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Investigation of Energy Efficiency of Broiler Farms in Different Capacity Management Systems

Research Article

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ABSTRACT

An experiment was performed to investigate the energy efficiency and effect of poultry house size on energy productivity in 3 different capacity management systems. Capacities of houses were 10000 (3 housings), 20000 (2 housings) and 28000 (1 housing) birds per production period and were assigned as HI, HII and HIII respectively. This experiment was conducted in a completely randomized design applying a 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 showed that inputs significantly decreased with increasing the size of poultry house from HI to HIII. A significant difference (P<0.01) in energy indexes was observed across the three capacities of housing investigated. Thus division input energy and cost in production of HIII exhiited better productivity than the other units in this study.

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 evaluating infrastructure (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 to compare all processing units within a modern production approach or even can alter the production lines (Jekayinfa, 2007).

The poultry industry is one of the biggest and more developed industries in Iran. By increasing the population and increasing the income as welfare and consequently increasing demand for white meat, developing of this industry in order to provide protein needs is inevitable. For the production of 1 kcal energy in the form of protein, poultry require 4 kcal energy input, whilst this ratio is lower than in other animals, the efficiency of poultry to utilize energy converttsion is better. Additionally on average energy requirement for production per bird is 0.1306 kW; this is utilized energy for poultry rearing and consists of energies in inputs that are consumed in a production unit (Jose *et al*. 2002). Table 1, outlines relevant data related to different input energies in a broiler production unit.

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

Input	Mcal/U	(Unit)	Reference
Maiz	1.89	kg	(Atilgan, 2006)
Soybean meal	2.88	〃	(Atilgan, 2006)
Fish meal	2.06	〃	(Sainz, 2003)
Dicalcium phophate	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, 2003)

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 relevant for any bird (Yılmaz *et al*. 2005). In cold climate birds, need less space while in the hot climate they need more, whilst sending all birds to market sooner, reduced 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 the quality of poultry carcasses and reduce bodyweight according to the importance of energy in the fields such as economics, environment sustainable development (Cravner *et al*. 1992; Puron *et al*. 1995).

Determining quantities of utilized energy in the poultry rearing in Iran is inevitable, because, no research has been undertaken to evaluate the amount of energy used and to determine suitable size of poultry houses. Hence, this research was performed to determine a suitable pattern of energy utilization in different capacity poultry houses that very effective in order to inform producers and aid efficacy in this industry.

MATERIALS AND METHODS

Housing conditions and management

Six broiler houses in close vicinity in area Ahvaz (tropic of Iran) were selected to conduct this research. The houses differed in size, thus the following capacities were compared: 10000 (3 housings), 20000 (2 housings) and 28000 (1 house) birds per production period. Houses were assigned as housing I (HI), housing II (HII) and housing III (HIII) respectively. 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, i.e. starting 33 ˚C, and reduced by 3 ˚C /wk 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 10.20, 8.52 and 9.86 birds/m^2 for HI, HII and HIII, respectively.

Cultural energy analysis

Cultural energy was used for various inputs and outputs were obtained considering their consumption and the energetic values for each of them from literature and shown as tabulated form from 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 the feed conveyor and water pump were 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 kcal and 9.4 kcal, respectively. Total cultural energy expenditure for housings included cultural energy expended for feed, brooding, electricity, labour and miscellaneous items. 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. All the inputs and outputs of the rearing units measured and their equivalent energy were calculated, using coefficient- energy values (Table 1). During each rearing period, the energy equivalent of various inputs (consisting 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 using the following formula:

Output-input ratio= Energy output (MJ) / Energy input (MJ)

Energy productivity= Stake poultry meat (MJ) / 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 consists of human power.

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

Statistical analysis

The data were analysed using the completely randomized design based upon the nested pattern of SAS (1996) by considering housing size in the model and production period.

RESULTS AND DISCUSSION

Cultural energy (CE) expended on fuel was highest between the other inputs. CE inputs are given in Table 2. For 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 the similar heat requirement amounts by broilers in those housings. For heating HI and HII used diesel stoves whereas HIII used a diesel torch, and since of the entirety of heat produced by diesel torches remain in the poultry housings, this could be reflected in the low fuel consumption. As shown in table 2, feed was the second of the higher 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 in relation to increasing poultry house size may relate to high conversion efficiency. These results are in agreement with Atilgan and Hayati (2006) who found that housing capacity increases CE expended per kg of weight gain, and per Mcal of protein energy output decreases until 30000 birds stocking capacity and then increases over 60000 birds.

CE expended on electricity increased as housing capacity increased. The HI had lower CE expended 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 and HIII, lighting was provided 24 hours d^{-1} whereas it was 12 hours d^{-1} in HII. Considering the lighting regimen and light bulbs, these 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 other housings. The 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 28000 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 a numerically higher carcass weight than in the 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 increased in HII because of its minimum stocking density. Also energy deposited in the litter was affected by housing capacity (P<0.01).

Energy ratio shows the MJ of energy deposited in output to cultural energy expended for input. HIII recorded 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 (28000 birds) are more sustainable in terms of CE. This suggests that the same management system (large capacity) is beneficial and economical with regards to energy productivity and energy intensity.

Livestock production is becoming an industrial-scale process in which 100000 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 hea-

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

Items		I (10000 birds)	II (20000 birds)	III (28000 birds)	P-values
Fuel	MJ	75.18	76.77	33.49	0.4
Electricity	"	6.95[b]	7.84[a]	4.21[c]	0.01
Feed	"	36.52[a]	31.72[ab]	20.99[b]	0.01
Chicks	"	0.418[a]	0.299[a]	0.161[b]	0.01
Bed	"	0.55	0.615	0.59	0.3
Labour	"	0.198[a]	0.131[b]	0.093[b]	0.01
Disinfectant	"	1.935[a]	0.482[b]	0.153[c]	0.01

The means that have at least one common letter within the same column, do not have significant difference with respect to their p-values.

HI= Housing I; HII= Housing II; HIII= Housing HIII.

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

Items		I (10000 birds)	II (20000 birds)	III (28000 birds)	P-values
Litter	MJ	12.59[a]	15.39[b]	12.9[b]	0.01
Meat	"	11.64[b]	16.109[a]	8.356[c]	0.01
Inputs	"	121.76[a]	117.87[a]	59.69[b]	0.01
Outputs	"	24.237[b]	31.505[a]	21.26[b]	0.01
Ratio	"	20.85[b]	27.02[b]	35.84[a]	0.01
Productivity	"	0.098[b]	0.138[a]	0.14[a]	0.05
Energy intensity	"	2.15[b]	1.96[c]	2.544[a]	0.01

The means that have at least one common letter within the same column, do not have significant difference with respect to their p-values.

HI= Housing I; HII= Housing II; HIII= Housing HIII.

lth 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.

CONCLUSION

Intensive production systems employing increased poultry housing sizes decrease prorate inputs per bird during the production period. Thus because of division input energy and cost in production, these exhibit better productivity than the other units. The experiment treatment also has a 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 is more than one. To increase this ratio, one can manage consumption, fuel and electricity and other technologies such as solar energy have the potential to warm poultry production houses and aid in achieving energy efficiency targets.

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