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Energy Input-Output Analysis in Wheat, Barley and Oat Production

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Abstract: The consumed energy, energy input-output relation of wheat, barley, and oat production in was analysed in Al-Qarneh al-Ghamayj (31° 1' 5.5956'' N and 47° 25' 23.4192'' E.). The irrigation consumed 32.99, 31.83 and 31.96% of the total energy inputs on wheat, barley and oat, respectively. Fuel is the second source of consumed energy in tractors, harvesting engines, pumps being. 8466.21 (27.84%), 9415.03 (28.45), and 8757.33 (28.41) for wheat, barley, and oats, respectively. The fertilizers consumed energy (Nitrogen especially) were 7291.94 (23.98%), 7658.35 (23.14%), and 7444.72 (24.15%) MJ ha^{-1} for wheat, barley, and oats respectively. The average energy output for grain wheat , barley and oat was 60469.63, 71960.66 and 70017.61 MJ ha^{-1}. Barley was the most energy-efficient crop (1.9 %) followed by wheat and oat (1.71 and 1.59 %). Barley yield was 4945.75 Kg ha^{-1} with input energy of 37776.46 MJ ha^{-1} while wheat yield was 4113.58 Kg ha^{-1} with input energy of 38095.52 MJ ha^{-1}.

***Keywords*:** Input and output energy, Energy efficiency, Wheat, Barley, Oats

Reduced energy consumption in cereal production leads to lower production costs. The use of traditional means of agricultural production increases the cost of agricultural production particularly in developing countries. Most developing countries rely mainly on fossil fuels to produce energy for agricultural production. These countries still use a modest percentage of renewable energy in production compared to the developed world. The agricultural production cannot increase except if sufficient fertilizers and water for irrigation are available in an appropriate time and utilized with scientifically methods. With increasing the world population, the energy consumption required efficient planning. This means the input components need to be specified to prescribe the methods most efficient for dominating them. Crop food and yields provisions to consumers are straight linked to energy and adequate energy is needed in the appropriate form at the suitable time to increase productivity. One method for improving the consumption of energy in agricultural production is to determine the competence of manners and techniques used (Safa and Tabatabaeefar 2002). The energy input had an influence directly on crop yield. Fossil fuel and fertilizers (N and P) account for the greatest share (>75%) of overall energy spent in a mixed cropping system (Safa et al 2010). Agricultural practices contain all crops processes that happen after its land reclamation such as plowing, seeding, fertilizing, weed control, combating insects, irrigation, harvest, and transportation. The energy needed for agricultural production was roughly 3% of the total in the developed countries national consumption. The percentage of energy consumption in developing countries increased to 6% of the total national consumption. There must be a plan for energy consumption, on the other hand, with the existing population increasing the current lifestyle will be unsustainable (Sahabi et al 2013). The energy used in agricultural production can be classified into direct and indirect energy. The essential means of direct energy used on the farm include fossil fuel consumption such as diesel, gasoline, furnace oil, electro power and coal. The energy consumed as indirect for transportation agricultural input, like pesticides, fodder, equipment, cereals, and the organic and chemical fertilizers. Indirect energy consumption is 70 percent in dairy farms and around 49.97 percent in arable fields (Saunders et al 2006). This investigation aimed to determine the energy consumption in wheat, barley and oat development based on farm operations and semi-arid farmland energy sources.

MATERIAL AND METHODS

Study site: A field experiment was conducted during seasons 2017 and 2018. The field experiments were carried out in the district of Al-Qarneh al-Ghamayj (65 km north of the city center of Basrah, 31° 1' 5.5956'' N and 47° 25' 23.4192'' E.). Average annual rainfall in spring of 2017 and 2018 was 100 mm and 180 mm respectively, with average temperatures of 21 ° C and 23 ° C for the same period's. Soil moisture content and bulk densities were 18.75% and 1.32 Mg $m^{-3,}$ respectively. Soil texture was clay content 52 %; silt 35 %; sand 13 %.

Methodology: The investigation has considered only the energy used in wheat, barley, and oat production, without considering natural sources of energy such as solar radiation, rain, wind. The equivalent input and output energy indicators for wheat, barley and oat production were determined depending on experimental field and ASAE standards (ASAE 2006). All farms are considered irrigated land and the rainfall rate in winter does not reach 180 mm, therefore, using the pumps for irrigation the crops. The irrigation for all growing season was between 5 to 20 times according to rainfall. Direct energy requires human labour, electricity, and fuel to have a reasonable estimate of energy consumption in wheat, barley, and oat output. Indirect resources, include pesticides, fertilizers, machinery, and crops. This research, therefore, examines the two significant portions of energy that use processes and energy sources.

Operations: The energy consumption in the production of barley, wheat and oat, include plowing, seeding, fertilizer distribution, irrigation, spraying, harvesting and transportation (Table 1). Direct energy means human effort, nourishment and electricity. Human labour-power is low, and the use of electricity in irrigation operations is slight. In other processes, the more substantial workable energy is a fossil fuel. The power comes from fuel use in tractors engines, pumps, and harvesters, the fuel also use in generating electricity in some farms.

Equipment, vehicles, and tractors: Several measures were taken in calculating this energy: first, the energy needed to produce raw materials; second, the energy used in industrial operations; third, the energy used to move machines to and from consumers; the energy used to upgrade and maintain them (from Ziaei et al (2015). In order to estimate the energy input for tractors and other machines, knowledge of the weight and work life span is essential. Determining life has been used from ASAE criteria in this analysis (ASAE 2006).

Human labour: The male and female energy outputs were about 1.96 and 0.8 MJ ha-1, respectively (Khan et al 2010). The approach used in these studies to determine human labour energy usage has been to estimate the number of hours of the fieldwork to achieve a task by human labour. Energy consumption was estimated by multiplying overall hours of human activities by the energy coefficient of labourers.

Pesticide: The energy consumption was determined by multiplying the energy coefficients of the pesticides by the overall value of the herbicides, insecticides and fungicides concerned.

Fertilizer: In this analysis, the quantity of each fertilizer was manually measured by scanning phosphate, and the nitrogen content of the different fertilizers. Nitrogen and phosphate have a production energy content of 78.1 and 17.4 MJ kg^{-1}, respectively (Mohammadi and Omid 2010). The addition of chemical fertilizers with quantities increasing or decreasing leads to energy waste and a negative impact on the yield, as fertilizers must be given to the plant within the appropriate times depending on the stage of plant growth.

Fuel: Fuel consumption was measured for the tractor engine by determination for a distance of 10 m which represented the test run. The graduated tube was filled by diesel fuel for each operation. The fuel consumption was measured for each operation(10m) by registering the difference between the level of fuel in the graduated tube at the starting and the finish of the operation. The unit of fuel consumed was converted from cubic centimeter to liter The energy output for this study was estimated from fuel consumption, as shown in the following equation for each operation of 1 hectare of land times the fuel equivalent energy per liter:

$$FC = \frac{Vfc * 1000}{W * d} \quad (1)$$

Where:

FC: Fuel consumption (L h^{-1}), Vfc: Volume of fuel consumed (L), W: Effective plow width (m), d: Tillage depth (m).

Seeds: There are many certified seed producers, but the majority of farmers use their seeds. Different types of seeds are used for each crop for the geographical patch under study. Seed quantities (seeding rate) and seeding methods are different where some farmers use the machines seeding and the other uses manual seeding. For these reasons, there is difficulty in determining the exact bases of energy consumption. However, the recommended seed quantities can be adopted as the seed quantity for wheat, barley and oats are 135, 155 and 145 kg ha^{-1}, respectively.

Energy efficiency: Energy efficiency, energy productivity, energy intensity and energy gain for wheat, barley and oat was calculated, based on the energy equivalents of the inputs and output For wheat, barley and oat energy efficiency, productivity, intensity and gain was measured, based on the input and output energy equivalents.

$$\text{Energy efficiency} = \frac{\text{Output energy (MJ h}^{-1})}{\text{Input energy (MJ h}^{-1})} \quad (2)$$

$$\text{Energy productivity (MJ kg}^{-1}) = \frac{\text{Crop yield (kg ha}^{-1})}{\text{Input energy (MJ h}^{-1})} \quad (3)$$

$$\text{Energy intensity (kg MJ}^{-1}) = \frac{\text{Input energy (MJ h}^{-1})}{\text{Crop yield (kg ha}^{-1})} \quad (4)$$

$$\text{Energy gain (kg MJ}^{-1}) = \text{Output energy (Mj h}^{-1}) - \text{input energy (MJ h}^{-1})$$

RESULTS AND DISCUSSION

Energy sources: The water irrigation recorded the highest energy consumption among direct energy consumption for wheat barley and oat production (Table 3). It was 12568.88 (32.99%), 13104.38 (31.96%), and12024.43 (31.83%) MJ ha^{-1}, respectively. These results can be attributed to replicating times of irrigation every two weeks, particularly when rainfall is low. The second source for energy consumption is diesel fuel used in most agricultural operations such as using it in tractors, harvesting engines, pumps, etc. It was 8466.21 (27.84%), 9415.03 (28.45), and 8757.33 (28.41) for wheat, barley, and oats, respectively. The fertilizers consumed energy (nitrogen especially) were 7291.94 (23.98%), 7658.35 (23.14%), and 7444.72 (24.15%) MJ ha^{-1} for wheat, barley, and oats respectively. The energy consumed by wheat is more than barley and oat crops, and this includes all the fertilizers studied. The wheat yield needs energy higher than that of barley and oat yield. Energy consumption in sowing operations often the same for wheat barley and oat. However, in the wheat crop, more seed energy was consumed due to this crop's higher seed rate compared to the barley and oat crops. Herbicide pesticide and fungicide consumed energy the lower than that of other input energy for all three crops. These results agree with the findings of Safa et al (2010) and Ziaei et al (2015).

Consumed energy in operations: The same processes were applied in crop production (wheat, barley, oats). The energy consumed in the production process includes tillage, drilling, irrigation, fertilizer distribution, spraying, harvesting. The irrigation operations had the highest energy consumption of 1956.80 MJ ha^{-1} (70%), followed by plowing, drilling, fertilizer distribution, and harvesting operations by recording energy consumption by 503.18 (18%), 83.86 (3%). 27.95 (1%) and 167.73 (6%), respectively (Table 4) Irrigation operations consume high energy because of need for water irrigation continuously every other week. In contrast, the other operations consumed energy lower because of was conducted one time or twice in the growing season. Irrigation operations can be reduced by using recent technologies such as pivotal irrigation where the surface irrigation is squandering much water. If the growing season has a high rainfall rate, the percentage for consumed energy by irrigation will be reduced to lower than 70% (Safa et al 2010).

Energy efficiency: Barley recorded the maximum value of energy efficiency 1.9, followed by oat and wheat (1.71, and 1.59) (Table 4). This was mainly because of increasing the output energy (71960.66 MJ ha^{-1}) in case barley. Oat had the highest energy productivity of 0.12, and the lowest was 0.07 for barley. If the field output energy value is lower than the energy value within the field, energy is therefore ineffective. Generally, barley achieved the maximum energy gain of 34184.2 MJ ha^{-1} followed by oat and wheat (29016.56 and 22374.11 MJ ha^{-1} respectively).

Grains yield: The barley had a high output (grain yield) although consumed input energy is low (Table 4). Barley yield was 4945.75 Kg ha^{-1} when input energy of 37776.46 MJ ha^{-1} while the wheat yield was 4113.58 Kg ha^{-1} with input energy of 38095.52 MJ ha^{-1}. The barley achieved a higher yield than that of oat and wheat in lower consumption energy, and this can be attributed to natural factors such as ability the barley to bear for the salinity of soil or irrigation water, cold weather and also barley more resistant to disease than wheat and oat

Table 1. Energy consumption depending on operations in wheat, barley and oat production

Operations	Consumed energy (%)	Consumed energy (MJ ha^{-1})
Tillage	18	503.18
Drilling	3	83.86
Spraying	2	55.91
Fertilizer distributor	1	27.95
Harvesting	6	167.73
Irrigation	70	1956.80
Total	100	2795.43

Table 2. Inputs and outputs equivalent energy into the production of wheat, barley, and oat

Energy input	Unit	Energy equivalent (MJ unit^{-1})
Human labour	H	1.96
Machinery	H	62.72
Diesel fuel	L	56.31
Chemical fertilizers		
Nitrogen (N)	Kg	66.14
Phosphate (P_2O_5)	Kg	12.44
Potassium (K_2O)	Kg	11.15
Herbicide	L	238
Pesticide	L	199
Fungicide	L	92
Water for irrigation	M3	1.02
Seeds (Wheat)	Kg	20.1
Seeds (Barley)	Kg	14.7
Seeds (Oat)	Kg	16.25
Total energy input		
Outputs energy		
Wheat grain yield	Kg	14.48
Barley grain yield	Kg	14.7
Oat grain yield	Kg	14.55

Table 3. Input and output energy in wheat, barley and oat production

Energy input	Quantity per unit (ha)			Total energy equivalent (MJ)		
	Wheat	Barley	Oat	Wheat	Barley	Oat
Human labor (h)	226.20	230.73	237.50	443.35 (1.16)	452.23 (1.20)	465.5 (1.14)
Machinery (h)	40.56	42.47	44.57	2543.92 (6.68)	2663.72 (7.05)	2795.43 (6.82)
Diesel fuel (liter)	150.35	155.52	167.20	8466.21 (22.22)	8757.33 (23.18)	9415.03 (22.96)
Chemical fertilizers (kg)						
Nitrogen (N) (kg)	110.25	112.56	115.79	7291.94 (19.14)	7444.72 (19.71)	7658.35 (18.68)
Phosphate (P_2O_5) (kg)	55.36	58.85	63.48	799.4 (2.10)	849.79 (2.25)	916.65 (2.24)
Potassium (K_2O) (kg)	50.08	52.78	50.55	558.39 (1.47)	588.5 (1.56)	563.63 (1.37)
Herbicide (l)	2.06	1.97	2.10	490.28 (1.29)	468.86 (1.24)	499.8 (1.22)
Pesticide (l)	1.41	1.48	1.5	280.59 (0.74)	294.52 (0.78)	298.5 (0.73)
Fungicide (kg)	0.33	0.33	0.34	30.36 (0.8)	30.36 (0.8)	31.28 (0.8)
Water for irrigation (m^3)	4787.65	4971.60	5100.15	12568.88 (32.99)	12024.43 (31.83)	13104.38 (31.96)
Seeds (Wheat) (kg)	220	200	250	4622.2 (12.13)	4202 (11.12)	52525 (12.81)
Total energy input (MJ)				38095.52	37776.46	41001.05
Outputs energy						
Grain yield (kg)	4113.58	4945.75	4835.47	60469.63	71960.66	70017.61

The values between parentheses are the percentage of total energy input (%)

Table 4. Energy efficiency within one hectare of the production of wheat, barley and oat

Parameters	Wheat	Barley	Oat
Energy input (MJ ha^{-1})	38095.52	37776.46	41001.05
Energy output (MJ ha^{-1})	60469.63	71960.66	70017.61
Energy efficiency (%)	1.59	1.90	1.71
Energy gain (MJ ha^{-1})	22374.11	34184.2	29016.56
Yield (kg ha^{-1})	4113.58	4945.75	4835.47
Energy productivity (kg MJ^{-1})	0.11	0.07	0.12
Energy intensity (MJ kg^{-1})	9.26	7.64	8.48

These results agree with the findings of Ziaei et al (2015) and Strnad and Míša (2016).

CONCLUSION

Barley achieved a higher yield than that of oat and wheat in lower consumption energy. The production of barley exceeded in terms of output energy, energy efficiency and energy gain from wheat and oat production. Barley recorded the lowest values of input energy and energy productivity and barley achieved a higher yield than that of oat and wheat in lower consumption energy.

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