Advances in Environmental Technology 2 (2020) 111-117

Advances in Environmental Technology

journal homepage: http://aet.irost.ir

Assessing the effects of wheat flour production on the environment

Kolsoum Pourmehdi, Kamran Kheiralipour*
Mechanical Engineering of Biosystems Department, Ilam University, Ilam, Iran.

ARTICLE INFO

Article history:
Received 15 February 2021
Received in revised form
11 April 2021
Accepted 12 April 2021

Keywords:
Wheat flour
Energy
Environmental indicators
Life cycle assessment

ABSTRACT

Evaluating the energy and environmental indicators allows for identifying the strengths and weaknesses of a system for optimizing material and energy consumption and developing strategies to reduce environmental impacts. This study determined and assessed the energy and environmental indicators of wheat flour production systems. The input and output materials and corresponding energy equivalents were calculated and then the energy indicators and forms. The environmental indicators were assessed by the life cycle assessment method in SimaPro software. The total input and output energies per year of flour production were 287935007 and 286675200 MJ, respectively. Wheat had the highest share (99.19%) of energy consumption in flour production; the energy ratio, productivity, intensity, and net energy gain indexes were equal to 1.02, 0.07 kg/MJ, 13.84, MJ/kg, and 0.31 MJ/kg, respectively. In the flour factory, the share of direct and indirect energy was 0.27 and 99.73%, respectively; the share of renewable and nonrenewable energy was 99.19 and 0.81%, respectively. Wheat input had the largest share of environmental indicators in flour production. The normalization step showed that the most important environmental indicator was marine water ecotoxicity (1.53×10^5 kg 1.4 DB eq/ton) followed by terrestrial ecotoxicity (36.59×10^5 kg 1.4 DB eq/ton), eutrophication (5.83 kg PO_4 eq/ton), and acidification potential (6.57 kg SO_2 eq/ton) indicator.

1. Introduction

Population growth and consequently increasing demand [1] have led to mass production. Then, quality issues were gradually raised, and today more attention has been paid to social responsibilities and environmental issues. The increasing pollution sources, activities harmful to the environment, the trend of increased energy consumption, and the consequences of climate pollution, highlight the need to monitor and manage the environment. Thus, assessing environmental impacts has become a priority. Life cycle assessment is a new approach in analyzing environmental indicators of various activities and is widely used in agriculture and industry. The results of LCA can be used in comparing different systems [2], design and redesign of ecosystem friendly systems [3], and decision-making tasks [4], and evaluating the effects of new technologies on the environment [5]. Agriculture, food industries, and agricultural conversion processes are the largest industrial sectors globally, and hence, the major energy consumers [6-9]. The LCA approach has been applied in the food processing area to assess the adverse environmental impact [10-12]. Gholamrezayi et al. [13] used LCA to study the environmental indicators of a 100-ton sugar production process. Pishgar-Komleh et al. [14] evaluated the life cycle of the tomato paste production process. They calculated the CO_2 emission of 1 kg of tomato paste. Marashi et al. [15] assessed the environmental impacts of producing sugar from sugarcane. Jalilian et al. [16] studied the environmental effects of producing one ton of two bread types. The method was applied to assess the environmental impact of cake [17] and bread production [18].Flour is one of the main ingredients in breads and foods, which is usually obtained through the milling of cereals that have starchy materials. Barley, rye, rice, and chickpeas are also used to make flour, but it is mostly prepared from wheat grain. For example, the annual wheat

*Corresponding author.
Email address: k.kheiralipour@ilam.ac.ir
DOI: 10.22104/AET.2021.4704.1280

flour production in Iran is around 21 million tons, but the total from other sources is less than one million tons. Another reason for the high consumption of wheat flour is that it contains gluten protein, making it appropriate for baking [19]. So, it is consumed in many forms such as bread, cake, noodles, and so on [20-22].Due to the amount of flour production and the various pollutants produced in the food industry and agricultural conversion processes, it is necessary to conduct research to evaluate the life cycle of flour production; by knowing the environmental effects, different strategies can be implemented to reduce emissions. Therefore, the purpose of the present study was to evaluate the life cycle of flour production, and estimate the extent of various environmental effects on the production process.

2. Materials and methods

The present research was conducted in the Chardavol Township, Ilam Province, Iran. The data of the Chardavol Flour Company was used to assess the environmental indicators of wheat flour production. At the factory entrance, the purchased grains are weighed, and then some samples are provided for testing. If the results are acceptable, the grain is sent to storage. The most important step of converting wheat to flour is the milling process. Before that, the undesired materials in the crop are removed; then, it is wetted to remove the husk. After milling, the sprouts and bran are separated and bagged. The input materials in the flour production system included wheat, premix, electricity, diesel, oil, labor, plastic bag, and water. The system's output included wheat flour, bran, and poultry feed (Figure 1).

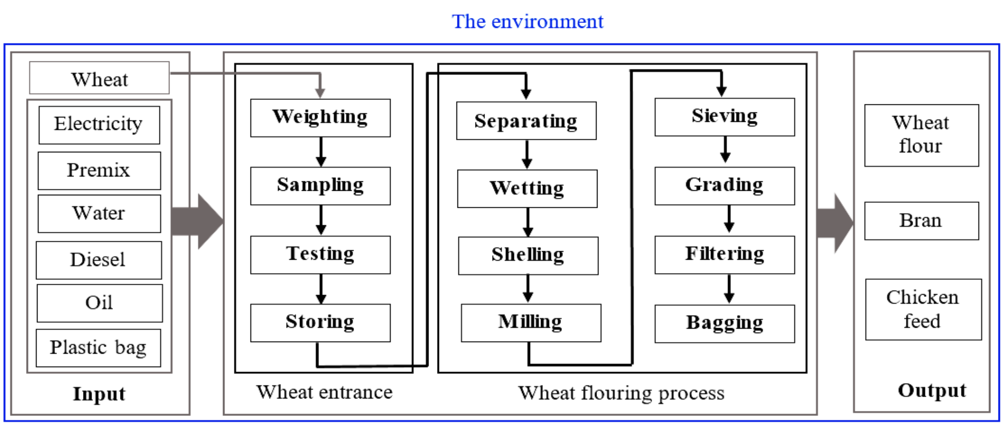

Fig. 1. Wheat flour production system.

2.1. Energy content

The energy content of inputs and outputs in the flour production system was obtained by multiplying the values of each material by the corresponding energy equivalent [23]. The energy equivalent of diesel [24], oil and grease [25], machinery [26], labor [27], plastic bag [25], wheat [28], electricity [29], water supply [23], and chicken feed [30] were selected from the references; then, the energy of the premix flour material was calculated (Table 1). The energy indicators in flour production were calculated. These indicators included the energy ratio, energy productivity, energy intensity, and net energy gain [30-32] the energy ratio represents the amount of obtained energy per unit of energy consumption. The energy intensity indicator shows the energy consumed to produce a unit of product. This index varies depending on the type of product, situation, and time; it can be used as an indicator to evaluate the energy performance in different production systems. It is obtained by dividing the input energy by the produced yield. Energy productivity expresses the amount of produced yield per unit of energy consumed. Energy productivity is obtained by dividing the amount of produced yield by the consumed energy [33]. The net energy gain shows the energy obtained or lost and calculated when input energy is mined from the output energy. The renewable and nonrenewable energy forms were calculated to show their shares of the total input energy [9,34]. Also, direct and indirect energy was determined as another energy form. The wheat grain and labor were considered renewable and nonrenewable energy and included water supply, premix, electricity, plastic bag, machinery, diesel, oil, and grease. The classification of direct input energy forms included in the flour production was labor, electricity, water supply, diesel, oil, and grease; the wheat grain, premix, plastic bags, and machinery were considered as the indirect energy. In the present study, the water supply was regarded as nonrenewable energy consumption due to the use of electricity for water pumping.

2.2. Life cycle assessment

The life cycle assessment method was performed based on ISO 14040 and in four phases: defining the goal and scope of the study, analysis of the systems inventory, analysis of the environmental impacts of the system, and interpreting the results [35]. In the present research, the environmental effects of flour production system was investigated. The boundary of the system included the entrance gate to and the exit gate of the factory. A list of life cycle inputs and outputs that were prepared involved collecting data from the factory and performing the exact calculations to quantify the product life cycle. As the third part the LCA, the environmental impact assessment phase was conducted to find and assess the magnitude and significance of the potential environmental consequences of the studied system through the product life cycle. This phase was done via SimaPro 9.1.0 software and the CML-IA baseline impact categorization model. These basic calculations of the interpretation phase were done by the software. It included finding the most effective factors on the environmental impacts. This information can help to present a combination of critical recommendations and options to reduce the environmental burdens.

3. Results and discussion

3.1. Energy

Wheat, labor, electricity, water, and diesel fuel were the most important inputs for producing wheat flour. Table 1 shows the amount of input and output materials and energy in flour production. Also, the percentage share of the inputs and outputs are provided in the table. According to these results, the total input energy was 287935007 MJ/yr, and its output energy was 291816000 MJ/yr for flour production. Fikado [37] assessed the environmental impacts of flour production in Ethiopia; the researcher stated that out of 252479 tons of imported wheat per year, 18600 tons of flour and 1943 tons of solid waste were produced. Around 61.7% of the total solid waste was discharged in the open environment, which was associated with undesirable environmental effects.

3.2. Energy forms

The values of input energy forms and the corresponding percentage shares in the wheat flour production system have been listed in Table 2.

According to Table 2 the share of renewable energy was 99.19%. The amount of indirect and renewable energy was higher than nonrenewable and direct energy due to the amount of wheat grain as input of the flour production system.

Table 1. The inputs and outputs materials and energy in flour production.

Input/output (Unit)	Material amount (Unit/yr)	Energy equivalent (MJ/Unit)	Energy (MJ/yr)	Energy share (%)
Input				
Wheat (kg)	200000000.00	14.70	285600000.00	99.19
Water supply (m^3)	1200.00	1.02	1224.00	0.43×10^{-3}
Premix (kg)	1923.60	16.00	30777.60	1.07×10^{-2}
Labor (h)	2400.00	1.96	4704.00	1.63×10^{-3}
Electricity (kWh)	6680.00	11.93	79692.40	2.77×10^{-2}
Plastic bag (kg)	84000.00	17.91	1504440.00	0.52
Machinery (kg)	370.81	62.70	23249.47	8.07×10^{-3}
Diesel (l)	12000.00	56.31	675720.00	0.23
Grease (l)	30.00	47.80	1434.00	0.50×10^{-3}
Oil (l)	288.00	47.80	13766.40	4.78×10^{-3}
Total	-		287935007.87	100.00
Output				
Wheat flour (kg)	16800000.00	15.24	254016000.00	86.97
Barn (kg)	3600000.00	9.07	32659200.00	11.09
Chicken feed (kg)	400000.00	14.28	5712000.00	1.94
Total	-		292387200.00	100.00

Table 2. The value of energy indicators and form in flour production.

Energy indicator/form	Unit	Value
Energy ratio	%	101.55
Energy productivity	Kg/MJ	0.07
Energy intensity	MJ/kg	13.84
Net energy gain	MJ/kg	0.31
Renewable Energy	2330303.87	0.81
Nonrenewable energy	285604704.00	99.19
Direct energy	776540.80	0.27
Indirect energy	287158467.07	99.73

3.3. Energy indicators

Table 2 shows the of energy ratio, energy productivity, energy intensity, and net energy gain indicators in flour production. The ratio of output energy to input energy was approximately equal to the unit that shows the equal energy content of both the total input and total output. The average of the energy intensity in flour production was 13.84 MJ/kg. The energy productivity showed that with consuming 1 MJ energy, only 0.07 kg flour was produced. The net energy gain was obtained as 0.31 MJ/kg. Payendeh et al. [34] obtained the energy ratio, energy productivity, energy intensity, and net energy gain as 0.15 to 0.21, 0.014 to 0.02 kg/MJ, -94922.28 to -143658.70 MJ/1000pic, respectively. Kheiralipour et al. [36] calculated the energy ratio, energy productivity, energy intensity, and net energy gain for sugar production as 0.56, 0.02 kg/MJ, 47.89 MJ/kg, and -125514.26 M/100ton, respectively.

3.4. Environmental indicators

The environmental impact indicators of the flour production system were studied applying the life cycle assessment method. The calculated environmental indicators in the production of one ton of wheat flour are given in Figure 2 and Table 3. shows the effect of each factor on the environmental indicators of flour production.

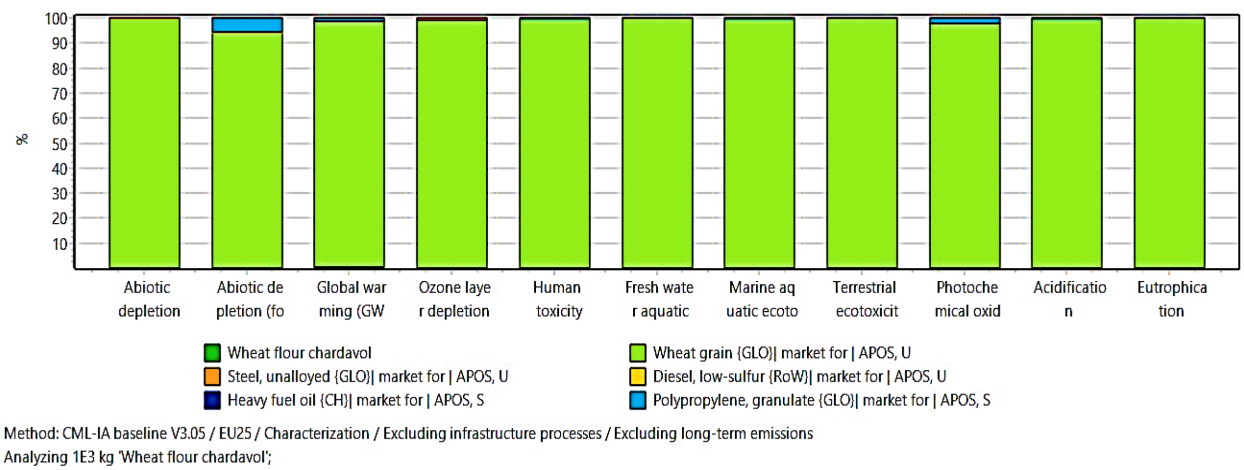

Fig. 2. The effects of factors on the environmental indicators of flour production.

Table 3. The value of environment indicators for producing 1 ton wheat flour.

Indicator	Unit	Value
Abiotic depletion	kg Sb eq	1.49×10^{-3}
Abiotic depletion (fossil fuels)	MJ	5.03×10^{3}
Global warming (GWP 100a)	kg CO_2 eq	6.93×10^{2}
Ozone layer depletion	kg CFC -11 eq	4.58×10^{-5}
Human toxicity	kg 1.4 DB eq	1.03×10^{2}
Fresh water aquatic ecotoxicity	kg 1.4 DB eq	97.93
Marine aquatic ecotoxicity	kg 1.4 DB eq	1.53×10^{5}
Terrestrial ecotoxicity	kg 1.4 DB eq	36.59
Photochemical oxidation	kg C_2H_2 eq	9.06×10^{-2}
Acidification potential	kg SO_2 eq	6.57
Eutrophication	kg PO_{24}eq	5.83

In order to have dimensionless impacts, the environmental indicators were normalized by SimaPro software. This task allows comparing the indicators with each other and finding the more significant indicators. Figure 3 lists the normalized environmental impacts of the wheat flour production system. After normalization of the environmental indicators, marine aquatic ecotoxicity was the most effective environmental load in flour production with a value of 152741 kg 1.4 DB eq. Also, the depletion of fossil resources, global warming, human toxicity, and surface water toxicity have the largest share of environmental burdens in flour production. The most effective input for flour production was wheat. Wheat has the greatest effect in all the indicators. This is because about 20,000 tons of consumed wheat grain are needed to produce 16800 tons of flour. Acidity, marine aquatic ecotoxicity, eutrophication, and global warming were the greatest indicators of canola production. Pishgar-Komleh et al. [14] reported that the production of 1 kg of tomato paste was equivalent to 3.2 kg CO_2, and the highest contributor to the emission was tomato input. Marashi et al. [15], in evaluating the life cycle of the sugarcane industry, reported that electricity and the burning of plant residues had the largest share per ton of sugar. Jalilian et al. [16] compared the effects of marine water ecotoxicity, abiotic depletion (fossil fuels), global warming, freshwater ecotoxicity, and acidification potential to other effective groups in the production of one ton of bread.

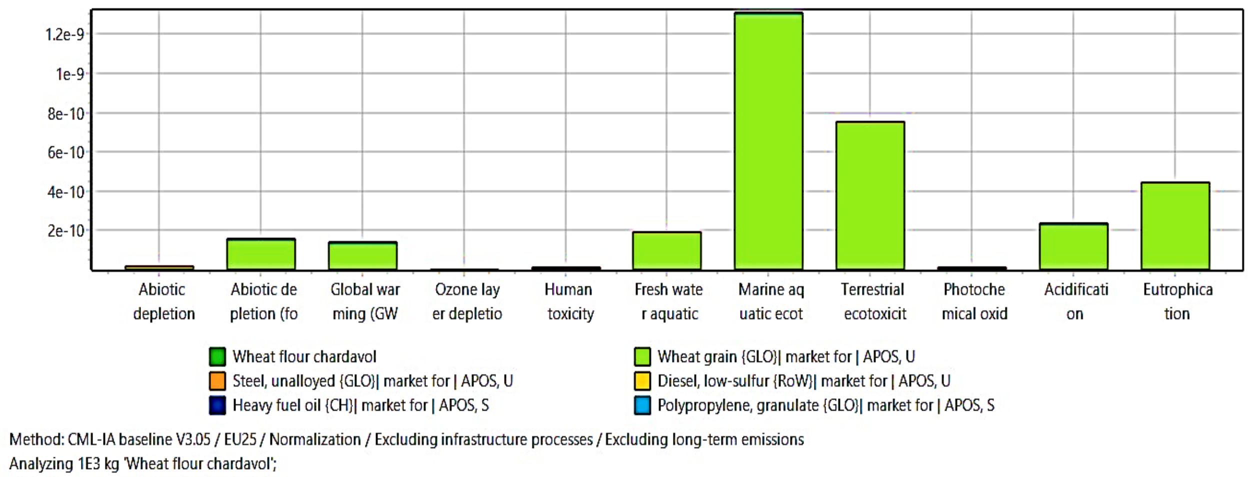

Fig. 3. The normalized environmental indicators of flour production system.

4. Conclusions

Wheat, whit 99.19%, has the highest share of renewable energy in flour production, followed by plastic bags. Although these inputs cannot be decreased in the factory, but others such as electricity and fuel can be optimized by applying management consumption methods. After the normalization of the environmental indicators, the marine aquatic ecotoxicity of 152741 was the most effective environmental load in the flour production system. Also, the abiotic depletion of fossil fuels, global warming, human toxicity, and freshwater ecotoxicity had a large share in the environmental loads in flour production. All inputs that affected the indicators can be further studied to reduce them. The contribution of the wheat factor in all environmental impacts was high because it is the main input in flour production. Material and energy consumption and process management regarding wheat farms should be emphasized to reduce adverse environmental effects.

Acknowledgement

The authors appreciate Ilam University for supporting the research project and Chardavol Flour Factory for providing the required data.

References

[1] FAO. (2012). Energy-Smart Food at FAO: An Overview. Rome.
[2] Ramedani, Z., Alimohammadian, L., Kheialipour, K., Delpisheh, P., Abbasi, Z. (2019). Comparing energy state and environmental impacts in ostrich and chicken production systems. *Environmental science and pollution research*, *26*(27), 28284-28293.
[3] Tillman, A. M. (2000). Significance of decision-making for LCA methodology. *Environmental impact assessment review*, *20*(1), 113-123.
[4] Moro Piekarski, C., Mendes da Luz, L., Zocche, L., De Francisco, A. C. (2013). Life cycle assessment as entrepreneurial tool for business management and green innovations. *Journal of technology management and innovation*, *8*(1), 44-53.
[5] Kheiralipour, K. (2020). Environmental life cycle assessment. 1st edition. Ilam university publication. Ilam, Iran. (In Persian).
[6] Roy, P., Nei, D., Orikasa, T., Xu, Q., Okadome, H., Nakamura, N., Shiina, T. (2009). A review of life cycle assessment (LCA) on some food products. *Journal of food engineering*, *90*(1), 1-10.
[7] Kheiralipour, K., Jafari Samrin, H. and Soleimani, M. (2017). Determining the environmental impacts of canola production by life cycle assessment, case study: Ardabil Province. *Iranian journal of biosystems Engineering*, *48*(4), 517-526. (In Persian).
[8] Kheiralipour, K., Payandeh, Z. and Khoshnevisan, B. (2017). Evaluation of environmental impacts in Turkey production system in Iran. *Iranian journal of applied animal science, 7*(3), 507-512.
[9] Kheiralipour, K., Sheikhi, N. (2020). Material and energy flow in different bread baking types. *Environment, development and sustainability*, 1-16.
[10] Colley, T. A., Birkved, M., Olsen, S. I., Hauschild, M. Z. (2020). Using a gate-to-gate LCA to apply circular economy principles to a food processing SME. *Journal of cleaner production*, *251*, 119566.
[11] Thomas, C., Grémy-Gros, C., Perrin, A., Symoneaux, R., Maître, I. (2020). Implementing LCA early in food

innovation processes: Study on spirulina-based food products. *Journal of cleaner production*, *268*, 121793.

[12]. Kumar Sharma, M., Pallakonda, S., Raju, G., Sarkar, P., Singla, E. and Singh, H. (2018). An approach to evaluate sustainability of a production process based on its LCA and environment impact analysis: A case study on a food product. *Materials today: proceedings*, *5*(5), 12467-12473.

[13]. Gholamrezayi, H., Kheiralipour, K., Rafiee, S. and Ghamary, B. (2021). Investigation of energy and environmental indicators in sugar production from sugar beet. *Journal of environmental science studies*, accepted manuscript. (In Persian).

[14] Fischer, G., Albrecht, A., Jäckel, U., Kämpfer, P. (2008). Analysis of airborne microorganisms, MVOC and odour in the surrounding of composting facilities and implications for future investigations. *International journal of hygiene and environmental health*, *211*(1-2), 132-142.

[15] Pishgar-Komleh, S. H., Akram, A., Keyhani, A. R. and Huijbregt Mark, A. J. (2017). Life cycle assessment of tomato paste product (case study: Alobrz Province). *Iranian journal of biosystems engineering*, *47*(4), 677-688. (In Persian).

[16] Jalilian, M. M., Kheiralipour, K. and Mirzaee-Ghaleh, E. (2020). Comparison of environmental indicators in Sangak and Lavash bread production in Eslamabad-e-Gharb, Kermanshah. *Journal of environmental science studies, 5*(4), 3198-3203. (In Persian).

[17] Khanali, M., Akram, A., Mohammadnia Galeshklamei, M., Hosseinzadeh-Bandbafha, H. and Elhami, B. (2019). Evaluating the energy flow and environmental effects of cake production in Guilan Province by life cycle assessment approach. *Iranian journal of biosystems engineering, 50*(3), 569-579. (In Persian).

[18] Hajiahmad, A., Mirbazel, F., Solki Cheshmeh Soltani, F. and Pishgar-Komleh, S. H. (2019). Energy indices and environmental impact assessment of industrial bread production by using life cycle. *Iranian journal of biosystems engineering*, *50*(1), 155-168. (In Persian).

[19] Goesaert, H., Brijs, K., Veraverbeke, W. S., Courtin, C. M., Gebruers, K., Delcour, J. A. (2005). Wheat flour constituents: how they impact bread quality, and how to impact their functionality. *Trends in food science and technology*, *16*(1-3), 12-30.

[20] Chen, Y., Wu, Y., Fu, J., Fan, Q. (2020). Comparison of different rice flour-and wheat flour-based butter cookies for acrylamide formation. *Journal of cereal science*, *95*, 103086.

[21] Tiga, B. H., Kumcuoglu, S., Vatansever, M., Tavman, S. (2021). Thermal and pasting properties of Quinoa—Wheat flour blends and their effects on production of extruded instant noodles. *Journal of cereal science*, *97*, 103120.

[22] Guo, L., Fang, F., Zhang, Y., Xu, D., Xu, X., Jin, Z. (2020). Effect of glutathione on gelatinization and retrogradation of wheat flour and starch. *Journal of cereal science*, *95*, 103061

[23] Singh, S. and Mittal, J. P. (1992). Energy in Production Agriculture. Mittal publications, New Dehli, India.

[24] De, D., Singh, R. S., Chandra, H. (2001). Technological impact on energy consumption in rainfed soybean cultivation in Madhya Pradesh. *Applied energy*, *70*(3), 193-213.

[25] Kitani, O., Jungbluth, T., Peart, R. M., Ramdani, A. (1999). CIGR handbook of agricultural engineering. *Energy and biomass engineering*, *5*, 330.

[26] Chauhan, N. S., Mohapatra, P. K., Pandey, K. P. (2006). Improving energy productivity in paddy production through benchmarking—an application of data envelopment analysis. *Energy conversion and management*, *47*(9-10), 1063-1085.

[27] Singh, H., Mishra, D. and Nahar, N. M. (2002). Energy use pattern in production agriculture of a typical village in Arid Zone India-part I. *Energy conversion and management*, *43*(16), 2275-2286.

[28] Ovtit-Canavate, J. and Hernanz, J. L. (1999). Energy Analysis and Saving. In CIGR Handbook of Agricultural Engineering. Energy and biomass Engineering. Vol. V, ASAE Publication; MI., 13-23.

[29] Ozkan, B., Kurklu, A. and Akcaoz, H. (2004). An input-output energy analysis in greenhouse vegetable production: a case study for Antalya region of Turkey. *Biomass bioenergy*, *26*(1), 189-195.

[30] Molaei, K.,Keyhani, A.,Karimi, M., Kheiralipour, K. andGhasemi Varnamkhasti, M. (2008). Energy ratio in dryland wheat-case study: Eghlid Township. *Iranian journal of biosystems engineering*, *39*(1), 13-19. (In Persian).

[31] Schweigert, M. K., Mackenzie, D. P., Sarlo, K. (2000). Occupational asthma and allergy associated with the use of enzymes in the detergent industry–a review of the epidemiology, toxicology and methods of prevention. *Clinical and experimental allergy*, *30*(11), 1511-1518.

[32] Payandeh, Z., Kheiralipour, K., Karimi, M. and Khoshnevisan, B. (2017). Joint data envelopment analysis and life cycle assessment for environmental impact reduction in broiler production systems. *Energy*, *127*, 768-774.

[33] Almasi, M., Kiani, S. and Louimi, N. (2008). Principles of agricultural mechanization. 4th edition, Jangal publication, Tehran, Iran. (In Persian).

[34] Payandeh, Z., Kheiralipour, K. and Karimi, M. (2016). Evaluation of energy efficiency of broiler production farms using data envelopment analysis technique, case study: Isfahan province. *Iranian journal of biosystems engineering*, *47*(3), 577-585. (In Persian).

[35] International organization for standardization. (2006).

Environmental management: life cycle assessment; principles and framework (Vol. 14044). International organization for standardization.

[36] Kheiralipour, K., Gholamrezaee, H. and Rafiee, S. (2018). Investigation of energy status in sugar production. 11th Iranian national congress on mechanical engineering of biosystems and mechanization, 3-5 September, Hamadan, Iran. (In Persian).

[37] Fikadu, M. (2019). Evaluation of environmental and social impacts of flour factory: a case of Kedija flour factory, Werabe, Ethiopia. *Journal of industrial pollution control,* 1, 1-8.