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Modelling Energy Efficiency in Broiler Chicken Production Units Using Artificial Neural Network (ANN)

Mohsen Yamini SEFAT[1*] Ali Mohammad BORGAEE[2] Babak BEHESHTI[2] Hossein BAKHODA[1]
[1] Department of Agricultural Mechanization, Science and Research Branch, Islamic Azad University, Tehran, Iran.
[2] Department of Mechanical Agricultural Machinery, Science and Research Branch, Islamic Azad University, Tehran, Iran.

*Corresponding author:
E-mail: mohsen.yaminisefatiau@gmail.com

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Abstract

The purpose of the current study is to determine the energy consumption and to investigate the relationship between input and output energy of producing units for broilers. Accordingly, data was collected from 50 broiler chicken production units using personal questionnaires in the winter 2013. The total energy and output were estimated at ~220.02 and 30.25 GJ, respectively, per 1000 birds. The most important energy inputs were gasoline, food, gas and electricity explaining 43.03%, 25.56%, 20.81% and 10.07%, respectively, of the total energy used. Minimal amounts of energy was inputs including day old birds, equipment and labor explaining 0.27%, 0.16% and 0.10%, respectively, of the total energy used. Energy index, energy ratio, energy efficiency, specific energy and net energy added were calculatedat0.15, 0.01 Kg/MJ, 76.59 MJ/Kg and 189.77 MJ per 1000 birds. Determination of different forms of energy also revealed that the contribution of direct energies (26%) was higher than indirect energies (74%); in addition, almost all the energy sources used in the production of broilers in Alborz Province were nonrenewable (99.90% renewable and 0.10% nonrenewable). Various neural networks (approximately 600 networks) were assessed to estimate the relative amount of energy used in production units. The results showed that feedforward neural network with two hidden layers (2 and 16 neurons for energy model) provided the best results; thus, it can be used for more accurate estimation of energy. The optimal model performance was evaluated using measures such as the coefficient of determination (R2), MSE, MAPE and MAE. The correlation coefficient for both energy models was reported at 99.

Keywords: Broiler Chicken, Efficiency, Energy Ratio, Energy Indicators, Artificial Neural networks.

INTRODUCTION

Energy plays an important and pivotal role in the development of nations. In every society, ranging from the traditional to industrial, not only energy costs but also the availability of the energy creates the crisis. Energy management is the only and closest way to exploit more available fuel and energy resources [1]. Due to the increasing food needs of the growing population of the world, the need to provide adequate food has recently increased agriculture needs to energy consumption. Agriculture as a productive part of the economy plays a significant role in national production. Agriculture as an important part of food producers is not only consumer of energy, but also one of the most important energy supplier [2]. A common source of energy is fossil fuels; thus, it is necessary for agriculture be managed carefully with regard to the concept of sustainability. On one hand, agriculture is faced with limited resources of production; on the other hand, it supplies nutritional needs of a growing population. Therefore, a balance is required between exploiting resources of production and agricultural productivity. In fact, the use of resources must satisfy food needs of the current generation without threatening the food security of future generations.

The amount of energy consumption in different production systems depends not only on the product but also on the type and quantity of inputs used in production. The difference in the behavior of different systems in the use of inputs and energy resources lead to differences in the energy efficiency of the production system whereby agricultural instability. Energy efficiency is one of the important indicators to measure sustainable agricultural development. Other advantages of the efficient utilization of energy resources can be economic savings, conservation of fossil resources and reducing the environmental effects and air pollution. Satisfaction of needs depend on the specific policies, reduction of waste and promotion of more efficient use of existing resources, utilization of new energy resources, along with the correct use of energy and encouragement of consumers to optimal use [2]. Thus, efficient use of energy in agriculture reduces environmental problems, prevents destruction of natural resources and develops sustainable agriculture as an economic production system [3]. In livestock production, sustainability means the ability to produce a same amount of meat from a certain amount of allocated land; in other words, level of production (meat) will not compromise the utilization of land allocated for future utilization [4].

Atilgan and Koknaroglu [5] analyzed the energy used for broiler chicken production units. The results showed that larger production units had higher energy efficiency compared to smaller units. On the other hand, the results indicated that increase in hatching rate significantly decreased the used energy. Their research was carried out at different levels of nest size; larger nests were more energy efficient than smaller units. The other results were reduced energy used and further savings with increasing herd size. A similar study was conducted by AlawQotbi et al. [6] in Iran to determine the effect of different herd sizes on energy efficiency of poultry production units. The study revealed that energy used by larger herds was significantly less than smaller herds. Calculating energy used in different parts of a 60,000-birdpoultry house, SedaghatHoseyni et al. [7] reported that electricity, fuel and human force used in poultry production units were 2395.8, 38563.88 and 94.85 MJ per day in winter and 3359.5, 66.124 and 94.58 MJ per day in summer. Najafi et al. [8] studied the effect of broiler hall sizes on energy productivity. The three studied capacities included 10,000 birds (three halls), 20,000 (two halls) and 28000 (one hall). The results showed that increase in hall capacity, namely from level 1 to level 3, significantly decreases input. Finally, it was found that 28000-birdhall was the most energy productive. Heidari et al. [9] used artificial neural network to model cost-benefit ratio of broiler houses of Yazd Province. The fitted neural network was a multilayer feed forward network with five neurons (bird cost, labor cost, food cost, fuel cost and electricity cost) in the input layer and one neuron in the output layer (benefit-cost ratio). The optima structure was 5-20-1. Statistical indicators were estimated in R2, MSE, MAE and MAPE to validate the model. The indicators were calculated at 0.978, 0.002, 0.037 and 2.695 [9].

Studying the poultry bed as an energy resource, Risse et al. [10] reported that poultry manure saved 283 million gallon fuel in America. In general, a 100,000 to 110,000 bird poultry house could produce 125 tons manure in a period.

Many studies have been conducted on artificial neural networks to model different agricultural products. Some of them are as follows:

Zangeneh et al. [11] estimated the mechanization of potato cultivation using artificial neural networks. They could estimate the mechanization level by 0.98 and 0.99 coefficient of determination.

Using artificial neural network, Taki et al. [12] estimated output energy of wheat production. Finally, they concluded that the most suitable network had two hidden layer each containing 8 neurons by which a good estimation could be obtained. Pahlavan et al. [13] used artificial neural networks to determine the relationship between output energy and input energies of basil production. In 2009, a study was conducted on prediction of energy demand of greenhouses by artificial neural network. The optimal structure was a 4-3-1 network in which R2, MSE and MAPE were 0.93, 0.187 and 0.058, respectively [14].

Moreover, many authors used artificial neural networks to achieve goals considered for different contexts. For example, Shakibai and Koochekzadeh [15] to model and predict energy used for agriculture, Kominakis et al. [16] to predict milk production, Uno et al. [17] to predict corn performance and Movagharnejad and Nikzad [18] to model drying potatoes.

Rahman and Bala [19] used artificial neural networks to predict hemp plant dry matter in Bangladesh using parameters related to climatic conditions. They concluded that the best model was a 6-9-5-1 structure with two hidden layers [19].

Khoshnevisan et al. [20] applied ANN approach and predicted wheat production yield and (greenhouse gas) GHG emissions on the basis of energy inputs. The coefficients of determination (R2) of the best topology were 0.99 and 0.998 for wheat yield and GHG emissions, respectively. Taki et al. [21] applied the various Artificial Neural Networks to predict the output energy for corn silage production in Esfahan province, Iran. Their results showed that diesel fuel and seeds had the highest and lowest sensitivity on output energy with 0.0984 and 0.0386, respectively. Sefeedpari et al. [22] developed an ANN model to assess the energy input–output prediction in dairy farms of Iran. The predicted values of the best and optimal structure of ANN model were correlated well with actual values with coefficient of determination (R2) of 0.88 and root mean square error (RMSE) of 0.015.

During recent years along with increasing population, the demand for proteins has been increased; thus, it is necessary to develop poultry industry as a major resource of food supply.

Iranian poultry producers have been encountered different challenges the most important of which is energy. During recent years by implementation of targeted subsidies plan, the major problem of domestic producers is the optimal utilization of different resources, energy suppliers and other inputs. Earlier, producers had less tendency for optimal energy utilization due to granted state subsidies for inexpensive energy. On the other hand, facilities and the production methods were used regardless of energy efficiency. The most and the main source of energy supply in Iran is fossil fuels. Energy price has been recently increased in Iran. Therefore, major changes are required for production cycle in terms of equipment used for production and production methods as well as demand for production inputs.

The remainder of the paper is organized as follows. Section 2 presents the objectives of paper. In Section 3, the various models of Artificial Neural Networks are presented. Calculations of Input and output energy are explained in section4. In Section 5, to show the applicability of the proposed model, a case study is discussed. The results of current research are presented in section 6. Finally, section 7 concludes our work.

Objectives

The purpose of the present study is to examine the energy consumption for broiler chicken production in Alborz Province considering:

1. To determine contribution of the used inputs in terms of energy used in broiler chicken production units of Alborz Province
2. To determine energy indices including energy ratio, energy productivity etc. and to evaluate them in broiler chicken production units of Alborz Province
3. To determine the importance of used inputs on output energy of broiler chicken production units of Alborz Province
4. To determine the effect of factors including education and experience on energy indices and benefit-cost ratio of broiler chicken production units of Alborz Province

5. To develop an energy consumption model and output energy to input energy ratio using artificial neural network (ANN) in broiler chicken production units of Alborz Province

Artificial Neural Networks

Artificial neural networks (ANNs) are recently used for various applications including forecasting, classification, pattern recognition, data mining and process modelling [23]. Although there are few studies conducted in Iran to compare the prediction performance of the ANN models and other models, these models have been widely challenging each other overseas.

ANNs are a simplistic modelling of real neural systems which are widely used to solve different problems. ANN is a computational method to identify the inherent relationships between data in order to map the input layer and the output layer by learning process using processors called as neuron. Hidden layer or layers processes the data received from the input layer and delivers them to the output layer. A network is trained by receiving some examples. Training is a process which finally leads to learning. Network learning happens when association weights between the layers change so that the difference between predicted and measured values is acceptable. These weights express memory and knowledge of the network. The trained neural network can be used to predict outputs relative to new datasets. Considering the structure of ANNs, their major properties are fast processing, ability to learn the pattern, ability to generalize knowledge after learning, flexibility to undesirable errors and insignificant dysfunction if a difficulty occurs in a part of connections due to weight distribution of networks [24].

Structure of Neural Networks

Neurons connect to each other to form an ANN. Their connection can create a single-layer or multi-layer network. Multi-layer networks are consisted of an input layer, to which input patterns are inserted, an output layer, which determines the network response, and one or several hidden layer between input and output layer to relate to them. Figure 1 shows the number of neurons and layers, arrangement and size of neurons and the structure of neural network.

Evaluation of ANNs

Performance of ANN models is measured by different statistical indicators including R2, MAPE, MAE and MSE to compare the capability of neural network models. The relations related to these indicators are as follows:

$$MSE = \frac{\sum_{i=1}^{n}(O_i - P_i)^2}{n} \quad (1)$$

$$MAE = \frac{1}{n}\sum_{i=1}^{n}\left|O_i - P_i\right| \quad (2)$$

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{\left|O_i \quad P_i\right|}{O_i}100\right) \quad (3)$$

$$R^2 = \frac{\sum_{i=1}^{n}(O_i - O_{ave})(P_i - P_{ave})}{\sqrt{\sum_{i=1}^{n}(O_i - O_{ave})\sum_{i=1}^{n}(P_i - P_{ave})}} \quad (4)$$

where, $O_i$is the measured data; P_i is the predicted data; O_{ave} is the measured average data; Pave is the predicted average data; and n is the number of data.

Calculation of Input and Output Energy

To calculate the used energy and the produced energy in broiler chicken production units, the energy coefficients and equivalences available in the literature were used. Table 1 shows energy coefficients used for inputs and outputs. To reveal that how these equivalences are used, the following explains how energy content of inputs and outputs are calculated. Inputs of agricultural production use two kinds of energy sources: direct and indirect [9]; the former including labor energy, fossil fuels (gasoline, diesel, LPG, CNG, coal and electricity) as well as biofuels; the latter includes energies required for producing agricultural and livestock equipment, food energy as well as bird energy.

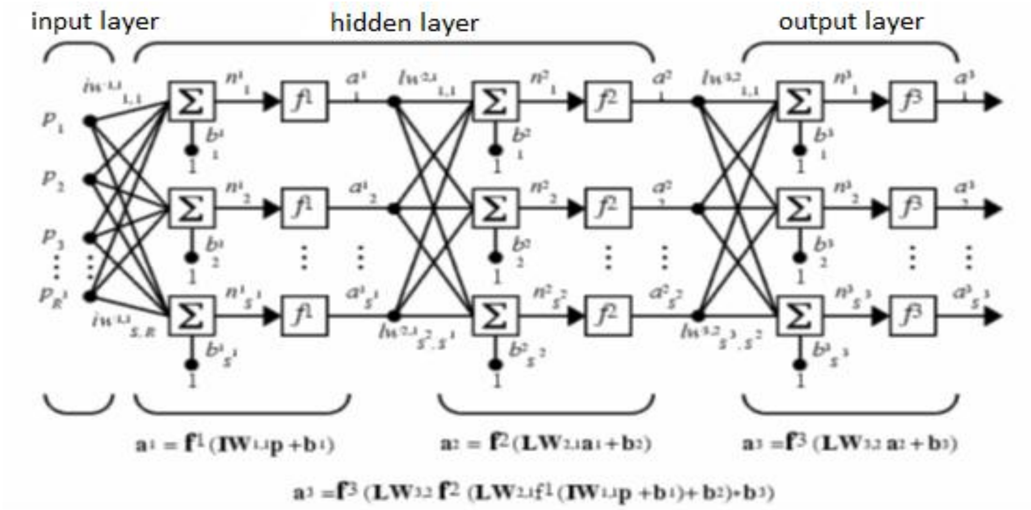

Figure 1. The structure of an ANN with back-propagation learning method

Table 1. Energy equivalents of inputs used in broiler chicken production

Input/output	Unit	Energy equivalent (MJ/unit)	Resource
Inputs			
1. Machinery and equipment			
Steel	Kilogram	62.7	[25]
Electric motor	Kilogram	64.8	[25]
Polyethylene	Kilogram	46.3	[26]
2. Work force	Time	1.96	[26]
3. Diesel fuel	Litre	47.8	[26]
4. Natural Gas	Cubic meters	49.5	[27]
5. Electricity	KWh	11.21	[28]
6. birds	Kilogram	10.33	[29]
7. Bird Feed			
Corn	Kilogram	7.9	[30]
Soya	Kilogram	12.6	[30]
Wheat	Kilogram	13.7	[29]
Di Calcium Phosphate	Kilogram	10	[31]
Vitamin	Kilogram	1.59	[32]
Salt and Minerals	Kilogram	1.59	[32]
Fatty acid	Kilogram	37	[33]
Output			
1. birdmeat	Kilogram	1.33	[34]
2. birdmanure	Kilogram	0.3	[35]

Energy Indicators

For better comparison and evaluation of manufacturing units, it is required to use certain criteria and indicators. In energy discussion, there are indicators which enable the producer to compare systems and study production systems. The three major indicators of energy used in energy studies include energy ratio, energy productivity, special energy and net energy efficiency [36,37].

Relations (5) to (8) were used to calculate the considered indicators.

$$(\text{energyefficiency})\text{energyratio} = \frac{(1000/\text{MJpart})\text{outputenergy}}{(1000/\text{MJpart})\text{inputenergy}} \quad (5)$$

$$\text{energyproductivity} = \frac{(1000/\text{Kgpart})\text{performance}}{(1000/\text{MJpart})\text{inputenergy}} \quad (6)$$

$$\text{specialenergy} = \frac{(1000/\text{MJpart})\text{inputenergy}}{(1000/\text{Kgpart})\text{performance}} \quad (7)$$

$$\text{net energyefficiency} = \text{output energy} - \text{input energy} \quad (8)$$

Case Study

The participants of the present study included active broiler producers available in the Alborz Province. According to statistics of the Agricultural Organization, there were 202 broiler chicken production units in 2012-2013; of this, only 119 units are active.

Information required to perform various analyzes used in this study were collected from active poultry houses of Alborz Province. Considering the fact that broilers grow during three to five periods of a year, a certain winter period was considered to match the environmental conditions. Accordingly, the information required for the study was related to hatching period from January 20, 2013 to February 19, 2013.

The required information was collected by distributing and completing the questionnaires among broiler producers of Alborz Province. Thus, sample size was determined considering the distribution of poultry houses available in different regions. Some preliminary questionnaires were developed to optimize the items. Then, the final questionnaire was prepared and distributed among participants. The information extracted from questionnaires contained information on the building and hall (total area, area of halls), type of the hall (dome/niche, number of halls), information related to birds (hatching date, breeds of birds, number of birds at the beginning of the period, total number of losses, bird loading date), information related to equipment (food mill, feeding type (auto/manual), type of drinker (auto/manual), type of ventilation system, the number of fans, the type of heating/cooling, the number of heater/cooler), information related to food (diet composition in different weeks of growth, the total amount of feed consumed), information related to labor, fuel, electricity and water (the number of workers, the number of workers added, the total amount of fuel, electricity costs, water costs), information related to drugs and chemicals (frequency of drug use, the kind and amount of medicines and vaccines, herd veterinarian's name and address, the amount of chemicals used to disinfect the hall), information related to yield (duration, the number and total weight of herd in the end of the period, type of litter, litter weight, the total amount of manure production, litter collection (worker/car) [37].

RESULTS

This section estimates the energy used by production inputs in broiler chicken production units. The energy indicators including energy ratio, energy productivity and net energy added are calculated and the present study and previous studies are compared. A proper non-parametric model is estimated by ANN.

Estimation of Production Inputs in Energy Used for Broiler chicken production Units

According to studies conducted in the region and results obtained from distributed questionnaires, it was revealed that growth period of broilers ranges from 47 to 60 days, on average; under certain conditions, this period may increase to 65 days.

Table 2 shows the amount and content of energy for inputs used by broiler chicken production units of Alborz Province. The results showed that total energy used in a growth period was 220.02GJ per 1000 birds which explained 43% of the total energy used (Figure 2). Estimations show that 1981 liters of gasoline, on average, was used per 1000 birds. In addition to gasoline, natural gas was also used contribution of which was 21% of the total energy used (Figure 2). The amount of energy content used by this input was calculated at 45872MJ per 1000 birds. In general, heating requirement can be considered as one of the most important problems in growing broilers in the winter. Thus, it is required to use more fossil fuel. Respiration (oxygen) of birds is required through frequent ventilation and air exchange with the outside. Thus, heating devices should be continuously turned on. This increases energy consumption. Gasoline is less popular than natural gas due to its more pollutants. Demand for gas heating facilities for broiler chicken production units have been increased in Alborz Province. Recently, degree of willingness to conduct activities such as more insulation of poultry houses and increased thermal efficiency of heating devices inside the halls has been increased due to cut state subsidies. The positive outcomes (decreases fuel consumption) can be observed in some units.

Table 2. Quantity and content of energy for the inputs used in broiler chicken production units

Inputs (unit)	Quantity (1,000 bird/unit)	Energy (1000 bird/MJ)
Input		
Diesel fuel (L)	1981	94674
Natural gas (m3)	925	45872
Electricity (kWh)	1976	22155
Food (kg)	5684	56247
Equipment (kg)	6.25	345.6
Labour force (h)	114	224
bird(kg)	57	591.1
Total input		220018
Output		
birdmeat (kg)	2868	29624
birdmanure (kg)	2083	625
Total Output		30249

Diesel fuel is followed by food with 56247MJ energy per 1000 birds explaining 25.56% of the total energy used (Figure 2). The results showed that ~5687Kg food, on average, was used per 1000 birds (Table 2). On average, 1976Kwh (22155MJ) electricity was used per 1000 birds explaining 10.07% of the total energy used. Electricity was mainly used to pump water from the wells to the halls, to start mill electromotor and blenders, to ventilate the halls, to illuminate as well as to start electromotor of heating devices. The results obtained from this study were consistent with Najafi Anari, et al. [29] who studied efficiency of broiler chicken production units in Ahvaz, Iran. They found that fuel (gasoline), feed and electricity had the highest contribution to the total energy used [29]. Nikpour et al. [37] determined the amount and efficiency of energy used for inputs of broiler chicken production units in Tehran Province. The inputs such as fuel, feed and electricity (70, 25 and 5%, respectively) were the highest energy of the used inputs [37]. The lowest energy belonged to day old bird, equipment and labor force (591.1, 345,6 and 224MJ, respectively, per 1000 birds) totally explaining 0.53% of the total energy used (Figure 2). In total, 220018MJ energy, on average, was used per 1000 birds for broiler chicken production units of Alborz Province. The results showed that 2868 and 2083Kg bird meat and manure, on average, were produced per 1000 birds. According to the results, the total output energy was estimated at ~30249MJ per 1000 birds; of this, 29624MJ and 625MJ belonged to the produced bird meat and birdmanure, respectively (Table 2). Nikpour et al. [37] estimated the average output energy of broiler chicken production units at 25188MJ per 1000 birds of 24381Kg birdmeat; their result was similar to the present study [37].

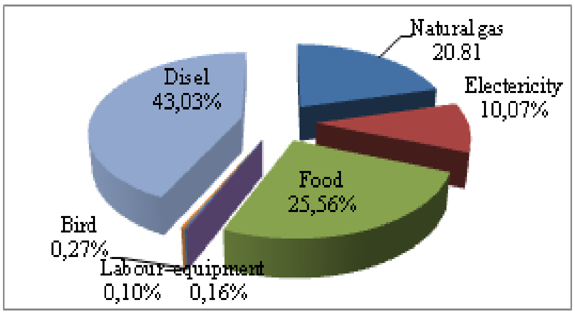

Figure 2. Ccontribution of energy used by inputs to the total energy used in broiler chicken production units of Alborz Province

Estimation of Energy Indicators

The purpose of estimating energy indicators is to provide an opportunity to compare production units of different regions. The present study calculated some of these indicators including energy ratio, productivity and intensity.

Energy ratio, known as energy efficiency, was estimated at 0.15 for broiler chicken production units of Alborz Province, as Table 3 shows. The fact that energy ratio is <1 suggests that less energy is produced once a certain amount of energy is used for production. As a case study, only 0.15MJ energy is produced per 1MJ energy used for production. To increase this indicator, there are three main solutions:

1. To increase output product
2. To decrease input energy
3. To adopt both solutions simultaneously

NajafiAnari, et al. [29] calculated energy ratio or efficiency at 0.23 for broiler chicken production units of Ahvaz. Nikpour et al.[37] estimated energy ratio at 0.11 which can be explained by adjacency of Alborz and Tehran Provinces and similarity of whether in both regions [37]. Naghibzadeh et al. [38] estimated the energy ratio at 0.70 in North Khouzestan which can be explained by warm weather of the region compared to Alborz Province and consequently lower utilization of inputs such as fuel.

Energy productivity which is obtained byKg produced meat divided by the amount of energy consumption per a certain number of birds was calculated at 0.01Kg/MJ (Table 3). This suggests that 0.01Kg bird meat can be expected per 1MJ energy used. Energy intensity was estimated at 76.59MJ/Kg indicating that 76.59MJ energy, on average, is used in the form of production inputs per 1Kg broiler at the end of the period. Net added energy which is obtained by subtracting the energy input from the energy output was calculated at -189769MJ per 1000 birds (Table 3). Other similar studies conducted in Iran reported this indicator as negative [29,37, 38]. This suggests that broiler chicken production is an energy consuming process. According to energy discussions, a negative net energy added indicates an inefficient manufacturer; however, justifiability of production by negative net energy added increases when considering economic discussions along with energy discussion. Simply, production of some items require energy loss; this is due to the nature of product. Fuel is the most important energy consumer in poultry houses; thus, heating requirements of manufacturing units can be met by insulation and using renewable systems including solar energy (as solar warmers and photovoltaic cells) which are widely used during recent years.

Table 3 Energy indicators of broiler chicken production units in Alborz province

Indicators	Unit	Average (units)	%
Energy ratio	-	0.15	
Energy productivity	(kg/MJ)	0.01	
Energy intensity	(MJ/kg)	76.59	
Net added energy	(MJ/(1000bird))	-189769	
Direct Energy	(MJ/(1000bird))	162,835	74.01
Indirect energy	(MJ/(1000bird))	57183	25.99
Renewable Energy	(MJ/(1000bird))	224.03	10.00
Non-renewable energy	(MJ/(1000bird))	219,794	99.90

Table 3 presents quantity and contribution of energies including direct, indirect, renewable and nonrenewable energies in broiler chicken production units of Alborz province. As table 3 shows, quantity of direct and indirect energies was 162835 and 57183MJ, respectively, per 1000 birds. Contribution of the considered energies was 74.01 and 25.99% of the total energy used indicating the higher dependence of broiler chicken production on the inputs of which energies are directly used (inputs including gasoline, natural gas, electricity and labor force). As Table 3 shows, contribution of renewable and nonrenewable energies was 0.10 and 99.90%, respectively; this is because all energy resources used for broiler chicken production were nonrenewable and the only renewable energy was related to labor force. These results suggest that broiler chicken production depends on fossil and nonrenewable sources including diesel, natural gas and electricity. Considering the limited fossil energy sources, high environmental pollution caused by fuel and increased global concern on renewable resources, it is necessary to increase percentage and contribution of renewable energies to broiler chicken production by replacing a part of the used energy to renewable inputs. Similar results have been reported by other studies conducted in Iran [29, 38].

Modelling Energy Inputs Using ANNs

ANNs were used to model the relationship between different energy inputs used in production and energy ratio. Accordingly, all inputs used in this study were considered as input layer and energy efficiency ratio which is an indicator to evaluate production efficiency of the studied poultry houses, was considered as the output layer.

To find the optimal network structure able to model the objective relationship with highest accuracy, different architectures with one and two hidden layers and the number of neurons varying from 1 to 20 were tested. Thus, input and output data were modelled within ~300 different architecture. The implemented networks were evaluated by four indicators including factor of determination (R2), mean absolute percentage error (MAPE), mean absolute error (MAE) and mean square error (MSE). Table 4 presents some results obtained from 27 networks. The functions used to transfer in the hidden layer were tangent sine.

Obviously, the model 5 containing two hidden layers with 2 neurons in the first hidden layer and 16 neurons in the second hidden layer was evaluated as the best model. The evaluation criteria, as noted earlier, were R2, MAPE, MAE and MSE (0.988, 1.925, 0.00002 and 0.003, respectively). Value of R2 was the highest for this model compared to other 300 models. On the other hand, the lowest values were for MAE and MAPE. MSE was not the lowest value in the network 5; however, its value was insignificantly different from the lowest MAE (Table 4).

According to results, the structure of network 5 can be considered as the optimal structure to model the relationship between energy inputs used in broiler chicken production and energy ratio of Alborz Province. In addition, it can be used to estimate energy efficiency of production units.

The other studies conducted on this discussion include Heidari et al. [9] who achieved a network with one hidden layer with 20 neurons as the best network to estimate the relationship between energy inputs and energy ratio of broiler chicken production units of Yazd Province. The factor of determination was 0.978 for the considered network. Values of MSE, MAE and MAPE were estimated at 0.002, 0.037 and 2.695, respectively [9]. Using ANNs, Zangeneh et al. [11] estimated mechanization indicators (mechanization factor and level) for potato production process in Hamedan Province. Value of R2 of the best network was calculated for mechanization factor and level at 0.98 and 0.99 [11].

Figure 3 shows error variations for 50 samples. Vale of error determines the difference between the value estimated by ANN from energy ratio (model output) and the real value observed from energy ratio in broiler chicken production units of Alborz Province. Obviously, error value varies near zero in most cases; this indicates that energy ratio can be estimated considering values of input energy for the model 5.

Figure 4 shows a schema of the ANN 5. Obviously, the model 5 well modelled the studied data and accurately estimated the values.

CONCLUSION

The total energy used and produced in one period of broiler chicken production unit of Alborz Province were calculated at 220.02 and 30.25GJ, respectively, per 1000 birds. The contribution of inputs such as gasoline, natural gas, food and electricity were calculated at 43%, 21%, 26% and 10%, respectively. On average, 1981 liter gasoline was used (94674MJ per 1000 birds).

Value of energy used for natural gas and food was 45782 and 56247MJ per 1000 birds. The energy used for electricity was 22155MJ per 1000 birds. A reason for high consumption of gasoline is the low temperature of the Alborz Province. On the other hand, thermal efficiency of warmers available in the region and high pollution of these heaters which directly increase gasoline and need for ventilation in the breeding hall and indirectly increase per capita consumption of gasoline by broiler chicken production units. Gasoline, natural gas, food and electricity as the highest energy consumer are followed by equipment, labor force and day old bird which totally explain 0.53% of the total energy used. The results showed that 2868 and 2083Kg birdmeat and manure was produced per 1000 birds; of this, 97% of the total output energy belonged to meat and the remaining 3% belonged to manure. Estimations indicate that energy ratio was 0.15 for broiler chicken production in Alborz Province. Accordingly, broiler chicken production has been an energy consuming process. Therefore, it is necessary to decrease the energy consumption of inputs like gasoline and food and increase output energy content by decreasing losses. Values of energy efficiency, energy intensity and net energy added were estimated at 0.01Kg/MJ, 76.59MJ/Kg and -189.77GJ, respectively, per 1000 birds. The modelling of the relationship between different input energies used for production and energy ratio using ANN showed that ANNs could be used to model the relationships. Therefore, an ANN with 2 hidden layers (with 2 and 16 neurons in the first and second hidden layer) provided the best results to estimate the considered model. The model was evaluated by R2, MAPE, MSE and MAE values of which were reported at 0.988, 1.925, 0.00002 and 0.003, respectively.

Table 4 architecture of different ANNs for non-parametric modelling with evaluation indicators

Model	No. of hidden layers	No. of neurons	MAE	MSE	MAPE	R^2
1	1	4	0.013	0.00032	9.449	0.821
2	1	14	0.016	0.00045	11.327	0.789
3	1	20	0.011	0.00024	7.373	0.893
4	2	2-8	0.011	0.00149	10.083	0.45
5	2	2-16	0.003	0.00002	1.925	0.988
6	2	3-13	0.011	0.00037	8.035	0.798
7	2	3-19	0.012	0.00031	9.096	0.822
8	2	2-4	0.017	0.00067	10.907	0.619
9	2	4-14	0.005	0.00015	2.918	0.916
10	2	5-10	0.006	0.00016	4.331	0.913
11	2	5-20	0.010	0.00029	6.447	0.843
12	2	6-10	0.011	0.00026	7.189	0.859
13	2	6-16	0.005	0.00007	3.663	0.96
14	2	5-7	0.016	0.00057	10.101	0.797
15	2	7-17	0.010	0.00018	7.944	0.893
16	2	8-9	0.008	0.00013	5.495	0.927
17	2	5-9	0.025	0.00117	17.261	0.441
18	2	9-10	0.006	0.00010	4.042	0.95
19	2	8-10	0.007	0.00023	5.109	0.87
20	2	11-19	0.011	0.00021	7.845	0.92
21	2	4-12	0.007	0.00021	4.902	0.902
22	2	18-12	0.018	0.00077	11.452	0.652
23	2	11- 13	0.010	0.00016	6.693	0.914
24	2	13	0.008	0.00016	5.768	0.915
25	2	7-14	0.019	0.00082	11.811	0.705
26	2	3-15	0.020	0.00073	12.901	0.601
27	2	20-15	0.010	0.00024	7.024	0.867

For future research, other predefining methods in fuzzy environment to model energy efficiency in broiler chicken production units can be applied. These methods are adaptive network-based fuzzy inference system (ANFIS), fuzzy regression, emotional learning based fuzzy inference system (ELFIS), and etc. The results of these methods can be also compared with results of current study.

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