SHORT COMMUNICATION

Cultural energy analysis on broilers reared in different capacity poultry houses

Atilgan Atilgan¹, Hayati Koknaroglu²

¹Tarımsal Yapılar ve Sulama Bölümü Süleyman. Demirel Üniversitesi, Turkey
²Zootekni Bölümü Süleyman. Demirel Üniversitesi, Turkey

ABSTRACT

Data obtained from 4 different capacity houses were evaluated to analyse the cultural energy and performance of broilers. Capacities of housings were 20,000, 25,000, 30,000 and 60,000 birds per production period and they were assigned as HI, HII, HIII and HIV, respectively. The study was conducted in 2005 in which there were 6 production periods of 45 days. Data collected for each period were: date of starting and finishing; number of chicks entered and broilers sold; live weight at slaughter; carcass weight; feed consumption for starting, growing and finishing phase; labour; medication, vaccination and disinfectant; electricity consumption; heating and cooling methods and amount spent; distance for transportation of feed, chicks, broilers, wood shaving, limestone; and other miscellaneous expenditures. Ross 308 chickens in all houses received the same commercial feed and water ad libitum. Chicks were reared under a conventional temperature regimen. Chicks were fed starter, grower and finisher diets according to their ages. Even though capacities for houses were different their stocking densities were 16.36, 16.00, 16.38 and 16.54 birds/m² for HI, HII, HIII and HIV, respectively. For cultural energy analysis, feed, transportation, labour, machinery, electricity, brooding, and other inputs were calculated and corresponding energy values for each input were obtained from literature. For the analysis it was assumed that carcasses would have 18.2% protein and 15.2% fat. Total cultural energy invested in broilers in HIII was lower than that of broilers in HI (P< 0.05). Energy input per kg live weight gain and per kg carcass of HIII were lower than that of HI (P< 0.05, P< 0.01, respectively). The HIII had lower cultural energy ratio for protein energy output than HI (0.01). Energy efficiency (kcal input/kcal output) of HIII was better than that of HI (P< 0.01). Results of the study showed that increasing capacity of housings decreases cultural energy input up to certain capacity and indicated that increasing housing capacity without interfering with performance could be a means for energy conservation in sustainable agriculture.

Key Words: Cultural energy analysis, Broiler, Performance, Housing capacity.
Introduction

The worldwide broiler chicken industry has continuously grown over the last 40 years and produced over 940 million tons in 2004. Poultry meat represents 29% of meat production from farmed animals and this proportion is rising each year. Poultry meat is the third most consumed meat in the world, after beef and pork. According to data obtained in 2006, Turkey has 940,000 tons of chicken meat production from 297 million broilers (Food and Agricultural Organization, 2006) constituting 47% of the total meat production in Turkey. Thus the broiler chicken industry is considered an important livestock sector in Turkey.

The main purpose of broiler production is to maximize growth, feed efficiency and profitability (Testik and Ghayuresedigh, 1990). The feed cost is the main contributor of total cost with a share of 70%, which can sometimes rise up to 80% (Erener and Sarıçicek, 1995).

The primary nutrients in broiler diets are protein (amino acids) and energy. Energy needs are primarily met with corn and fat. Corn and soybean meal are considered to be the best ingredients available in the world to blend a poultry diet.

Intensive animal production uses considerable quantities of support energy. Since this increases the production costs, it should be used with a greater efficiency. The major support energy inputs include energy related to the production of feedstuffs, the manufacture of materials for buildings and machinery and, in some cases, fuel for heating.

Sustainable agriculture has been a subject of great interest and ongoing debate in animal agriculture (Heitschmidt et al., 1996). Sustainable agriculture is a production system in which the management and conservation of the resources base and the orientation of technological and institutional components changes in such a manner as to ensure the attainment and continued satisfaction of human needs for the present and the future generations (Food and Agricultural Organization, 1991).

Sustainability has gained great importance due to increases in population and energy demands in recent years. The world population is
increasing at a growth rate of 1.3% whereas energy use is projected to increase at the rate of 2.2% between years 1995 to 2015 (Energy Information Administration, 1995; Anonymous, 2004). The energy output/input ratio is one of the most useful methods for evaluation of the potential long-term sustainability of various agricultural practices. This analysis is performed to quantify the energy return from products relative to the cultural energy invested for their production (Heitschmidt et al., 1996). The objective of this study was to carry out cultural energy analysis in the poultry field by comparing different housing capacities for the determination of the optimum capacity for sustainability.

### Material and methods

**Housing conditions and management**

Four broiler houses in close vicinity in Adana province were selected to conduct this research. The houses differ in size, thus the following capacities were compared: 20,000, 25,000, 30,000, and 60,000 birds per production period. Houses were assigned as housingI (H1), housingII (HII), housingIII (HIII), and housingIV (HIV), respectively. The study was carried out in the 2005 and six 45 days productive cycles per each house were evaluated. Data collected during each production period in each housing were: the starting and the finishing date of the rearing period; number of housed chicks and sold broilers; live body weight at slaughter; carcass weight; feed consumption at starting, growing and finishing period; labour cost; medication, vaccination and disinfectant expenditure; electricity consumption; heating and cooling methods and amount spent; distance for transportation of feeds, chicks, broilers, wood shaving, limestone; and other miscellaneous expenditures.

During the 45 days of rearing Ross 308 chicks received commercial broiler diets and water ad libitum. Chicks were reared under a conventional temperature regimen, i.e. starting 33°C, and reduced by 3°C/week to 21°C. The relative humidity was maintained between 60-70%. Starter, grower and finisher diets were fed to chicks.
according to their ages. Even though capacities for houses were different their stocking densities were similar with 16.36, 16.00, 16.38 and 16.54 birds/m² for HI, HII, HIII and HIV, respectively.

During the experiment, growth performance was evaluated by recording body weight and feed intake. Individual body weights of the chicks were recorded at the beginning of the experiment (1 day old) and on a weekly basis thereafter. Feed intake was recorded weekly. The feed efficiency was calculated weekly as the amount of feed consumed per unit of body weight gain. Birds were slaughtered at the age of 45 days. The carcasses were immediately plucked, eviscerated, weighed and then chilled overnight in a fridge at 4 °C in order to estimate the cold carcass weight and amount of abdominal fat.

Dressing was calculated as ratio of carcass weight to live weight at slaughter. Survival rate was found by dividing the number of broilers sold to the number of chicks entered into the house. Heating was provided by burning coal or propane, whereas cooling was provided forcing air into pads filled with water.

Cultural energy analysis

Cultural energy used for feed was obtained considering the feed consumption and the energetic values for each feed ingredient from literature and shown as tabulated form in Table 1. Cultural energy expended on transportation included energy used for the transportation of chick, chicken, feed, wood shaving, limestone transportation energy. Cultural energy spent for heating was calculated by multiplying the amount of coal or propane used with corresponding energy values for coal and propane from literature. The electricity consumption by fans used for cooling was calculated by multiplying the power (kW h⁻¹) of each fan pad and the time it ran per day (h). Cultural energy for cooling was calculated by multiplying electricity consumed by fan pads and the cultural energy of electricity. The electricity consumed for lighting was calculated by multiplying number of lamps with their power and multiplying this value by hours of lighting during a production period. Electricity consumed by feed conveyor and water pump was calculated using the same approach.

In order to calculate the energy deposited in the carcass of broilers, it was assumed that the carcass contains 18.2% protein and 15.2% fat (Celik and Ozturkcan, 2003). Energy values of 1 g of protein and fat were taken as 5.7 kcal and 9.4 kcal, respectively. Total cultural energy expended for housings included cultural energy expended for feed, brooding, transportation, electricity, labour and miscellaneous items. Since cultural energy values for medicines and disinfectants were not found in the literature, the energy of these items was derived from their formulas and was included in miscellaneous cultural energy part.

Energy required to produce a kg of live weight gain was calculated by dividing total cultural energy expended by total live weight gain calculated as chick weight subtracted from final weight. The efficiency defined as cultural energy input per energy output was calculated by dividing total cultural energy expended by energy deposited in carcass. Energy required to produce unit protein was calculated by dividing total cultural energy expended by carcass protein energy content. In order to facilitate calculations, cultural energy expenditure values were given for 1000 birds.

Statistical analysis

The data were analysed using the General Linear Model procedure of SAS (1999) by using housing size in the model and PDIFF statement was used to compare housing means for dependent variables.

Results and discussion

Cultural energy (CE) input and output for 1000 birds are given in Table 2. Although not significant, CE expended on feed was highest for HII
and decreased as the capacity increased (P > 0.4). The reason for similar CE expenditure on feed was the ingestion of similar amounts of feed by broilers in those housings.

Cultural energy expended on feed constituted most of the total cultural energy expended, varying from 81 (HI) to 87% (HIII). Typical broiler rations consist of concentrates and contain good feed that are high in nutrients (Ensminger, 1992) and require high cultural energy for production (Table 1). The HI and HIV had higher cultural energy expended for brooding (P < 0.03; Table 2) than HII and HIII. For heating HI and HIV used coal burning stoves whereas HII and HIII used propane, and since it is easier to control propane heaters this could be reflected in CE for brooding. There was no significant differences in terms of CE expended on transportation (P > 0.4) even if HI and HII had higher values presumably due to higher feed consumption leading to buy more feed (Table 3). Cultural energy expended on electricity decreased as housing capacity increased. The HIII and HIV had lower CE expended on electricity compared to HI and HII (P < 0.01), similarly HI had significantly higher values than HII (P < 0.01). Electricity consumption consisted of lighting, cooling, water pump and spiral feed conveyor, but consumption by lighting was the major factor. As a management practice in HI and HII, lighting was provided 24 hours d⁻¹ whereas it was 12 and 8 hours d⁻¹ in HIII and HIV, respectively. On the other hand producers in HI used normal light bulbs whereas others used energy saving light bulbs. Considering the lighting regimen and light bulbs, these factors combined together caused HI and HII to have higher electricity consumption. Miscellaneous expenditures included limestone, water, diesel, medicine and labour. For these HI and HIV had lower miscellaneous CE expenditures (P < 0.01) than other housings. The HII had higher miscellaneous CE expenditure than HIII (P < 0.01). Cultural energy for diesel was the major contributor of miscellaneous energy consumption and the reason for HI and HII to have higher miscellaneous CE expenditure was that these houses used higher quantities of diesel for electricity generators due to their extended hours of lighting regimen. Total CE expenditure of HI was the

Table 2. Cultural energy (CE) input and output per 1000 birds by capacities.

| Items                      | HI (20,000 birds) | HII (25,000 birds) | HIII (30,000 birds) | HIV (60,000 birds) | P-values |
|---------------------------|-------------------|--------------------|---------------------|-------------------|----------|
| CE for feed Mcal          | 6781.55           | 6895.76            | 6667.06             | 6655.33           | 0.40     |
| CE for brooding           | 568.40            | 200.98             | 206.64              | 580.31            | 0.03     |
| CE for transportation     | 553.21            | 562.40             | 546.28              | 543.29            | 0.40     |
| CE for electricity        | 352.88            | 265.85             | 136.33              | 92.26             | 0.01     |
| CE for miscellaneous      | 32.55             | 176.51             | 104.77              | 44.93             | 0.01     |
| Total CE expended         | 8288.59           | 8101.50            | 7661.08             | 7916.12           | 0.05     |
| Energy deposited          | 4251.42           | 4365.23            | 4289.70             | 4226.81           | 0.30     |
| CE live weight gain Mcal/kg | 3.71              | 3.49               | 3.36                | 3.53              | 0.05     |
| CE carcass                | 4.81              | 4.58               | 4.41                | 4.62              | 0.01     |
| Protein efficiency        | 4.63              | 4.41               | 4.25                | 4.45              | 0.01     |
| (CE/protein energy output) |                  |                    |                     |                   |          |
| Total efficiency (input/output) | 1.95              | 1.86               | 1.79                | 1.87              | 0.01     |

abcMeans with different superscripts in the same row are significantly different with respect to their P-values. HI=Housing I; HII=Housing II; HIII=Housing III; HIV=Housing IV.
highest and this was different from that of HIII (P<0.05). Total CE expended decreased as housing capacity increased up to 30,000 birds, however, it increased when the capacity reached 60,000 birds. This suggests that total CE expenditure does not necessarily decrease with an increase in capacity.

Energy deposited in the carcass did not show significant differences although this value tended to be higher for HII. This could be expected since energy deposited in the carcass is a function of carcass weight. Thus broilers in HII had numerically higher carcass weight than other housings (Table 3). It is reported that as stocking density increases breast muscle thickness is expected to decrease, since the more crowded birds are not expected to grow to their full potential (Feddes et al., 2002). This is well demonstrated in this research as carcass weight decreased in HIII and HIV.

Cultural energy expended per kg live weight gain was the highest for HI and this differed from HII and HIII (P<0.05). Broilers in HII and HIII were the most efficient in converting CE to live weight gain than those in HI, while the conversion efficiency did not differ significantly between HI and HIV. The lower values found in HII and HIII were due to the lower total CE expenditure as well as higher live weight gains. The higher value in HIII and HIV (Higher CE expenditure and lower weight gain) and shows that as the capacity increases there would not necessarily be an increase in conversion of CE to live weight gain. Previous research showed that high stocking densities can contribute to reduced performance due to a number of factors. High stocking density decreases airflow at the level of the bird and it results in reduced dissipation of body heat to the air, reduces air quality due to inadequate air exchange, and increased ammonia, and reduces access to feed and water (Feddes et al., 2002). At stocking densities ranging from 10 to 20 birds per m², Puron et al. (1995) found a linear reduction in body weight and feed intake of male broilers but no differences in feed conversion by 7 weeks of age was observed. Cravener et al. (1992) reported lower body weight and decreased carcass quality of birds raised in high density stocking suggesting that birds in higher density housing were stressed.

Cultural energy expended per kg of carcass was higher in HI than HIII (P<0.01) while HI, HII and HIV had similar values. Broilers in HIII had lower CE expenditure per kg carcass because they had lower total CE expenditure due to lower CE expenditure on feed, brooding and electricity (Table 2). Broilers in HIII had lower feed consumption and live weight, but higher dressing out and carcass weight.

Concerning cultural energy expended per 1

| Variable                  | HI (20,000 birds) | HII (25,000 birds) | HIII (30,000 birds) | HIV (60,000 birds) | P-values |
|---------------------------|-------------------|--------------------|---------------------|-------------------|----------|
| Feed consumption (kg)     | 3.95              | 3.98               | 3.85                | 3.84              | 0.40     |
| Weight gain               | 2.27              | 2.36               | 2.32                | 2.28              | 0.10     |
| Feed conversion           | 1.77              | 1.72               | 1.69                | 1.71              | 0.09     |
| Carcass weight (kg)       | 1.72              | 1.77               | 1.74                | 1.71              | 0.30     |
| Dressing out (%)          | 75.82a            | 75.00b             | 75.00b              | 75.00b            | 0.01     |
| Survival rate (%)         | 0.97b             | 0.95a              | 0.96b               | 0.96b             | 0.02     |

*Means with different superscripts in the same row are significantly different with respect to their P-values. HI=Housing I; HII= Housing II; HIII= Housing III; HIV= Housing IV.*
Mcal of protein energy, broilers raised in HIII had lower value than broilers in HI (P<0.01). On the other hand, broilers raised in HII and HIV showed values similar to those in HIII and no significant difference was found between HIV and HI (P>0.1). Since animal origin protein intake in human nutrition is important, this outcome shows that capacity increase does not always decrease the cultural energy required for the production of 1 Mcal of protein energy because after a certain point of capacity increase, there is a negative association between broiler performance and stocking density. Thus maximizing efficiency would be a better approach for sustainability purposes. These results are in agreement with the findings of Pimentel (2004) who reported that broilers required 4 kcal cultural energy to produce 1 kcal protein energy and this ratio was lower than other livestocks. Even though broilers require less kcal cultural energy per kcal protein energy their dependence on grain for feeding place them in competition with humans.

The total efficiency shows the Mcal of cultural energy expended for Mcal of food energy. The HIII had better efficiency than HI (P<0.01) and other treatments did not differ from each other (P>0.05). The HIII had better efficiency due to its lower total CE expenditure and comparable carcass energy deposited. This indicates that bigger capacities (60,000 birds) are not always more sustainable in terms of cultural energy. Livestock production is becoming an industrial-scale process in which 100,000 or more chickens are fed grains and produced in a single facility (Tilman et al., 2002). In the United States, the average number of animals per livestock operation increased 2.5-fold for broiler chickens over 14 years (United States General Accounting Office, 1995). Large-scale facilities are economically competitive because of production efficiencies (Martin et al., 1999) but have health and environmental costs that must be better quantified to assess their potential role in sustainable agriculture. High-density animal production operations can increase livestock disease incidence, the emergence of new, often antibiotic-resistant diseases, and air, groundwater and surface water pollution associated with animal wastes (Tilman et al., 2002). Thus even though they are not economically competitive, smaller scale broiler production should be supported by governments by providing subsidies to the producers. In 1999, member countries of the Organisation for Economic Co-operation and Development provided 283 billion dollars in subsidies to support agricultural production (OECD, 2000) and these funds need to be reoriented to support sustainable practices (Tilman et al., 2002).

**Conclusions**

This study shows that as housing capacity increases cultural energy expended per kg of weight gain, and per Mcal of protein energy output decreases until HIII (30,000 birds) but they increase in HIV (60,000 birds). Since broilers raised in HIII showed lower total CE expenditure but comparable growth rate and carcass weight to broilers raised in HI they had better efficiency. In general cultural energy expended per Mcal of protein energy output was in agreement with those reported in the literature. The results of this study show that an increase in housing capacity does not necessarily mean greater sustainability as higher stocking density interferes with growth performance.

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