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Full Length Research Paper

Investigation of poultry housing capacity on energy efficiency of broiler chickens production in tropical areas

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The aim of this study was to investigate the evaluated energy efficiency and effect of poultry house size on energy productivity in three different capacity. Capacities of houses were 10,000 (3 housings), 20,000 (2 housings) and 28,000 (1 house) birds per production period and were assigned as HI, HII and HIII respectively. For calculating the effective factors on energy efficiency in the studied poultry housing, this experiment was conducted in a completely randomized design as basis in nested pattern. Utilized energy in the form of fuel, electricity, feed, labour, wood shaving, chicks and utilized chemical as inputs and litter and broilers as outputs were measured in each production period. Result shows that inputs significantly decreased with increasing the size of poultry house from 10,000 to 28,000. Thus, division input energy and cost in production of HIII had better productivity than the other units. Also, experiment treatment had significant effect on energy indexes (p<0.01).

Key words: Energy efficiency, inputs, outputs, poultry housing capacity.

INTRODUCTION

The knowledge of energy consumption in each unit operation of a production system is useful for determining high energy consuming areas (Miller, 1986; Jekayinfa, 2007). These areas can only be identified by methodological energy analysis of all processing operations. Energy analysis allows the energy cost of existing process operations to be compared with that of new or modified production lines. It also enables a plant operator to compare his energy efficiency with that of a competitor or with that of another factory within the same company. Therefore, the knowledge of energy consumption for each product in a factory is useful for several purposes, such as budgeting, evaluation of energy consumption for a given product, forecasting energy requirement in a plant, and for planning plant expansion. Thus, the purpose of any energy management scheme is to minimize the energy cost component of the production costs, but not at the expense of product quality or higher overall costs (Miller, 1986). Energetic analyzes can give the ability for producers that compare all processing unit with modern production approach or even can alter the production lines (Jekayinfa, 2007).

Insulation is one of the best ways for management of energy and reducing energy loses in the form of heat especially in cold areas with long winters. By this approach, the heat losses from heaters and broilers body are not lost and broilers can utilize feed energy for their growth. Managing equipments and consumption patterns in reducing utilize energy and therefore in reducing costs are effective. All of these ingredients and rapid increase in production cost of broilers has caused producers to have more attention to their energy consumption (Alam et al., 2005).

Poultry industry is one of the biggest and more

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Table 1. Energy co-efficient for various inputs and outputs in poultry production.

Input	Mcal/unit	Unit	References
Maize	1.89	kg	Atilgan, (2006)
Soybean meal	2.88	″	Atilgan (2006)
Fish meal	2.06	″	Sainz (2003)
Dicalcium phosphate	2.39	″	Atilgan (2006)
Salt	0.38	″	Sainz (2003)
Limestone	0.31	″	Atilgan (2006)
Mineral and vitamin	0.38	″	Sainz,(2003)
Labour	0.54	h	Cook et al. (1980).
Electricity	2.85	Kw/h	Singh (2002)
Diesel	11.38	l	Singh (2002)
Medicine	3.26	kg	Atilgan (2006)
Disinfectant	0.1	″	Supposed
Output			
Bed	4.02	kg	Calculated
Meat	0.32	″	(Celik and Ozturkcan 2003)

developed industries in Iran. By increasing the population and increasing the income as welfare and consequently increasing demand for white meat, developing this industry in order to provide protein needs is inevitable (Yılmaz et al., 2005). For the production of 1 kcal energy in the form of protein, poultry needs 4 kcal energy, while this ratio in other animals compared to poultry is higher; therefore the efficiency of poultry in utilizing energy conversion is better (Pimentel, 2004). Also, on average, energy requirement for production per bird is 0.1306 kW; this utilized energy for poultry rearing is consisted of energies in inputs that are consumed in a production unit (Jose et al., 2002). In Table 1, there are some data about different input energies in a broiler production unit.

Poultry house size is a factor that is effective in the efficiency of using energy in a unit. This is a function of stocking density that is for any bird (Yılmaz et al., 2005). In cold climate, birds need less space while in the hot climate they need more. When all birds are sent to market early, lesser space is needed, and vice versa. Broiler rearing in the density of 10 to 20 birds in any square meter result in a negative and linear relationship between weight of body and consumed feed. In addition, a high population density can decrease quality of poultry carcass and reduce weight of body according to the importance of energy in the fields such as economics, and environment sustainable development (Cravner et al., 1992; Puron et al., 1995). Determination of utilized energy in poultry rearing in our country is inevitable, because, no research has been undertaken to evaluate the amount of energy used and to determine suitable size of poultry houses. Hence, doing this research and determining suitable pattern of energy utilization in different capacity poultry houses is very effective in order to help producers in this industry, and support sustainable development of poultry production.

MATERIALS AND METHODS

Housing conditions and management

Six broiler houses in close vicinity in the area of Ahvaz (is area tropic of Iran) were selected to conduct this research. The houses differ in size, thus the following capacities were compared: 10,000 (3 housings), 20,000 (2 housings) and 28,000 (1 house) birds per production period. Houses were assigned as housing I (HI), housing II (HII) and housing III (HIII) respectively. The study was carried out in the 2007 and three 47 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; feed consumption; labour cost; medication and disinfectant expenditure; electricity consumption; heating and cooling methods and amount spent; wood shaving, limestone; and other miscellaneous expenditures. During the 47 days of rearing, Ross 308 chicks received commercial broiler diets and water *ad libitum*. Chicks were reared under a conventional temperature regimen that is, starting at 33℃, and reduced by 3℃/week to 21℃. The relative humidity was maintained between 60 to 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 10.20, 8.52 and 9.86 birds/m^2 for HI, HII and HIII, respectively.

Cultural energy analysis

Cultural energy used for various inputs and outputs were obtained considering their consumption and the energetic values for each of

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

Item	I (10,000 birds)	II (20,000 birds)	III (28,000 birds)	P-value
Fuel (MJ)	75.18	76.77	33.49	0.4
Electricity (MJ)	6.95[b]	7.84[a]	4.21[c]	0.01
Food (MJ)	36.52[a]	31.72[ab]	20.99[b]	0.01
Chicks (MJ)	0.418[a]	0.299[a]	0.161[b]	0.01
Bed (MJ)	0.55	0.615	0.59	0.3
Labour (MJ)	0.198[a]	0.131[b]	0.093[b]	0.01
Disinfectant (MJ)	1.935[a]	0.482[b]	0.153[c]	0.01

[abc]Means values within a column with unlike superscripts differ significantly with respect to their p-values. HI= Housing I; HII= Housing II; HIII= Housing HIII.

them from literature and shown as tabulated form (Table 1). Cultural energy spent for heating was calculated by multiplying the amount of coal or diesel used with corresponding energy values for coal and diesel from literature. The electricity consumption by fan pads used for ventilation 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 (Al-Helal, 2003). 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 and 9.4 kcal, respectively. Total cultural energy expended for housings included cultural energy expended for feed, brooding, electricity, labour and miscellaneous items. Energy required to produce a kilogram 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. All the inputs and outputs of the rearing units were measured and their equivalent energy calculated, using coefficient- energy values (Table 1). During each rearing period, the energy equivalent of various inputs (fuel, feed, electricity, labour, chemical material) and outputs (live weight and litter) were determined. Based on the energy equivalents of the inputs, outputs and yield (Table 1), energy ratio (energy use efficiency) and energy productivity were calculated.

$$\text{Output- input ratio} = \frac{Energy\ output\ (MJ)}{Energy\ \ Input\ (MJ)}$$

$$\text{Energy productivity} = \frac{\text{Stake poultry meat (MJ)}}{\text{Energy Input (MJ)}}$$

The input energy was divided into direct, indirect, renewable, and non-renewable (Yılmaz et al., 2005). Indirect energy included energy embodied in feeds and chemical while direct energy covered human power and diesel used in the production period. Non-renewable energy included diesel and chemical while renewable energy consisted of human power.

To determine the litter energy, litter samples were taken from several points of poultry houses besides nipples, feeders and walls. Samples were weighed and dried in an oven for 24 h at 105°C. After drying the litter, its dry matter and moisture content was calculated. Finally, the entire poultry houses energy efficiency was determined by dividing total output energy by total input energy during a rearing period.

Statistical analysis

The data were analysed using the completely randomized design as basis in nested pattern by using SAS (2005) and by using housing size in the model and production period.

RESULTS AND DISSCUSION

Cultural energy (CE) expended on fuel was highest than the other inputs. CE inputs are given in Table 2. Energy analysis all of the inputs are given in mj/kg for live weight gain. CE expended on fuel was highest for HII and decreased as the capacity increased (P>0.4). The reason for similar amount of fuel consumed was that there were similar heat requirement amounts by broilers in those housings. For heating HI and HII diesel stoves were used whereas HIII used diesel torch, and since all of the heat produced by diesel torch remained in the poultry housings, this could be reflected in low fuel consumption.

As showed in Table 2, feed was the second consumption inputs in the poultry housings. Energy expenditure on feed was highest for HI and decreased as the capacity increased. This reduction in feed consumption as in poultry house size increased may relate on high conversion efficiency. These results are in agreement with Atilgan and Hayati (2006), who showed that housing capacity increases CE expended per kg of weight gain, and per Mcal of protein energy output decreases in 30,000 birds but increased in 60,000 birds.

CE expended on electricity increased as housing capacity increased. The HI had lower CE expense on electricity compared to HII and HIII (P<0.01). Similarly, HIII had significantly higher values than HII (P<0.01). Electricity consumption consisted of lighting, water pump and spiral feed conveyor, but consumption by lighting was the major factor. As a management practice in HI

Table 3. Cultural energy (CE) output and indexes per birds by capacities.

Item	I (10,000 birds)	II (20,000 birds)	III (28,000 birds)	P-value
Litter (MJ)	12.59[a]	15.39[b]	12.9[b]	0.01
Meat (MJ)	11.64[b]	16.109[a]	8.356[c]	0.01
İnputs (MJ)	121.76[a]	117.87[a]	59.69[b]	0.01
Outputs (MJ)	24.237[b]	31.505[a]	21.26[b]	0.01
Ratio (MJ)	20.85[b]	27.02[b]	35.84[a]	0.01
Productivity (MJ)	0.098[b]	0.138[a]	0.14[a]	0.05
Energy İntensity (MJ)	2.15[b]	1.96[c]	2.544[a]	0.01

[abc]Means values within a column with unlike superscripts differ significantly with respect to their p-values. HI= Housing I; HII= Housing II; HIII= Housing HIII.

and HIII, lighting was provided 24 h d^{-1} whereas it was 12 h d^{-1} in HII. Considering the lighting regimen and light bulbs, the factors combined together caused HII to have higher electricity consumption. Other inputs energy expenditures included chicks, bed, labour and disinfectant. For these, HIII had lower energy expenditures (P<0.01) than the other housings. HII had higher miscellaneous CE expenditure than HIII (P<0.01)

Energy indexes

CE for output energies, sum of inputs and outputs, and also for energy indexes are given in Table 3. Total CE expended decreased as housing capacity increased up to 28,000 birds. Energy deposited in the meat showed significant differences and this value was higher for HII. These results are in agreement with the findings of Hayati and Atilgan (2007) and 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 was 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 increased in HII because of its minimum stocking density. Also, energy deposited in the litter was affected by housing capacity (P<0.01). That is why we had higher energy deposited in the form of outputs in HII.

Energy ratio shows the Mj of energy deposited in output to cultural energy expended for input. HIII had better efficiency than HI and HII (P< 0.01). The HIII had better efficiency due to its lower total CE expenditure while in carcass and litter energy, HII was better. This indicates that bigger capacities (28,000 birds) are more sustainable in terms of CE. We had the same condition for energy productivity and energy intensity that demonstrated big capacities are beneficial and economical. 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). 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.

Conclusıons

With increase in poultry housing sizes, input energies were decreased by intensive production and prorate inputs per bird in production period. Thus, because of division, input energy and cost in production had better productivity than the other units. Also, the experiment treatment had significant effect on energy indexes. Output to input energy ratio of all poultry housings was approximately below 0.4, while this ratio in energy equations for agriculture products was more than one. To increase this ratio, one can manage consumption, fuel and electricity and also useg solar energy to warm poultry production house, which can also help in achieving this target.

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