Energy audit of broiler production upon different production seasons in Northern Iran

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Abstract. The aim of this study was to investigate the energy use indices of broiler production upon warm and cold seasons in Northern Iran. The data were collected from 25 broiler farms with face-to-face questionnaire method. The results showed that the total energy input and energy use efficiency were 22357.71 Mcal 1000birds^{-1} and 0.26 for warm season, and 30653.47 Mcal 1000birds^{-1} and 0.20 for cold season, respectively. Feed and diesel fuel were ranked as the first (43.44%) and second (33.43%) energy inputs for broiler production in warm season, while, the diesel fuel (51.58%) and feed (31.73%) were ranked as the first and second most important energy inputs in cold season, respectively. The share of non-renewable energy inputs for cold season was less than that for warm season of production. Therefore, some suggestions were proposed to better management of using the non-renewable energy inputs in broiler production in cold season of production.

Keywords: energy use indicators; poultry; renewable; non-renewable energy.

1 Introduction

Poultry production is the most important agro-industry in Iran. Iran is ranked as the 20th broiler producers of the world. However, the domestic production does not meet the home requirements. Broiler production industry consumes large amounts of direct and indirect energy inputs including fossil fuels, electricity, and feed. Energy use efficiency of broiler production in Iran is not satisfactory (Amid *et al*., 2016). Using a large amount of non-renewable energy inputs including fossil fuels and electricity leads to decrease the economic productivity and cause the undesirable environmental impacts. Therefore, identifying energy saving approaches for broiler production systems is a key proceeding in order to keeping the sustainability of broiler production in Iran.

Analyzing the input-output energy and computing the energy indices are the most reliable method to investigate the energy usage in agriculture (Rajaniemi and Ahokas, 2012). Table 1 summarizes the top points of the related studies. The energy consumed by heating system is ranked as the most important energy input among the direct energy inputs in broiler production (Rajaniemi and Ahokas, 2015). Its share varied with production season, the highest one being in cold seasons. Thus, the highest energy saving is related to the heating system in broiler farms. Katajajuuri *et*

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al. (2006) and Horndahl (2008) have also shown that energy consumed by heating system contributes the most energy input of broiler production farms. According to the Table 1, the fossil fuels specially for diesel oil has been known as the most important energy input among the inputs consumed in broiler production agro-industry in Iran.

To the best knowledge of the authors, no study has been yet done on the analysis of energy use of broiler production inputs in Guilan Province, Iran. Moreover, the effects of production season (warm and cold) on the energy use inputs and indices are absent in the corresponding literatures cited. So, the present study aimed at evaluation of the impact of production season on the energy consumption indices of broiler production in Guilan Province, Northern Iran.

Table 1. Summary of the literature on the energy analysis of broiler production

Authors	Number of broiler farms	Energy use efficiency	Energy use hotspots
Amini *et al*., 2015	70	0.16 for traditional and 0.17 for modern farms	Diesel fuel & feed
Kalhor *et al*., 2016	40	0.26	Feed & Electricity
Amid *et al*., 2015	70	0.18	Diesel fuel & feed
Kilic, 2016	29	0.94	Feed & water
Heidari *et al*., 2011	44	0.15	Diesel fuel & feed
Yamini Sefat *et al*., 2014	50	0.15	Gasoline & Feed
Najafi *et al*., 2012	3 small 2 medium 1 large	0.21 0.27 0.36	Diesel fuel & feed
Current study, 2016	25 farms	---	---

2 Materials and Methods

This study was carried out in Rasht City, Guilan Province, Iran in the summer and winter of 2015. Guilan Province lies between the latitudes of 36°34' and 38°27' N and the longitudes of 48°53' and 50°34' E. Rasht City is the center of Guilan Province and the leading broiler producer of the province with 146 small and large broiler farms around it. Given the limitations of the study and the precision intended in data collection, energy consumption dataset represents 25 broiler production farms.

Research data were collected using a questionnaire and face-to-face interview with the managers of broiler farms. All questions were asked for warm season (summer) production and cold season (winter) production separately.

The inputs of broiler production systems included (1) machinery, (2) fossil fuels, (3) electricity, (4) labor, (5) feed, (6) medications, (7) disinfectants, and (8) chicks, and the output included (1) broilers and (2) poultry wastes or litter.

Energy equivalent of inputs (in Mcal U^{-1}) were calculated for fossil fuels, electricity, labor, chicks, feed ingredients, disinfectants and medications by multiplying their consumption quantity for 1000 birds by their equivalent energy (Table 2). Also, energy equivalent of system outputs (broiler and poultry litter) was calculated by multiplying equivalent energy by the output quantity.

Table 2. Different forms of energy inputs of broiler production in Northern Iran

Items	Energy coefficients (Mcal U^{-1})	Reference
Input		
Labor	0.54	(Cook *et al*. 1980)
Machinery (h)	62.70	(Singh *et al*. 2002)
Diesel fuel (l)	11.38	(Singh *et al*. 2002)
Electricity (kWh)	2.85	(Singh *et al*. 2002)
Feed		
-Dicalcium phosphate (kg)	2.39	(Atilgan, 2006)
-Salt (kg)	0.38	(Sainz, 2003)
-Corn (kg)	1.89	(Atilgan, 2006)
-Soybean (kg)	2.88	(Atilgan, 2006)
-Minerals and Vitamins (kg)	0.38	(Sainz, 2003)
Medicines (kg)	3.26	(Atilgan, 2006)
Disinfectants (kg)	0.1	(Najafi *et al*., 2011)
Chick (kg)	2.47	Amid *et al*. (2014)

1 cal=4.184 J

Total energy input was divided into direct and indirect and into the renewable and non-renewable forms. Direct energies included energy equivalent of labor, fossil fuels, and electricity. Indirect energies included feed, machinery, poultry litter, disinfectants, medications, and chicks. Renewable energies were energy equivalent of feed, labor, chicks, and poultry litter and non-renewable energies included machinery, fossil fuels, electricity, and disinfectants. Renewable energies are energy sources supplied from natural resources and are capable of natural restoration, whereas, the non-renewable energies like fossil fuels are derived from energy sources produced from animal and plant residuals in lower layers of the Earth under pressure and heat and will be depleted some day (Demirel, 2012).

Energy consumption indices including energy ratio, energy productivity, specific energy and net energy gain were calculated for two production seasons (warm and cold), and for total poultry farms by the following equations (Kalhor *et al*., 2016):

$$\text{Energy ratio}=\text{Output energy (Mcal 1000bird}^{-1}\text{)/Input energy (Mcal 1000bird}^{-1}\text{)} \qquad \textbf{(1)}$$

$$\text{Energy Productivity} = \text{Broiler Production (kg 1000bird}^{-1}\text{)/Input Energy (Mcal 1000bird}^{-1}\text{)} \quad (2)$$

$$\text{Specific Energy} = \text{Input Energy (Mcal 1000bird}^{-1}\text{)/ Broiler Production (kg 1000bird}^{-1}\text{)} \quad (3)$$

$$\text{Net energy} = \text{Output energy (Mcal 1000birds}^{-1}\text{) - Input energy (Mcal 1000birds}^{-1}\text{)} \quad (4)$$

3 Results and Discussion

This section first determines the contribution of individual inputs consumed for broiler production. Then, the energy indices are calculated and the results are contrasted with other studies on consumed energy indices for broiler production.

3.1 Energy Inputs and Outputs

Results showed that the interviewed broiler farms included 10 small-sized (<20,000 birds), 8 medium-sized (20,000-30,000 birds), and 7 large-sized broiler farms (>30,000 birds). Table 3 shows the average energy equivalents of inputs used to produce broilers in summer and winter seasons in Guilan Province, Northern Iran. Total energy inputs were estimated at 22,357.71 and 30,653.47 Mcal 1000birds^{-1} for summer and winter seasons, respectively. All values are lower than those reported by Amini *et al*. (2015) for broiler production in Mazandaran Province, Iran (42,625 and 45,124 Mcal 1000birds^{-1} in traditional and modern broiler production systems, respectively). It implies that the energy input in summer was lower than the winter. It can be related to the lower diesel fuel consumption in warm season. Figs 1 and 2 show that the diesel fuel contributed for 33.43 and 51.58% of the total energy input in warm and cold seasons, respectively. Moreover, diesel fuel ranked the first energy input to produce broiler in cold production season in Northern Iran. Therefore, it has the highest energy saving potential in the broiler production agro-industry in winter. Rajaniemi and Ahokas (2015) also introduced the heating energy of broiler farm having the most important energy saving potential in Finland. Choosing more efficient heating systems and giving sufficient notice to their adjustments and maintenance have profound impacts on the fuel energy use in broiler farms. In this regard, enhancing the information of broiler farms managers about the technical specifications of heating systems in accordance with the broiler farms buildings and suggested preventing solutions to save heating energy in broiler farms is of highly importance.

Table 3. Amounts of various energy inputs for broiler production in warm and cold seasons in Northern Iran.

Items	Warm season (Mcal 1000birds^{-1})	Cold season (Mcal 1000birds^{-1})
Inputs		
Labour	74.27	74.25
Machinery	285.83	282.97
Diesel fuel	7473.83	15809.61
Electricity	4698.76	4645.67
Feed	9713.31	9729.00
Medicines	11.71	11.91
Disinfectants	1.17	1.19
Chick	98.83	98.87
Total input	22357.71	30653.47
Outputs		
Poultry meat	5677.50	6006.89
Poultry litter	158.63	149.88
Total output	5836.13	6156.17

Figs 1 & 2 show that the broilers' feed ranked the first in warm season and second energy input in cold production season (43.44 and 31.73% of the total energy input, respectively). Therefore, management the feed consumption besides the special notice to the chicken feed should be considered by the broiler farms managers. Kilic (2016) also reported the chicken feed as the first ranked input of broiler and laying hen production in Bursa region of Turkey (70.49 and 78.86% of the annual total energy input). Feeding broilers with a low-protein feed and using well-designed feeder implements are among management proceedings to achieve optimal use of broiler feed and then, improving the energy input of feed in broiler production.

Besides the importance of fossil fuels in terms of depletion of non-renewable resources, the CO_2 emissions of burning fossil fuels is a global challenge which should be considered in poultry production ago-industry in Northern Iran. Using biofuels may be considered as a solution to lower the CO_2 emissions of poultry agro-industry in the study region.

To save energy use in broiler production systems, the farmers should have means to measure energy consumed and follow the energy consumption. Moreover, they must be informed about the energy saving possibilities and machinery energy consumptions.

3.2 Energy Indices

Energy consumption indices are shown in Table 4 for broiler production in warm and cold seasons in Guilan Province, Iran. Energy ratio for broiler production in warm season (0.26) was estimated at 0.26 compared to that of cold season (0.20). In other words, broiler production in warm season possesses more favorable energy advantage. Energy productivity for broiler production was 0.10 and 0.08 kg Mca^{-1} in

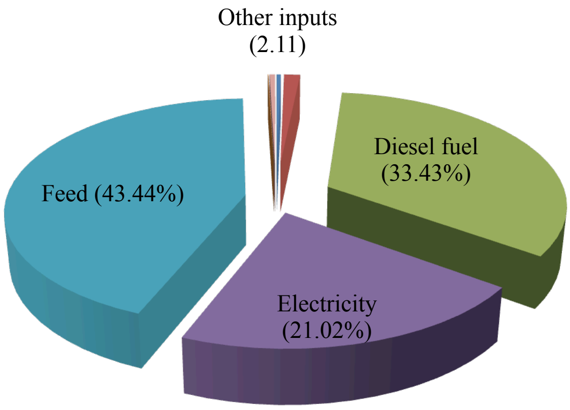

Fig. 1. Contribution of main energy inputs for broiler production in warm season

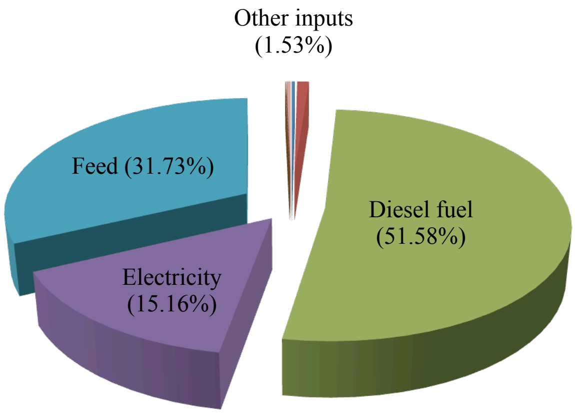

Fig. 2. Contribution of main energy inputs in broiler production in cold season

warm and cold seasons, respectively. It means that 0.1 and 0.08 kg broiler meat are produced in warm and cold seasons as per 1 Mcal energy consumed, respectively.

Fig. 3 shows the shares of various forms of energy inputs in terms of direct and indirect energy, and renewable and non-renewable energy inputs. The share of renewable energy inputs in cold season (32.25% of the total energy inputs) is lower than the half the non-renewable energy inputs (67.75%). Therefore, substituting the

Table 4. Energy indices of broiler production in warm and cold seasons in Northern Iran.

Indicators	Unit	Warm season	Cold season
Energy ratio	%	0.26	0.20
Energy productivity	kg Mcal $^{-1}$	0.10	0.08
Specific energy	Mcal kg $^{-1}$	9.79	12.74
Net energy gain	Mcal 1000birds^{-1}	-14468.44	-24549.73

non-renewable resources with the renewable energy ones and substituting the warming implements with the modern and more efficient systems must be considered for enhancing the energy productivity and mitigating the negative impacts of using the non-renewable energy inputs in broiler production in Northern Iran, especially for cold production seasons. Also, recovering some of heating energy from the exhaust warmed air, optimization of ventilation systems, and appropriate isolations of broiler farm saloons and heated air conveying ducts may be among the useful applied proceedings to lessen energy inputs in broiler production (Rajaniemi and Ahokas, 2015).

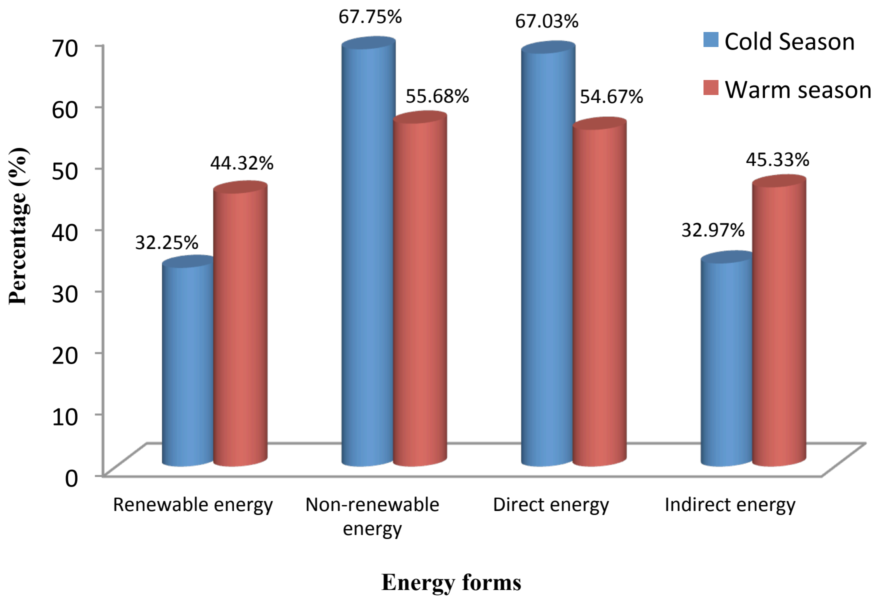

Fig. 3. Various energy forms used for broiler production in warm and cold seasons

3.3 Correlation between Farm Sizes, Energy Input, and Output

Table 5 indicates the correlations between the farm size and energy input and output for broiler production upon warm season in Guilan Province, Iran. An inverse significant correlation was found to be between the farm size and energy input for broiler production ($p \leq 0.05$). It implies that the large farms used the least amount of energy input. It was also reported that there were negative correlations between the farm size and energy use in paddy and corn farms in Iran. Generally, large farms were more energy efficient than the medium and small farms (Pishgar Komleh, 2011; Pishgar Komleh, 2012).

Table 6 also illustrates the correlation between the farm size, energy input and output for broiler production upon cold season. The inverse significant correlation also is seen between the farm size and energy input for broiler production in cold seasons ($p \leq 0.05$). This result also may be contributed to the better energy use management in large broiler farms compared to the medium and small broiler farms.

Table 5. The correlation between farm size, energy input and output for broiler production upon warm season in Guilan Province, Iran ($p \leq 0.05$).

	Farm size	Energy input	Energy output
Farm size	1.00	-0.76	-0.41
Energy input	-0.76	1.00	0.20
Energy output	-0.41	0.20	1.00

Table 6. The correlation between farm size, energy input and output for broiler production upon cold season in Guilan Province, Iran ($p \leq 0.05$).

	Farm size	Energy input	Energy output
Farm size	1.00	-0.83	-0.34
Energy input	-0.76	1.00	0.21
Energy output	-0.34	0.21	1.00

4 Conclusions

The results of the study showed that the diesel fuel and feed were ranked as the first and second energy inputs for the broiler production in cold season, while, the feed and diesel fuel had the greatest energy shares among energy inputs in the warm production season in Guilan Province, Iran. The share of renewable energy inputs in broiler production (32.25% and 44.32% of the total energy input for cold and warm seasons, respectively) were determined to be less than those of the non-renewable inputs (67.75% and 55.68% of the total energy input for cold and warm seasons, respectively). Therefore, management of fossil fuel use as the most important non-renewable energy resource consumed in broiler production through selecting more energy efficient heating systems and using the renewable energy resources for heating broiler farms are suggested to enhance the energy efficiency and mitigate the negative environmental impacts of broiler production in cold seasons in Guilan Province, Iran.

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