

Original article

Modeling of energy ratio index in broiler production units using artificial neural networks



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ABSTRACT

The present study was conducted in Varamin city of Tehran province in Iran. This research addressed the energy analysis of broiler production units. Artificial neural networks (ANNs) were used in order to model energy ratio index on the basis of input energies. Data were gathered from 40 broiler production farms in summer season using a face to face questionnaire approach. The total input and output energy of broiler production were 94783 and 24341.93 MJ (1000 birds)^{−1}, respectively. The energy ratio, energy productivity, specific energy and net energy were 0.26, 0.024 kg MJ^{−1}, 41.16 MJ kg^{−1} and −70441.07 MJ per thousand birds, respectively. The results revealed that feed, electricity and fuel account for 55%, 29% and 11% of total energy consumption. The developed ANN model with 8-8-13-1 configuration was identified as an optimum topology for predicting the energy ratio. For the best ANN model, the coefficient of determination (R^2), mean square error (MSE) and mean absolute error (MAE) were calculated as 0.974, 0.0018 and 0.0337, respectively.

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Introduction

Energy plays a fundamental role in many aspects of human life. In developing countries, the rate of energy utilization should be investigated to promote energy efficiency in production systems. During recent years, the demand for food has been increased due to the population growth. This reason make agriculture sector one of the most important sectors that generate food products. Many direct and indirect energy resources (fuels, electricity, farm machinery, water consumption, etc.) are utilized within the agriculture sector.

Most of Iran's revenue comes from oil and gas [1], therefore, to achieve sustainable development, diesel and natural gas utilization should be reduced in all manufacturing systems such as agriculture sector. On the other hand, the low price of natural gas and petroleum in Iran has caused wasteful consume of these fuels in transportation and industrial sectors [2].

Consequently, there is a close relationship between energy consumption and agricultural production, because the agriculture sector is both consumer and supplier of energy [3]. Agriculture residues and energy crops provide important sources of biomass to produce bioenergy. Additionally, production of biofuels from

energy crops is profitable for the reduction of greenhouse gases [4]. Agricultural production systems have some adverse impacts on the environment [5]. In agriculture sector, reduction of environmental issues, prevent ruination of natural resources and development of sustainable agriculture are the aims of efficient use of energy [6]. Several studies have been carried out to evaluate the energy performance of crop and livestock production such as soybean [7], potato [8–10], rice [11], dairy farms [12], broiler farms [13,14] and etc.

The poultry industry is one of the biggest industries in Iran [15]. Studies on energy consumption pattern on broiler farms are important due to tremendous energy use on broiler farms [16]. Artificial neural networks (ANNs) have been widely used in predicting energy consumption, energy demand, environmental issues, and etc. [8]. Several studies have used ANNs in the field of energy for livestock and agriculture sectors such as dairy farms [12], wheat [17–19], basil [20], jute [21] and etc.

This study attempts to (a) determine contribution of the used inputs in terms of energy in broiler production farms of Varamin city, (b) determine energy indices including energy ratio (energy use efficiency), energy productivity, energy intensity and net energy in order to provide opportunity to compare different broiler production units of Varamin city, (c) Predict the energy ratio index on the basis of input energies in broiler production units with artificial neural networks. Therefore, several ANN models were assessed and the accuracy of the predictions was evaluated by

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the statistical parameters, (d) provide suggestions for farmers in order to improve the energy efficiency and optimize the energy indicators of the broiler production units in the studied region, and (e) help farmers to have a better insight into the relationship between energy inputs and energy efficiency by using the ANNs.

Materials and methods

Selection of case study region

This research was carried out in Varamin city of Tehran province, Iran. Varamin region is located within 35° 12' north latitude and 51° 42' east longitude. Varamin city was selected as the studied area due to the significant share of this region in broiler meat production of Tehran province.

Energy evaluation

The total number of active broiler production units of Varamin city was 40, therefore the required data were gathered through the distribution of the questionnaires among all 40 broiler farms of Varamin region during summer season. Average capacity of investigated broiler houses was 10,000 birds with an area of 1040 square meters. Questionnaires were completed and the information about the quantities of all inputs and outputs in a breeding period were recorded. The input energy resources were chick, feed, electricity, human labor, fuel, machinery, disinfectant and bedding material, output resources were meat and manure. In order to calculate energy equivalent of sources, the input and output values per 1000 birds, were multiplied by their corresponding energy coefficients. Energy coefficient equivalents are listed in Table 1. The formula used to compute machinery (equipment) energy is presented below:

$$ME = \frac{\sum_{i=1}^n W_i E_i}{LPn_{ch}} \quad (1)$$

where ME is the machine energy (MJ per broiler for each breeding period), 'W' the weight of each component (steel, polyethylene, electric motor) used in machine (kg), 'n' the number of each component, 'E' the energy coefficient of specific component used in machine (MJ kg⁻¹) that is presented in Table 1, 'L' the useful life

of machine (year), 'P' the number of breeding periods per year, 'n_{ch}' the number of chicks using machine.

After calculating energy values of the inputs and outputs, energy indicators were computed. The indicators of energy such as energy ratio, energy productivity, specific energy and net energy [33] were used in this study. These indicators help to assess performance of each production unit and compare different production systems to improve energy efficiency.

The relations of indices are defined as:

$$\text{Energy Ratio} = \frac{\text{Output energy (MJ (1000 birds)}^{-1})}{\text{Input energy (MJ (1000 birds)}^{-1})} \quad (2)$$

$$\text{Energy Productivity} = \frac{\text{Yield (kg (1000 birds)}^{-1})}{\text{Input energy (MJ (1000 birds)}^{-1})} \quad (3)$$

$$\text{Specific Energy} = \frac{\text{Input energy (MJ (1000 birds)}^{-1})}{\text{Yield (kg (1000 birds)}^{-1})} \quad (4)$$

$$\text{Net Energy} = \text{Output energy (MJ (1000 birds)}^{-1}) - \text{Input energy (MJ (1000 birds)}^{-1}) \quad (5)$$

In agriculture energy demand can be grouped into direct and indirect, renewable and non-renewable energy categories [34]. In this study, direct energies (DE) include human labor, electricity, diesel and natural gas fuels, whereas indirect energies (IDE) consist chick, feed, machinery, disinfectant and bedding material. Renewable energies (RE) comprise chick, feed, human labor and bedding material, while non-renewable energies (NRE) include diesel and natural gas fuels, electricity, machinery and disinfectant.

Development of ANN model

Artificial neural network (ANN) is an information processing paradigm inspired by nervous systems of the brain. ANNs have been used for various applications such as prediction, data processing, classification and etc. For modeling, the ANNs are better, faster and more practical compared to the traditional methods [35]. ANN is a nonlinear statistical data modeling device where the relationship between input and output vectors are modeled by using learning process. The most common structure of ANNs is called the multi-layer perceptron (MLP) which consists of an input layer, one or several hidden layers and an output layer (Fig. 1). Each layer is made up of a number of interconnected processing elements called neurons. The inputs are multiplied by the connection weights are summed and then transformed through a transfer function to produce output for that neuron. ANNs learn by receiving example. In training phase, the network learns by adjusting weights between the layers so that the error between the network output and desired output is reduced.

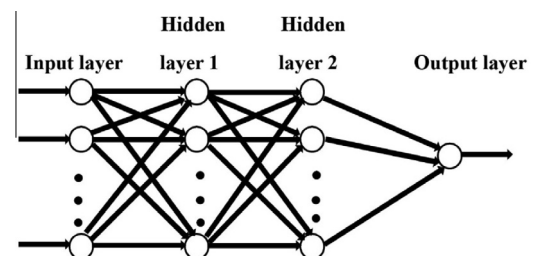


Fig. 1. A multi-layered perceptron (MLP) network with two hidden layers.

Table 1
Energy coefficient equivalents of different inputs and outputs used.

Item	Unit	Energy equivalent (MJ unit ⁻¹)	Refs.
A. Inputs			
Chick	kg	10.33	[22]
Feed			
Corn	kg	7.9	[23]
Soybean meal	kg	12.6	[23]
Di calcium phosphate	kg	10	[24]
Vitamin	kg	1.59	[25]
Salt and minerals	kg	1.59	[25]
Fatty acid	kg	37	[26]
Electricity	kWh	11.93	[3]
Human labor	h	1.96	[27]
Diesel fuel	L	47.8	[27]
Natural gas	m ³	49.5	[27]
Machinery			
Steel	kg	62.7	[28]
Electric motor	kg	64.8	[28]
Polyethylene	kg	46.3	[29]
Disinfectant	kg	100	[22]
Bedding material	kg	17.95	[30]
B. Outputs			
Broilers meat	kg	10.33	[31]
Broilers manure	kg	0.3	[32]

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