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# New Method of Artificial Neural Networks (ANN) in Modeling Broiler Production Energy Index in Alborz Province

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## ABSTRACT

During the past few years, modeling in agriculture has attracted considerable attention. New modeling methods including neural networks are employed in various industries, and it is necessary that their use in agriculture be also considered. This research addressed the trend of energy use in broiler farms in Alborz Province and sought to model the trend of energy consumption and production in these farms. For this purpose, 45 questionnaires were distributed among broiler producers of the province. The reported levels of energy consumption and production were 218.40 and 30.13 GJ per thousand broilers, respectively. The largest share of the energy consumed, 40%, 25%, 23% and 9%, was related to gas-oil, feed, natural gas, and electricity inputs. Indices of ratio, productivity, special energy, and net energy gain were reported to be 0.15, 0.01 kg per MJ, 76.28 MJ per kg and 188268 MJ per thousand broilers, respectively. Modeling of energy inputs and the index of energy ratio as the inputs and outputs, respectively, of various artificial neural networks indicated that the network having two hidden layers with 12 and 9 neurons in the first and second hidden layers, respectively, was the most suitable network for modeling. Results of evaluation of networks suggested that the values for the $R^2$ and MAPE indices for the 12-9 neuron network were 0.98 and 3.078, respectively, which showed that about 98 percent of the actual data could be estimated with the help of this artificial neural network.

**Key words:** Broiler, Alborz Province, Energy efficiency, Sustainable agriculture, Artificial Neural Network

## INTRODUCTION

The agriculture sector, as the most important of the sectors producing the foodstuff of the country, is not only a consumer of energy but also the most important supplier of energy. Since this sector is faced with limitations of production factors on the one hand, and is the provider of food security for the increasing population on the other, an equilibrium and balance must be struck between the levels of extraction and utilization of resources for production and the levels of production of agricultural products. In fact, the

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trend of utilization of resources for production must be in such a way that the needs of the present generation for food are met without threatening food security of future generations. This consideration forms the basis of what is presently referred to as sustainable agriculture (Almasi *et al.* 2005). Besides technical analyses, economic, energy, and environmental analyses are among the important requirements of agricultural projects. Energy analysis first started in earnest in the 1970s due to the steep rises in prices of petroleum products, and research was conducted on the issues of recognizing the level of energy consumption, alternative energy sources, and better production methods (Kochaki, 1989). The purposes of energy analyses are reduction in energy inputs, replacement of non-renewable energy sources with renewable ones in agriculture, maximum possible reduction of production costs, and use of environment-friendly methods of production as a part of an optimal management system. Modern management can make it possible to save energy through engaging in accurate agricultural practices. Using the correct quantities of seeds, fertilizers, and pesticides to satisfy the local needs for these inputs, minimizing movement of machinery on farms and employing machines with suitable sizes and acceptable levels of fuel consumption, help in achieving this goal. So do performing operations at optimal times, using technologies that require low levels of energy such as planting high yielding varieties. Essentially, employing any method that increases production or reduces energy consumption helps in saving energy (Almasi *et al.* 2005; Heydari, 2011). The poultry industry is one of the largest and most developed industries in Iran and, due to the ever-increasing rise in population, increases in levels of income and prosperity of people, which lead to rising demands for white meat, the expansion of this industry seems to be necessary to be able to provide protein needs of people (Khalaji *et al.*1998). The poultry industry is one of the energy-consuming industries, with energy being used in different forms and being wasted, for different reasons, in the process of white-meat production. Poultry farmers, through employing various production methods, play a basic role in the efficiency of energy use in their farms. There are many ambiguous aspects in energy consumption for broiler production. The main reason for this ambiguity is that chickens are living beings and poultry farming is a dynamic system. Energy is wasted in broiler production in various ways, but it is not quite clear in which parameter of energy consumption this waste occurs or to how much does this waste amount (Heydari, 2011). Artificial neural networks are one type of simplistic modeling of actual nervous systems with numerous applications in solving various problems in different sciences. They are a computational method that, with the help of the learning process, use processors called neurons in an attempt to discover innate relationships among data. They then provide a mapping between the input space (the input layer) and the desired space (the output layer).The hidden layer(s) processes (process) information received from the input layer and sends (send) it to the output layer. Neural networks are trained through providing them with examples. This training is a process that will eventually lead to learning. Network learning occurs when the relational weights among layers vary in a way that the differences between the expected and the computed values are at an acceptable level. When these conditions are met, the learning process materializes. These weights express network memory and knowledge. A trained neural network can be used to predict outputs commensurate with a new set of data. The main characteristics of an artificial neural network are its high processing speed, ability to learn patterns through the method of pattern representation, ability to generalize knowledge after the learning process, flexibility when faced with inadvertent errors and the lack of considerable disruption in case a problem arises in a part of the connections. These characteristics of artificial neural networks result from the distribution of weights in their structure (Khanna, 1990).

## Previous research

In this section, we review some research that were conducted on broiler production farms. On a 10000-piece broiler farm in Mollasani situated in Ahvaz, input energies in the forms of fuel, electricity, labor, feed, and output energies in the form of weight retention in broilers and broiler litter, were used to study the level of energy consumption in the different sections of the farm. Results indicated that broilers needed 4 kilocal of energy to produce one kilocal of energy in the form of proteins. The largest components of input energy were gas oil and feed, respectively (Najafi anari *et al.,* 2008). Overhalts et al. evaluated energy efficiency of 7 farms with 37 poultry houses and reported that in all of the houses (in which propane was used as fuel) the range of propane consumption was from 10603 to 22194 liters per house, and electricity consumption was from 24157 to 37337 Kwh per house (Overhults *et al.,* 2009). In a study in Fars Province, the efficiencies of 35 poultry farms were measured. Three of these farms had efficiencies of 100 percent, while the rest showed various degrees of inefficiency; and it was determined how much these inefficient farms had to modify their inputs to change into efficient poultry farms. Analysis of results indicated that there was a significant correlation between the efficiencies of these farms, their production capacities, and the equipment used in the houses (Mohamadi, 2008). Reese et al. studied utilization of broiler litter as a source of energy and reported that their use in the United States could save energy by 283 million gallons of fuel. They calculated that each 100000-110000 piece poultry farm could produce up to 125 tons of manure during each rearing period (Reese *et al.,* 2007). Nagheebzadeh et al. studied energy consumption in different sections of a 30000-piece poultry farm in northern Khuzestan. The main energy inputs consisted of feed, electricity, labor, and the energy outputs included weight retention in broiler carcasses and broiler litter. The total energy input was 1646237.03 MJ and the total energy output 1151978.30 MJ. The diet accounted for the largest portion of the total energy consumption with 1305570.04 MJ, while the energy ratio, the net energy gain, and energy productivity were 0.669, -494258.73 MJ, and 0.033 kg per MJ, respectively (Nagheebzadeh *et al.,* 2010). Sedaghathosseini et al. calculated energy consumption in different sections of a 60000-piece poultry farm and reported that electricity and fuel energy inputs and labor force used in broiler production units were 2395.7, 38563.88 and 94.85 MJ per day in winter and 3359.5, 66.124 and 94.58 MJ per day in summer, respectively (Sedaghathosseini *et al.,* 2008). In another study in the United States, the two inputs of propane and electricity were evaluated over a 16-year interval. Results showed that the yearly electricity consumption was in the range of 55000 to 120000 Kwh, and that propane consumption varied from 11000 to 33800 gallons per year (Tabler *et al.,* 2008). Tacky et al. used an artificial neural network to estimate energy output in wheat production and concluded that the most suitable network, that could yield an acceptable estimate, was the one with two hidden layers each with eight neurons (Taki *et al.,* 2012). Pahlavan et al. also used artificial neural networks to determine a suitable relationship between energy inputs and outputs in basil production (Pahlavan *et al.,* 2012). Zanganeh et al. estimated the situation with regard to mechanization in potato production with the help of artificial neural networks. They were able to estimate the degree and level of mechanization with determination coefficients of 0.98 and 0.99 (Pahlavan *et al.,* 2012). Conducted research in different parts of the world has yielded different results with respect to energy use in crop production. On the other hand, since no comprehensive research has been conducted on the use of new modeling systems on broiler farms in Alborz Province, it is necessary to use artificial neural networks to study energy consumption on these farms.

## MATERIALS AND METHODS

This research dealt with the issue of energy consumption in broiler production in Alborz Province. This province has an area of about 5800 square kilometers and a latitude of from $35^{\circ}$ 31 ′ to $36^{\circ}$ 12 north and a longitude of $50^{\circ}$ 11′ to $51^{\circ}$ 29 ′ east. Karaj, the capital city of the province, is only 20 kilometers from

Tehran (the capital city of Iran) and, because of the large population of Tehran, is of great importance both as a city and with respect to food production.

The required data for the research was collected through the distribution of the related questionnaires among broiler farms in Alborz Province. Statistical population included all active broiler farms in the province. The rearing period about which data was collected was in winter, and the sample size was calculated using the Neyman method as follows [33, 34]:

$$n = \frac{\sum N_h S_h}{N^2 d^2 + \sum N_h S_h^2} \qquad (1)$$

where "n" is the required sample size; "N" is the number of farmers in the target population; "$N_h$" the number of the farmers in the "h" stratification; "$S_h^2$" the variance of the "h" stratification; "d" permitted error ratio deviated from average of population $(\bar{x} - \bar{X})$, "z" the reliability coefficient (1.96 which represents 95% confidence) and $D^2 = \frac{d^2}{z^2}$ is the permissible error in the sample population was defined to be 5% within 95% confidence interval. After determining sample size, 45 questionnaires were distributed among broiler producers and information regarding the production inputs and the performance of each of these farms was recorded. Energy coefficients and energy equivalents listed in Table 1 were used to calculate energy consumption and energy production in each broiler house. After multiplying the value of each input or output in its corresponding energy equivalent, their energy values were determined.

**TABLE 1**. Energy equivalents of inputs and output.

| Inputs / Output | Unit | Energy equivalent (MJ unit$^{-1}$) | Reference |
|---|---|---|---|
| A. Inputs | | | |
| 1. Implement and machinery | | | |
| Steel | kg | 62.7 | (Chauhan et al. 2006) |
| Electric motor | kg | 64.8 | (Chauhan et al. 2006) |
| Polyethylene | kg | 46.3 | (Kittle 1993) |
| 2. Human labor | h | 1.96 | (Kittle 1993) |
| 3. Diesel fuel | L | 47.8 | (Kittle 1993) |
| 4.Natural Gas | $m^3$ | 49.5 | (Pishgar-Komleh |

| | | | |
|---|---|---|---|
| | | | et al. 2011) |
| 5.Electricity | Kwh | 11.21 | (Mazandarani et al. 2011) |
| 6.Chicken | kg | 10.33 | (Najafi anari *et al.*, 2008) |
| 7. Feed | | | |
| Corn | kg | 7.9 | (Atilgan and Koknaroglu 2006) |
| Soybean | kg | 12.6 | (Atilgan and Koknaroglu 2006) |
| Wheat | kg | 13.7 | (Najafi anari *et al.*, 2008) |
| Di Calcium Phosphate | kg | 10 | (Alrwis and Francis 2003) |
| Vitamin | kg | 1.59 | (Sainz 2003) |
| Salt and Minerals | kg | 1.59 | (Sainz 2003) |
| Fatty acid | kg | 37 | (Berg et al. 2002) |
| B. Output | | | |
| 1. Broilers meat | kg | 10.33 | (Celik 2003) |
| 2. Broilers manure | kg | 0.3 | (Kizilaslan 2009) |

Energy indices were used to better evaluate and compare obtained results in broiler farms. These indices make it possible to compares systems and, besides that, to study each part of every production system. The common energy indices used in this study were energy ratio, energy productivity, special energy, and net energy efficiency indices (Canakci *et al.*, 2005). The relations of each of these indices are presented below:

$$\text{Energy Ratio} = \frac{\text{Energy Output}}{\text{Energy Input}} \quad (2)$$

$$\text{Energy Productivity} = \frac{\text{Yeild}}{\text{Energy Input}} \quad (3)$$

$$\text{Energy Special} = \frac{\text{Energy Input}}{\text{Yeild}} \quad (4)$$

Net Energy Gain = Energy Output - Energy Input (5)

The Matlab 2010 toolbox was used to produce and expand the suitable artificial neural network. The network input included the energy equivalent of each of the inputs studied in the research, and the network output was the total energy output. A maximum of two layers each with 1 to 20 neurons were used for modeling. The feed-forward back propagation is the most commonly used network for modeling, and it was used in this research too. Given the goal of this study, other networks could also be employed. Therefore, the Levenberg-Marquardt function was used as the activation function, the tangent sigmoid (TANSIG) function was used as the transfer function of hidden layers, and the linear transfer function ( that is normally employed in modeling) was also utilized. After entering all the inputs into the software, the model was simulated and the results were evaluated (while considering evaluation indices) to determine the best model. The MAPE and $R^2$ indices were used to compare the power of neural network models. Relations of these statistical indices are presented below:

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{|O_i - P_i|}{O_i}100\right) \quad (6)$$

$$R^2 = \frac{\sum_{i=1}^{n}(O_i - O_{ave})(P_i - P_{ave})}{\sqrt{\sum_{i=1}^{n}(O_i - O_{ave})\sum_{i=1}^{n}(P_i - P_{ave})}} \quad (7)$$

In the relations above, $O_i$ is the measured data, $P_i$ the predicted data, $O_{ave}$ the mean of measured data, $P_{ave}$ the mean of predicted data, and “n” the number of data items.

## RESULTS AND DISCUSSION

After collecting information from the questionnaires, the input- and output-energy contents of each of the items in broiler farms were determined. As is shown in Table 2, the total quantities of consumed and produced energies in producing broilers in Alborz Province were 301311 and 218400 MJ per thousand broilers in each rearing period, respectively. The largest quantity of energy used among all production inputs was that of gas oil with 88032 MJ per thousand broilers. Feed with 5695 kg, natural gas with 1051 $m^3$ (equivalent of 50869 MJ), and electricity (another of intensive inputs in broiler production) with 1973 kwh (equivalent to 22111 MJ) per thousand broilers ranked second to fourth with respect to energy consumption, respectively. The low efficiency of heating systems, the lack of sufficient insulation in poultry houses, and the fact that new heating systems such as radiant heating systems have not been introduced in the poultry houses, are some of the factors contributing to energy loss and to high levels of energy consumption. As can be seen in Table 2, gas oil, feed, natural gas, electricity, equipment, labor, and broilers constituted 40, 25, 23, 9, 1, 1 and 1 percent of the total energy consumption. The total energy output of broiler meat and manure were 29508 and 623 MJ per thousand broilers, respectively (which are equivalent to 2852 kg of broiler meat and 2078 kg of broiler litter per thousand broilers, respectively). Heidari (2011), who conducted a study on energy consumption and energy production in broiler farms in Yazd Province, obtained similar results. The largest energy consumers in his study were gas oil, feed, and electricity with 49, 26, and 24 percent of the total consumption, respectively. Moreover, results of the present study are very close to those Najafianari et al. (2008) found in their study on the efficiency of broiler production in Ahvaz ( in which gas-oil and feed were the first and the second largest energy consumers, respectively).

Table 2. Energy inputs and outputs for broiler production in Alborz.

| Input/Output | Energy (MJ/1000 broiler) | Mean(unit/1000 broiler) | % |
|---|---|---|---|
| A.Input | | | |
| gas oil(L) | 88032 | 1804 | 40 |
| natural gas($m^3$) | 50869 | 1051 | 23 |
| Electricity(kwh) | 22111 | 1973 | 9 |
| Feed(kg) | 56231 | 5695 | 25 |
| Equipment(kg) | 337 | 6 | 1 |
| Labor(h) | 226 | 116 | 1 |
| Broilers(kg) | 594 | 58 | 1 |
| Total input | 218400 | | |
| Output | | | |
| Broiler meat | 29508 | 2852 | 98 |
| Manure | 623 | 2078 | 2 |
| Total output | 30131 | | |

The estimated ratio, productivity, energy special, and net energy gain indices in this study, listed in Table 3, were 0.15, 0.01 kg $MJ^{-1}$, 76.28 MJ $kg^{-1}$ and -18826 MJ per thousand broilers, respectively. Based on the energy ratio index, 0.15 MJ of energy was produced for every MJ of input energy. To improve this index, performance should be improved, or input energy should be reduce, or both. Researchers have reported similar energy ratios (that were less than one in all cases) in studies conducted in other places. For example, Najafianari et al. (2008) reported energy ratio index of 0.23 for broiler production in Ahvaz, while Nagheebzadeh et al. (2008) found this ratio to be 0.70 in northern Khuzestan Province. This difference could be due to differences in climatic conditions, and be the result of differences in management practices in various areas too. In the present research, this index was 0.01, which indicates that for every MJ of input energy about 0.01 kg of broiler meat was produced. The energy special index of 76.28 means that 76.28 MJ of input energy were used for every kg of broiler meat produced.

**TABLE 3.** Energy indices in broiler production.

| Indices | Unit | Mean |
|---|---|---|
| Energy ratio | - | 0.15 |
| Energy Productivity | )kg/MJ( | 0.01 |
| Energy special | )MJ/kg( | 76.28 |
| Net energy gain | )MJ/(1000 broilers)( | -188268 |

Results concerning the power of all networks that were modeled with the help of the artificial neural network are presented in Table 4. The two indices of coefficient determination ($R^2$) and mean absolute percentage error (MAPE) were used to help in the evaluation and comparison of all the implemented networks. Results indicated that the network that can best estimate the trend of energy use in broiler farms was a two-layer network with 12 and 9 neurons in the first and second hidden layers, respectively. This network had the coefficient determination of 0.982 and the mean absolute percentage error of 3.078.

**Table 4.** Compare and evaluate different networks implemented in ANN

| Number of layers | $R^2$ | Network topologies | MAPE |
|---|---|---|---|
| 1 | 0.585 | 0-3 | 6.229 |
| 1 | 0.856 | 0-20 | 7.797 |
| 2 | 0.951 | 2-7 | 5.168 |
| 2 | 0.894 | 3-8 | 6.805 |

| | | | |
|---|---|---|---|
| 2 | 0.899 | 4-5 | 6.703 |
| 2 | 0.977 | 4-15 | 3.602 |
| 2 | 0.838 | 6-12 | 6.186 |
| 2 | 0.893 | 7-8 | 7.944 |
| 2 | 0.786 | 8-6 | 10.088 |
| 2 | 0.762 | 9-2 | 10.450 |
| 2 | 0.883 | 10-10 | 4.976 |
| 2 | 0.732 | 11-3 | 10.822 |
| 2 | 0.982 | 12-9 | 3.078 |
| 2 | 0.867 | 13-11 | 5.453 |
| 2 | 0.949 | 14-5 | 4.010 |
| 2 | 0.710 | 15-7 | 12.233 |

Figure 1 shows the trend of changes in the actual and estimated values of the energy ratio index in the 12-9 artificial neural network. As was expected, and as can be clearly observed in Figure 1, the 12-9 network could estimate the actual values of the energy ratio index with the coefficient of determination of 0.98. Obtained results show that this artificial neural network can be suitably used for modeling energy in broiler farms.

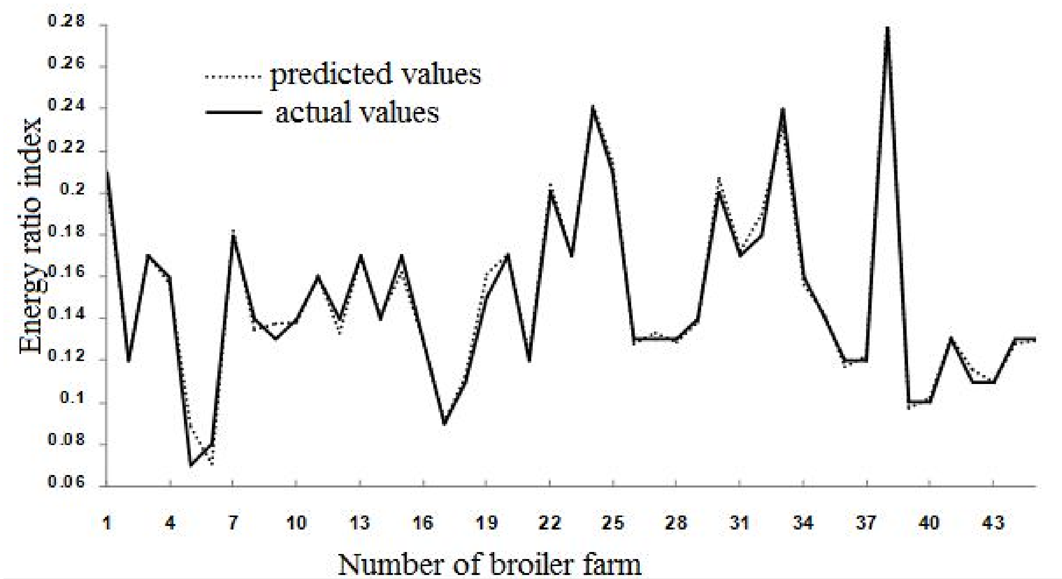


**Figure 1.** Changes in the actual and predicted values by ANN network 9-12

## CONCLUSION

This research dealt with energy consumption in broiler production in Alborz Province, and the artificial neural network method was used in an attempt to model energy consumption in broiler farms in that province. Obtained results in this regard are as follows: The total quantities of energy consumed and produced in one rearing period of broilers in Alborz Province during winter were 218.40 and 30.13 GJ per thousand broilers, respectively. Inputs such as gas oil, feed, natural gas, and electricity with 40, 25, 23 and 9 percent of the total consumed energy, respectively, were the most energy consuming inputs in broiler production in the province. The low thermal efficiency of heaters used in production houses and the heavy pollution caused by gas oil heaters (and, as a result, the use of ventilators in the houses) were among the reasons for the high level of gas oil use. Other production inputs such as rearing equipment, workers, and one-day-old chicks contributed to less than three percent of the total energy consumption, while broiler meat and litter constituted about 98 and 2 percent of the total energy output, respectively. The quantities of energy output in the form of broiler meat and litter were 29508 and 623 MJ per thousand broilers, respectively. The estimated energy indices suggested that the ratio, productivity, energy special, and net energy gain indices were 0.15, 0.01 kg $MJ^{-1}$, 76.28 MJ $kg^{-1}$ and -188268 MJ per thousand broilers, respectively. Modeling of energy inputs and energy ratio index as the inputs and the output of the artificial neural network, respectively, demonstrated that suitable estimates were made in this method. The network with 2 hidden layers of 12 neurons in the first hidden layer and 9 neurons in the second hidden layer was found to be the most appropriate network for modeling. Results indicating the values of $R^2$ and MAPE indices were 0.98 and 3.078, respectively, meant that about 98 percent of the actual data could be estimated with the help of the artificial neural network.

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