production practices having a site-specific application over the long-term that will satisfy human food and fiber needs, enhance enviroumental qnality and the natural resource base upon which the agriculture economy depends. It also, make the most efficient use of nonrenewable resources and on-farm resources and integrate, where appropriate, natural biological cycles and controls, sustain the economic viability of farm operations and enhance the qnality of life for farmers and society as a whole gained importance in recent years. As it is mentioned in the definition of sustainable agriculture, efficient use of nonrenewable resources is required for sustainable animal agriculture. Thus energy output/cultural energy input ratio is of considerable value because they provide an estimate of our level of dependence

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on exogenous energy sources to meet established production goals (Heitschmidt *et al*., 1996). Furthermore, this ratio is one of the most useful methods to examine the potential long term sustainability of various agricultural practices and this analysis is performed to quantify the energy return from products relative to the cultural energy invested in the product (Heitschmidt *et al*., 1996).

Dairy cattle production is an important industry of the animal production sector and has an important position in world economy with its employment rate and values of products. Based on data for the year 2006, milk production in world was approximately 653.8 million ton while cow milk accounted for 83.57% of this production (FAO, 2006). Studies have examined the profitability of dairy cattle (Demircan *et al*., 2006) and Cultural Energy (CE) analysis of beef cattle by farm (Demircan and Koknaroglu, 2007). However, no study has examined the CE analysis of dairy cattle by farm size. Thus, the objective of this study was to assess the effect of farm size of dairy cattle on cultural energy use and to incorporate it into sustainability.

MATERIALS AND METHODS

The study is based on primary information collected during 2004 from 132 dairy cattle farms located in 18 villages of 3 districts of Burdur Province, namely, Bucak, Yesilova and Central Burdur Province.

Districts chosen for research purpose constituted 79.7% of dairy cattle population in Burdur Province (Anonymous, 2003). Stratified random sampling method was used to select number of dairy cattle farms.

Sampling size that would represent population was found to be 118. However, taking into account that some questionnaires would not be qualified for analyses, 138 dairy farms were randomly chosen to conduct questiounaire interviews. Of the 138 farms 6 had misinformation and did not qualify for analyses, thus 132 farms were used for study. In this study only cows were chosen as material. Considering cow population of farms and frequency distribution, farms were divided into three groups:

Group 1 : Farms that have 1-2 lactating cows (53 farms)
Group 2 : Farms that have 3-5 lactating cow (51 farms)
Group 3 : Farms that have more than 5 lactating cow (28 farms)

Cultural Energy Analysis

Cultural energy used for feed was derived from their corresponding feed consumption and corresponding values for each feed ingredient from literature and are given in Table 1. In order to find

Table 1: Cultural energy inputs for feed, operations and transportation

Inputs for feed	Units	Mcal/units	Reference
Concentrate mixture	kg	1.13	Calculated
Barley	kg	0.91	Sainz (2003)
Wheat	kg	0.96	Sainz (2003)
Cotton seed meal	kg	0.31	Sainz (2003)
Oat	kg	0.66	Sainz (2003)
Dried sugarbeet pulp	kg	2.90	Sainz (2003)
Straw	kg	0.33	Calculated
Alfalfa	kg	0.38	Sainz (2003)
Corn	kg	1.23	Sainz (2003)
Grass hay	kg	0.66	Sainz (2003)
Salt	kg	0.09	Sainz (2003)
Silage	kg	0.56	Sainz (2003)
Wheat bran	kg	0.08	Sainz (2003)
Mineral	kg	0.09	Sainz (2003)
Vitamin	kg	9.89	Calculated
Input for transportation	km	0.0013	Cook *et al.* (1976)

cultural energy for feed, total feed consumption and ingredients of ration of cows were determined and corresponding values for each feed ingredient from literature were multiplied to find cultural energy expended for feed.

Energy expended for preparing feed, feeding, inspection, veterinary care, waste removal and milking were included in energy expended for dairy operations. Thus energy expended for dairy operations includes labor required to raise dairy cattle. In addition energy used for watering was also included in energy expended for dairy operations.

Transportation energy was also included in the analysis. Shipping milk to milk processing units and feeds from feed manufacturer accounted for transportation energy. When calculating transportation energy, amount of milk shipped (kg), amount of feed bought, distance (km) between farm and milk processing and feed manufacturing units were considered. Cultural energy expended for machinery and equipment was 6% of the CE expended on feed, dairy operations and transportation. Total energy expended was summation of feed energy, dairy-operations energy, transportation energy and machinery and equipment energy. When calculating energy deposited in milk, it was assumed that milk content would have 3.3% protein, 3.6% fat and 4.7 % carbohydrates (Ensminger, 1993). Energy values of 1 g of protein, fat and carbohydrate were taken as 5.7, 9.4 and 4.27 kcal, respectively. Total energy deposited in milk was calculated as milk energy,

$$\begin{aligned} \text{Mcal} = \; & (\text{milk produced} \times \text{milk protein ratio} \times \text{unit protein energy}) + \\ & (\text{milk produced} \times \text{milk fat ratio} \times \text{unit fat energy}) + \\ & (\text{milk produced} \times \text{milk carbohydrate ratio} \times \text{unit carbohydrate energy}) \end{aligned}$$

Since cows deposit some of the energy they consume into calf, energy value of the calf had to be calculated. Thus it was assumed that a newly born calf would weigh 40 kg and have 2.5% fat and 19% protein (Ensminger, 1993). Thus energy content of calves was calculated by considering their weight, percentage of fat and protein they have and respective energy values of protein and fat. Since cows produced one calf every year, energy of calf had to be deducted from total cultural energy because energy expended on a cow results a calf a year which is considered as return. Thus cultural energy expended for kg of milk was calculated by dividing total cultural energy minus energy deposited in calf into lactation milk yield. Energy required to produce a unit of protein energy was calculated by dividing total cultural energy expended minus energy deposited in calf by total milk protein energy content. Efficiency defined as cultural energy input per energy output which is calculated by dividing total cultural energy expended minus energy deposited in calf by total energy deposited in milk.

Statistical Analysis

Iuformation obtained from farmers by questiounaire was analyzed and evaluated by using Excel spread sheet. The data were analyzed using the General Linear Model procedure of Statistical Analysis Systems (SAS, 1999) and PDIFF statements were used to compare farm groups.

RESULTS AND DISCUSSION

Cultural energy expended on feed was highest for group 2 and lowest for group 3. All three groups had similar CE expenditure on feed ($p>0.05$; Table 2). Cultural energy expended on feed paralleled dry matter intake as cows in group 2 had highest DMI and group 3 had the lowest DMI (Table 3). Cultural energy expended on feed for all farms constituted 77.15% of total cultural energy expenditure. These results are in agreement with Sainz (2003) who reported that contribution of feed to total fossil energy cost for dairy operations was 78%. However, these results were lower than that found by Cook (1976), who found that cultural energy expended on feed for 15,000-head feedlot

Table 2: Cultural energy (CE) input and output for farm groups

	Farm groups		
Parameters	1	2	3
CE expended for feed (Mcal/cow)	3846.42	3852.91	3362.06
CE dairy operations (Mcal/cow)	819.13[a]	512.96[b]	370.78[c]
CE for transportation (Mcal/cow)	247.44	256.62	258.23
CE for machinery and equipment	294.78[a]	277.35[ab]	239.46[b]
Total CE expended (Mcal/cow)	5207.77[a]	4899.84[ab]	4230.53[b]
Energy deposited in calf (Mcal/calf)	52.72	52.72	52.72
CE for feed (Mcal/day)	10.54	10.56	9.21
CE for kg of milk (Mcal/kg)	1.21[a]	1.09[a]	0.86[b]
Protein efficiency (Mcal CE expended/Mcal protein energy output)	6.50[a]	5.82[a]	4.63[b]
Efficiency (Mcal input/Mcal output)	1.66[a]	1.49[a]	1.18[b]

Means with different superscript in the same row differ ($p<0.05$)

Table 3: Feed consumption in terms of DMI for cattle farm groups

	Farm groups					
	1		2		3	
Feed ingredients	DMI/cow day	%	DMI/cow day	%	DMI/cow day	%
Concentrate	6.40	42.11	6.44	40.60	5.62	39.44
Roughage	7.40	48.68	7.33	46.22	5.76	40.42
Green chopped forage	1.40	9.21	2.09	13.18	2.87	20.14
Total	15.20	100.00	15.86	100.00	14.25	100.00

DMI: Daily dry matter intake

operation constituted 84.6% of total cultural energy expenditure and higher than Koknaroglu *et al*. (2007a), who found that cultural energy expended on feed for cattle fed in feedlot throughout feeding period was 61.9% of total cultural energy expenditure.

Dairy operations included electricity, watering, preparing feed, feeding, inspection, veterinary care, waste removal and milking (Table 2). As farm size increased, cultural energy expended for dairy operations decreased ($p<0.05$). The reason for cultural energy expended for dairy operations to decrease as farm size increases is that as farm size increased electricity and labor spent per cow decreased. Even though the same amount of labor and electricity might have been spent for care of cows and illumination of barns, the larger the herds size lower the amount of labor and electricity per cow it gets.

Cultural energy expended for transportation tended to increase with increasing farms size ($p>0.05$; Table 2). Cultural energy expended on transportation included energy expended on bringing feed to the farm and shipping milk to milk processing units. Even though cows in group 3 tended to have lower dry matter intake and thus less feed purchased, their higher milk yield and energy expended on shipping milk resulted them tended to have higher transportation energy.

Cultural energy expended for machinery and equipment decreased as farm size increases and was highest for group 1 and lowest for group 3 ($p<0.05$; Table 2). Group 2 was intermediate in terms of CE expended on machinery and equipment thus not differing other groups ($p>0.05$). Since summation of CE expended on feed, dairy operations and transportation was higher for group 1 and lower for group 3 this was reflected in CE expended for machinery and equipment.

Total cultural energy expended which is summation of cultural energy expended on feed, dairy operations, transportation and machinery and equipment is presented in Table 2. Total cultural energy expended was highest for group 1 and was lowest for group 3 ($p<0.05$) and group 2 was intermediate thus not differing from other groups ($p>0.05$). Group 1 had higher total cultural energy expenditure than group 3 due to their higher cultural energy expenditure on feed, dairy operations and machinery and equipment.

Table 4: Performance and carcass characteristics for cattle by farm groups

	Farm groups		
Parameters	1	2	3
Dairy cow (head)	1.55[a]	3.88[b]	9.58[c]
Milk yield (kg/cow day)	18.65	18.72	19.50
Average lactation length (days)	228.40[a]	238.64[ab]	249.19[b]
Lactation milk yield (kg/cow)	4259.66[a]	4467.34[a]	4859.21[b]

Means with different superscript in the same row differ ($p<0.05$)

Cultural energy for feed per day is obtained from cultural energy expended for feed over a one year period (365 days). Even though there were no differences among farm groups, group 2 tended to have higher CE for feed per day ($p>0.05$).

Cultural energy expended per kg of milk defined as total cultural energy expended divided by lactation milk yield decreased as farm size increased and was group 3 differed from other farm groups ($p<0.05$; Table 2). This value was lower than that found by Oltenacu and Allen (1980) who reported that average cultural energy used to produce a liter of milk was 1.66 Mcal kg^{-1} for the United States. Cultural energy expended per kg of milk decreased as farm size increased because as farm size increased total cultural energy expended decreased (Table 2) and lactation milk yield increased (Table 4). Oltenacu and Allen (1980) also found that the two regions with lowest cultural energy input per kg of milk were also the regions with the greatest number of cows per farm thus indicating effect of farm size on cultural energy expended per kg of milk.

Cultural energy expended (Mcal) per Mcal protein energy output is given in Table 2. This value decreased as farm size increased and was group 3 differed from other farm groups ($p<0.05$). The reason for protein efficiency to decrease as farm size increased is that protein energy output is a function of milk yield and as farm size increased milk yield increased and total cultural energy decreased. This followed the pattern of cultural energy expended for kg of milk. Oltenacu and Allen (1980) also found that cultural energy per kg protein followed the same pattern as the regions having lower cultural energy input per kg of milk were also the regions with the better protein efficiency. Cultural energy expended for protein energy output was lower than that of sheep and beef cattle (Koknaroglu *et al*., 2007a, b). Pimentel *et al*. (1975) found that energy use estimates for protein production was 10 Mcal/Mcal protein for range and 78 Mcal for feedlot beef, whereas it was 2 to 4 Mcal of cultural energy per Mcal of protein from various plants. Pimentel (2004) reported that kcal of fossil energy required to produce 1 kcal of animal protein was 40 and 20 kcal input/ kcal protein for beef cattle fed with grain and forage mixture and those fed only with forage, respectively.

Energy efficiency defined as total cultural energy expenditure minus calf energy divided by total energy deposited in milk is presented in Table 2. This shows the Mcal of cultural energy expended for Mcal of food energy. Efficiency became better as farm size increased and Group III had better efficiency than other groups ($p<0.05$). The reason for Group III to have better efficiency was lower total cultural energy expenditure due to lower cultural energy expended on feed, dairy operations, machinery and equipment and higher milk yield. Efficiency was better than other animal species and this shows that dairy cattle are efficient converter of cultural energy into food energy (Koknaroglu *et al*., 2007a, b).

Results show that as farm size increases efficiency of converting cultural energy into milk and energy from milk increases and thus in order to be more sustainable farm size should be increased without interfering cattle performance.

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