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ORIGINAL ARTICLE

Full Chain Energy Analysis of Ethanol Production from Date palm

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ABSTRACT
An assessment of net energy and supply potentials was performed to evaluate ethanol production from Date palm in Iran. Date production in the world is other than 7 million ton per year and Iran is in the second rank with 14% and one million ton per year and just recently, the Iran government invested in bioethanol production. The Date fuel ethanol (DFE) system involves for main segments: Date production including processing, Date syrup production, ethanol conversion, and transportation. All materials, fuels, and human labor inputs to each segment were traced back to the primary energy expense level. Expended energy for one liter ethanol production was 28.8 MJ. Negative Net Energy Value, - 7.6 MJ/L, and Net Energy Ratio, 0.74 were found for the DFE system in Iran proved that it is not energy efficient. Without coproduct energy credits, DFE in Iran is not efficient than ethanol production from other crops such as sugar beet. In-development of co-industrials and don't optimum use of coproducts such as feedstock and distillation waste, are two main reasons for this. Regarding supply potentials, about 40% of the national Date production would be waste and could be used to feed approved DFE factories. A shift of Date waste to ethanol fuel rather than its current use for feed stock products could be a probable solution.
Keywords: Date, Date syrup, Ethanol, Full chain energy, Co-product allocation, Energy indices, Renew ability

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INTRODUCTION
Energy is a kind of strategic resource and it is an important substantial basis for economic increase and social development (1, 2). In fact, per capita energy consumption is an index of growth of any nation in all forms of inputs (3) and energy is essential to economic and social development and improved quality of life in world. Energy use in agriculture has been increasing in response to increasing population, limited supply of arable land, and a desire for higher standards of living [4, 5]. The agriculture sector, like other sectors, has become increasingly dependent on energy resources such as electricity, fuels, natural gas and coke. This increase in energy use and its associated increase in capital intensive technology can be partially attributed to low-energy prices in relation to the resource for which it was being substituted [6,7]. Use of these fossil fuels will be cause environment problem in all over the world [8, 9]. Continuous demand in increasing food production resulted in intensive use of chemical fertilizers, pesticides, agricultural machinery and other natural resources however intensive use of energy causes problems threatening public health and environment [5]. It has made a direct threat to world peace and development, becoming a common problem in any part of the globe [10,11]. Agricultural production sustainability is a complex concept embracing issues relating to the biophysical, social and economic environment. Workable definitions on sustainability have been hampered by conceptual inconsistencies. The meaning of agricultural sustainability is strongly dependent on the context in which it is applied and on whether its use is based on a social, economic or ecological perspective [12]. Energy use is one of the key indicators for developing more sustainable agricultural practices (13) and effective energy use in agriculture is one of the conditions for sustainable agricultural production, since it provides financial savings, fossil resources preservation and air pollution reduction [14]. In fact, the important subject in sustainable agriculture isn't consuming a least energy yea optimum production whit maximum of benefit and efficiently (15). Efficient use of energy in agriculture will minimize environmental problems, prevent destruction of natural resources, and promote sustainable agriculture as an economical production

system. Energy input–output analysis is usually used to evaluate the efficiency and environmental impacts of production systems. Considerable researches have been conducted on energy use in agriculture [16,17]. It is important, therefore, to analyze cropping systems in energy terms and to evaluate alternative solutions, especially for arable crops [18].
In its effort to reduce its dependence on imported oil, Iran pays much attention to biomass-derived and waste liquid fuels substituting for conventional gasoline and diesel in transportation and other industrial uses. The most common crop waste-derived liquid fuel is ethanol. At present, bioethanol in Iran is produced mainly from molasses, but Date palm waste, seems more advantageous to be used for the alcohol fuel industry.
Conventionally, the first instrument used to evaluate bioethanol efficiency is the net energy value (NEV) which is defined as the energy content of bioethanol minus the net energy inputs to produce bioethanol, the total energy inputs, excluding the energy recovered from system coproducts.
Since the very beginning when the shortage of world oil supply was seen and it cause need for alternative fuels, researchers have leaded evaluations of ethanol's potential to replace fossil fuels through Life Cycle Assessment (LCA) studies [19].
Not Maximization of crop yield per unit cultivated area for Date palm production and minimization of energy inputs need to be established in order to have an ecological balance in the village eco-system (20). Bioethanol production needs to be augmented to meet the global demand. So, by considering energy importance in fields of economic, environmental and human's health, determining of full chain energy analysis in Date waste ethanol production system is an essential affair. The purpose of this study is determining energy efficiency in consuming and producing energy in process of Date waste ethanol production.
Since a full chain energy analysis of bioethanol production in Iran has not yet been done, this study could perform as a framework supporting energy policy makers to judge whether bioethanol as a potential energy alternative, is possible and practical. In addition, as a large portion of Date palm in the country (about 40%) is waste and currently used for feed stock products, an assessment of supply potentials for bioethanol needs to be done.

METHODOLOGY

This study was conducted in Bushehr province that is located in the west south of Iran, within 27° 16' and 30° 18' north latitude and 50° 6' and 52° 56' east longitude. Data includes horticulture practices of Date production (pollination, irrigation, labor, diesel fuel usage, manure, fertilizer and pesticide usage and Date palm harvesting) and industrial stage of ethanol production (Date syrup production and ethanol production from syrup), were collected from the orchardists and syrup and ethanol production industrials by using a face-to-face questionnaire.
Energy equivalents of the inputs used in Date palm ethanol production are illustrated in Table 1. Basic information on energy input and output of Date production and ethanol production from Date were included human labor, diesel fuel, natural gas, chemical fertilizers, pesticides, manure and electricity. Chemical fertilizer included nitrogen, phosphate and potassium fertilizer and so pesticide included roundup, Gramaxone, diazinon, malathion, deltamethrin, tetradifon and carbaryl.

Table 1. Energy equivalent of inputs in ethanol production from Date waste

Inputs	unit	Energy equivalent (MJ unit^{-1})	Reference
Labor	MJ h^{-1}	2.2	[33]
Diesel fuel	MJ L^{-1}	47.8	[32]
Natural Gas	MJ L^{-1}	49.5	[32]
Chemical fertilizer			
Nitrogen (N)	MJ kg^{-1}	78.23	[30]
Phosphorus (P_2O_5)	MJ kg^{-1}	17.5	[31, 30]
Potassium (K_2O)	MJ kg^{-1}	13.8	[30]
Manure	MJ kg^{-1}	0.3	[28]
Pesticide	MJ kg^{-1}	85.5	[32]
Electricity	MJ kw-hr^{-1}	15.28	[32]

Industrial stage is formed by two branches, Date syrup production part and ethanol production from syrup part. Inputs in Date syrup production stage were include of Date, natural gas and the electricity, and in ethanol production stage inputs were include of Date syrup, diesel fuel and electricity. Inputs such as saccharomyces Cerevisiae as a zymogenic and Peptone, potassium de-hydrogen phosphate and

magnesium sulphate as nutritious were used in syrup fermentation in this step but percentage of this was so seldom.
Fermentation process of Date syrup is followed by equation 1.
Equation 1. $C_6H_{12}O_6 \rightarrow 2C_3H_60_3 \rightarrow 2C_2H_5OH + 2CO_2$

Energy co-product allocation
Usually more than one final product is generated during bioethanol production. These co-products share the input energy and must be reduced from the total energy input. Since information is often unavailable to estimate the energy needs for a co-product, hence an applicatory method was necessary to estimate co-products energy share. Indeed there are two method for estimation the co-products' share of energy, allocation and displacement methods (21).
By the allocation method, we can allocate energy between the primary product and co-products according to mass, energy content, or economic revenue (22). In the economic value method of allocation the biofuel ultimately must cause a profit to be subsistence. In this method we must share input energy between main product and co-products based on their economic value. Hence in this study we used economic value method for allocation of input energy between main product and the co-products as shown in equation 2.
Equation 2. $PE_E = \frac{PM}{\sum_{i=0}^{n} P_i M_i} \times 100$

Where in which;
PE_E: Energy allocation by economic method
P: Product or co-product price
E: Product or co-product mass

Assessment indices
Energy ratio of Fuel Ethanol
Based on the energy equivalents of inputs and outputs, output-input energy ratio, that is the ratio between output and input energy was calculated according to equation 3 (23, 24 and 25).

Equation 3. $\text{Output- input energy ratio} = \frac{\text{Output energy (MJ/ha)}}{\text{Input energy (MJ/ha)}}$

The input energy is also divided into direct, indirect, renewable and non-renewable forms of Energy (16,24). Indirect energy consists of fertilizers, pesticides energy and indirect energy in irrigation, while direct energy covered human labor, diesel used and electricity in the Date ethanol production. Non-renewable energy includes diesel, pesticide, fertilizers and electricity, and renewable energy consists of human labor.
Net Energy Value of Fuel Ethanol.
Net Energy Value (NEV) is the difference between the energy content of bioethanol and the amount of net energy inputs in the fuel production cycle (both fossil and non-fossil, excluding the energy recovered from system coproducts). The solar energy absorbed by Date palm crop through photosynthesis, was not taken into account. NEV will be calculated as equation 4.
Equation 4. NEV= energy content of ethanol - net energy inputs

Although energy efficiency indicated by NEV is of concern, it may not be the best instrument to evaluate biofuels' contribution to energy security. An appropriate evaluation should address how much energy is gained when non-renewable fossil fuel energy is expended to produce renewable biofuels. Thus, a new definition of Net Renewable Energy Value can be presented as equation 5.
Equation 5. NRnEV= energy content of ethanol - total fossil energy inputs

RESULTS AND DISSCUSIOM
Input and output energy
Energy inputs of horticulture segment for Date production are shown in table 2. As shown in this table, the used energy for irrigation with 33% has maximum share of energy inputs in Date production between all energy inputs. This is because of electricity use for irrigation in horticultural practices, after that Chemical fertilizer (especially nitrogen) was the most energy consumption with 31% of total energy inputs and this cause is intense energy usage in manufacturing of fertilizers particularly nitrogen. Likewise in some researches electricity energy was allocated maximum share of energy consumption i.e. Eskandaricherati et al, 2011, in energy survey of mechanized and traditional rice production system in Iran, calculate electricity energy with 79.55% as maximum share of energy consumption. The reason for allocated less

share of energy in this study to electricity than Eskandaricherati et al research is that just 13% of whole orchardists in study zone were used electromotor for irrigation and 77% remnant use gravity irrigation. Pesticide, diesel fuel, manual labor and manure are allocated 13, 11, 8 and 4 percentage of total energy input and were placed in subsequent ranking respectively.

Table 2. Inputs energy in Date production (1 ha)

Inputs		Energy (MJ)	Percentage
Labor		2010	8
Diesel fuel		2772.4	11
Irrigation	Electricity	7860.9	31.2
	Indirect	370.4	1.8
	Total	8231.3	33
Chemical fertilizer	Nitrogen (N)	6414.9	25
	Phosphorus (P_2O_5)	376.25	1.5
	Potassium (K_2O)	1159.2	4.5
	Total	7950.35	31
Manure		936	4
Pesticide		3323.6	13
Total		25223.65	100

Co-products energy allocation

According to allocation method (equation 2), just 6% of total energy inputs in Date production system were devoted to Date wastage that used for ethanol production. Hence waste Date energy used for each liter of Date syrup production will be equal to 0.27 Mega Joule (one liter ethanol was obtained from 4.59 kg waste Date).

Energy inputs in industrial segment

Inputs of energy in Date syrup production was shown in table 3. As illustrated in this table, 160 MJ of energy was consumed for 100 liter Date syrup production and energy used in electricity consumption was the maximum in whole inputs of energy contribution with 50.41 percent of all. After that natural gas has 45.72% and then Date waste has 3.87% of whole inputs of energy consumption.

Table 3. Inputs energy in Date syrup production (100 liter)

Inputs	Content	Energy equivalent (MJ $unit^{-1}$)	Energy (MJ)	Percentage
Date	45	0.27	12.15	3.87
Natural Gas	1.42	49.50	70.29	45.72
Electricity	5.08	15.28	77.60	50.41
Total			160	100

Table 4 illustrates the inputs of energy in ethanol production from Date syrup. According to this table 12.5 liter of Date syrup was consumed for each liter ethanol production and the whole energy consumed for 100 liter ethanol production was 2880 MJ. In this stage Date syrup with 77.52% has the maximum of energy consumption between all inputs of energy and diesel fuel and electricity with 21.2% and 1.28% was in second and third ranking of all energy consumption inputs respectively. According to this passage Date syrup was maximum energy consumed input because of high use of this input for ethanol production (for 8 liter ethanol production 100 liter of Date syrup must be used).

Table 4. Inputs energy in ethanol production from Date syrup (100 liter)

Inputs	Content	Energy equivalent (MJ $unit^{-1}$)	Energy (MJ)	Percentage
Date syrup (L)	1250	1.6	2000	77.52
Diesel fuel (L)	16.87	47.8	806.4	23.2
Electricity (Kw-hr)	4.82	15.28	73.6	1.28
Total			2880	100

Energy indices

According to table 4, the inputs of energy in ethanol production from Date in all sequences was 28.8 MJ per each liter of ethanol production, therefore as regards heating value of ethanol equal to 21.2 (26,27), hence Net Energy Ratio (NER) of ethanol production from Date waste will be 0.74, and the Net Energy Value (NEV) of it so will be – 7.6 Mega Joule and since reduction the manual labor energy as renewable energy the Net Renewable Energy Value (NRnEV) will be – 7.48, that it had not significant different from NEV. This means that 7.6 MJ of energy (or 7.48 MJ of fossil energy) will be lost for each liter of ethanol production from Date waste and this is not justifiable by energy consumption, therefore we had to find solutions for extending NEV (or NRnEV) from negative state to positive state.

CONCLUSION

Because studies on ethanol production by Date waste is in confine of waste management, hence even if the NER was bellow one and NEV was negative, bioethanol production continuance in this qualification will be still justifiable for other benefits such as environmental and employment benefits. Similar to this study was done in 2002 in Thailand, where in Puppans study on environmental assessment of biofuels, although the NEV was calculated as negative (- 5.67 MJ), but because of production of this fuels with bi-products, production flow resumption was suggested.

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